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Methodological approaches to the valuation of forest ecosystem services: An overview of recent international research trends

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Abstract: Forests represent the most important source of ecosystem services (ES) on a global level both for the production of goods and for the provision of services and externalities, nevertheless scientific research in the economic field is lacking. Currently the number of documents relating to ES is 16 673, of which only 1 379 concern the forestry sector. The aim of this study is to provide an overview of scientific research trends in the field of economic evaluation of forest ecosystem services (FES). To this end, an on-line bibliographic survey was carried out on the main scientific search engines, which made it possible to quantify the works and at the same time to detect the main evaluation methods used for the different FES. This survey allowed to collect 93 articles meeting the search criteria: the most active continents were Europe and Asia, whereas most of the articles focused on the joint evaluation of provisioning, regulation and cultural services, even if a good number of them only concerned cultural services. The most widely used valuation methodologies were the contingent valuation among the stated preference techniques and the market price among direct observation criteria.

Keywords: international classification; forests; methodologies; monetary; valuation

Changes made by man to forest ecosystems due to a growing demand for raw materials (food, fresh water, wood, fibre, energy sources, etc.) are recognized as the main factor of climate change, deterioration of ecosystems and air pollution.

Cultural growth and a deeper environmental sensitivity of local communities have increasingly brought out the role of forest ecosystems as assets of general interest. On the institutional level, this change is identifiable in the current framework of international conventions and is reflected in the political orientation of individual countries that more and more recognize the social role of forestry heritage.

The issue of the valuation of ecosystem services has therefore carried out a crucial role in order to acquire knowledge for policy development, ecosystem management and spatial planning. Consequently, a new branch of research has been generated in the field of the economic evaluation of forest ecosystem services (FES) which has produced scientific literature that has not been widely quantified, analysed and organized yet.

The main objective of this study is to fill the literature gap, coming to the detection of the papers, as well as to provide an analysis of the trends of international scientific research, over the last 22 years, in the field of the economic evaluation of ecosystem services (ES) of specific forest sites. They were sorted out with reference to publication year, to country, to valuation methodology which was used to estimate each single category of ES.

The information thus obtained can contribute to broadening the knowledge of the economic approach to the valuation of different ecosystem ser-

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vices, and might be used by the scientific community to undertake sectorial studies, considering the methodologies applied to the various original case studies found through a bibliographic search conducted both on Scopus database and Google Scholar.

LITERATURE REVIEW

Ecosystem services and their classification. The term "ecosystem services" was first introduced by Ehrlich and Ehrlich (1981). The concept was originally intended to arouse public interest and establish a framework for highlighting the social benefits of ecosystem conservation as the rate of biodiversity loss was becoming increasingly evident (Westman 1977; Pimentel et al. 1980; De Groot 1987). Since the 1990s, the study of ES has become a focal point of numerous research projects.

An analysis of their current conditions and the consequent effects on the wellbeing of the populations was promoted by the United Nations with the Millennium Ecosystem Assessment (MEA 2005) project launched with the aim of identifying eco-compatible development strategies and consolidating the culture of valorisation of "multiple benefits provided by ecosystems to mankind".

Cultural growth and the increase in the environmental sensitivity of the community have increasingly brought out the role of forest ecosystems as assets of collective interest. Forests and woods have been defined as the most important source of ES (FAO 2010), in fact they represent the natural system with the highest content of genetic, specific and ecosystem, as well as historical and cultural diversity. The international recognition of the multifunctional character of forest ecosystems derives from the joint production of goods (wood and non-wood renewable products), services and externalities. Despite this, a number of scientific works concerning the forestry field is sensibly missing.

At the international level, three classification systems have been developed to define the typology of ecosystem services: Millennium Ecosystem Assessment (MEA); The Economics of Ecosystems and Biodiversity (TEEB); Common International Classification of Ecosystem Services (CICES).

The MEA organizes ecosystem services into four categories: Support, Procurement, Regulation and Cultural Ones.

The TEEB proposed 22 ecosystem services divided into three main categories that revisit those of the MEA: Supply, Regulation and Habitat and cultural and aesthetic beauty services (Pascual et al. 2010).

Finally, the CICES, after an initial series of methodological proposals for the classification of ecosystem services (Haines-Young, Potschin 2010, 2011), has developed a hierarchical structure organized in three sections: Provisioning, Regulation and Maintenance, Cultural Services; in divisions (main processes or outputs); in groups that distinguish the processes in biological and physical ones that can be linked to tangible resources; in classes that identify individual entities, of which the unit of measurement and indicators to measure ecosystem services are provided (Version 4.3) (Haines-Young, Potschin 2013).

In the latest version (Version 5.1) (Haines-Young, Potschin 2018), for a better conformity with the principles of ecosystem accounting (United Nations 2003) and to address the key issues identified in the literature, the scope of the CICES focused on the identification of final services and the classification was broadened to cover abiotic aspects.

Its hierarchical structure allows for an adequate level of detail, in fact, moving from the Section to the Division, to the Group and to the Class, the services are increasingly specific, but the characteristics used to define them at the lower levels are dependent on the categories above them.

The structure of the Provisioning section has been modified with "Biomass" and "Genetic material of all biota" to distinguish the results of biotic ecosystems from abiotic ones at the division level. This section covers all nutritional, non-nutritional material and energy outputs from living systems as well as from abiotic outputs (including water).

The Regulation and Maintenance section includes ways in which living organisms can mediate or moderate the environment that affects human health, safety or comfort, along with abiotic equivalents. The division covers the transformation of biochemical or physical inputs into ecosystems in the form of waste, toxic substances and others; and the regulation of physical, chemical and biological conditions. Finally, the Cultural section includes all non-material, non-rival and non-consumptive outputs of ecosystems (biotic and abiotic) that affect people's physical and mental states.

The economic valuation of ecosystem services. In recent decades, the awareness that many of the negative impacts are at the basis of current global challenges (climate change, loss of biodiversity, pollution, etc.) has prompted the scientific community to start

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studies and research also on economic evaluation; in fact, different methods have been proposed for the economic evaluation of ecosystem services that are based on the utilitarian approach, grounded on the fact that people exploit directly or indirectly the benefits of ecosystems, according to individual choices. Therefore, all goods and services are traced back to the total economic value (VET) which includes two components (Gómez-Baggethun, De Groot 2010): the use value, in turn divided into direct and indirect, and the non-use value (Krutilla 1967), generally classified into existence, bequest and option. As to the latter, some authors instead place it in the category of use values, although it can be considered as a sort of insurance in anticipation of a possible future use of the resource (Gren et al. 1994; Pearce 2001; Balmford et al. 2002; Silvestri 2003; Turner et al. 2003; EFTEC 2005).

The use value can be attributed to ecosystem services exploited, directly or indirectly, for reasons of production or consumption.

The second, on the other hand, is more difficult to assess because it corresponds to what is intrinsic to a resource and therefore not used directly or considered in a future perspective.

To determine the values of ecosystem goods and services, in the literature there are various evaluation methods that can generally be divided into the following categories (Schirpke et al. 2014; Soraci et al. 2016; Pillari 2018):

– Methods based on direct observations for goods that have a reference market and are therefore tradable. The direct use value can be defined through the market price, which is used when there is an immediate relationship between a market good and the ecosystem service itself; the cost necessary to produce the goods, that is, the amount of money necessary to replace or restore an ecosystem service following damage; the production function which relates the good resulting from a production process with the factors of production used to obtain it. These techniques are particularly suitable for evaluating the services of the provisioning and regulation and maintenance function.

– Methods based on indirect observations, used for ESs lacking in a target market, including the travel cost which is grounded on the travel costs that people incur to reach a site where they can enjoy the desired ES; the avoided cost, that is the cost necessary to avoid the possible damage deriving from the loss of a service; hedonic prices used to define the economic value of ecosystem services that directly influence the prices of the real estate market. These methods are mainly suitable for evaluating regulation and maintenance and cultural services.

– Methods based on stated preferences, including the contingent valuation which consists in a sample survey of the reference population, hypothesizes development scenarios for a given ecosystem service, allows to reveal the willingness to pay or the willingness to accept a compensation for the loss of the service itself; the choice experiment method (CEM), in which the interviewees must choose between baskets of attributes present at different levels both in quantitative and qualitative terms, which constitute the environmental good, arriving at the determination of the marginal willingness to pay for each attribute. These methods are crucial above all for estimating non-use values (bequest, existence, option).

However, the application of these methods is generally expensive both economically and temporally; therefore, in the last few decades, various scientific studies have made use of the benefit transfer (BT) method, which makes extensive use of the results obtained with different evaluation methods applied at a specific place and time, transferring them to environmental goods and services of a different place and time (Wilson, Hoehn 2006; Plummer 2009).

Finally, open source computer models were created that are able to map and evaluate ecosystem services, currently used in many programs and initiatives with both scientific and planning purposes. These models include the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) (Sharp et al. 2014), which treats ES in both biophysical and economic terms; the Social Values for Ecosystem Services – SolVES (Sherrouse, Semmens 2015), which evaluates and maps the social values of the ESs; the Artificial Intelligence for Ecosystem Services (ARIES) (Villa et al. 2014), which aims to balance the user's need for clarity without renouncing at the same time the maintenance of the complexity of the space-time flows of the benefits provided to the community (Pillari 2018).

SURVEY DESIGN

In order to quantify and analyse the scientific activity related to the economic evaluation of forest ecosystem services (FES), a bibliographic search

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was carried out with a quantitative approach, using two of the major search engines dedicated to scientific research, namely Google Scholar and Scopus, both created in 2004.

The time interval analysed is 1997–2019, where the choice of the starting date is linked to the publication of the scientific article by Robert Costanza "The value of the world's ecosystem services and natural capital" (Costanza et al. 1997), which introduces one of the first definitions of ecosystem services, and the volume by Gretchen Daily, "Nature's services" (Daily 1997), in which the author, in addition to describing the main ecosystem services, emphasizes the importance of their evaluation also in economic terms.

The research on the Scopus database was conducted on March 3rd 2020 by combining the "ecosystem AND services" search words both as "title of the article" and as "keywords" to identify the works concerning ecosystem services in general; a total of 8 864 documents were present in the database, of which 8 195 published in English. In the first step the search also involved secondary documents, i.e. those not indexed in the Scopus database, equal to 7 809. There are three possible reasons for their inclusion in the above category: they derive from bibliographic references or from citations contained in Scopus documents; inability to index them with certainty due to incomplete or incorrect data; impossibility of finding the text (https://service.elsevier.com/app/answers/detail/a_id/11239/supporthub/scopus/#:~:text=Secondary%20documents%20are%20documents%20that%20are%20not%20indexed,incomplete%20or%20incorrect%20data.%20There%20is%20missing%20content.). Overall, the works relating to the ES therefore amounted to 16 673.

Among all the Scopus documents only articles in scientific journals were selected which amounted to 6 192, and in particular those written in English that equal to 5 600.

These figures might seem to be rather low because the search has been intentionally limited to "ecosystem" and "service" keywords referring to the seminal work by Costanza et al. (1997), while other ones, even if relevant, have not been taken into account, such as "multifunctional" and "management", "environmental services", "local services", etc.., since they were more in use in the previous years.

Subsequently, the works concerning the forest ecosystem services were identified using the keywords "forest AND ecosystem AND services AND NOT agricultural". Overall, there were 703 Scopus documents, of which 636 were published in English; while the secondary documents were 676. The articles in scientific journals were 557, lowered to 495 when excluding those ones written in languages other than English.

At the same time, another search was carried out on Google Scholar, directly targeting the FES and using the same keywords as before. It should be noted that the procedure followed in the latter case was very laborious as Google Scholar does not allow filtering and limiting the search field as Scopus does. The initial number of documents is in fact indeterminate and not always totally consistent with the entered keywords, so the researcher is forced to examine an unlimited list of documents without any clue on their overall number.

Despite the obvious limitations related to the choice of Google Scholar, this search engine has made it possible to intercept scientific works not indexed in the major databases (Scopus, Web of Science, Science Direct), which instead would have been neglected.

The initial amount of articles obtained by the two search engines was remarkable. To achieve the objective of quantifying the research activity carried out at an international level in the field of the economic evaluation of specific forest sites and with reference to individually considered FES, we proceeded by gradually eliminating all the articles concerning the mere descriptive aspects relating to the habitats and those which dealt only with the ES classification; this preliminary work made it possible to obtain a set of articles with an economic angle on which to focus the analysis. Subsequently, also the articles relating to payments for ecosystem services (PES) and those that provided an overall economic evaluation of the ES or just a part of them without reaching the value of the single ecosystem service were excluded from the subsequent analysis.

After the above described filtering work, the studies selected for the subsequent descriptive analysis were found to be 80 on Google Scholar and 28 on Scopus, for a total of 108 articles. After verifying the simultaneous presence of 15 works on both platforms, the final number of papers was reduced to 93 (see Electronic Supplementary Material where a complete list of these 93 papers is provided).

For each article, the title, the authors, the year of publication, the investigated ecosystem services,

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the applied evaluation method and the country of the case study were subsequently identified.

The studied ecosystem services were then divided into the three macro-categories of the CICES Version 5.1 classification (Haines-Young, Potschin 2018): Provisioning (P), Regulation and Maintenance (R) and Cultural (C).

– Provisioning: this service category mainly includes food, fibre, genetic material, surface and ground water.
– Regulatory and Maintenance: this category includes bio-remediation, filtration or sequestration by microorganisms, algae, plants and animals, smell reduction, noise attenuation, visual screening, fire protection, air quality regulation, climate regulation, water cycling and water flow regulation, erosion control, nursery population and habitat maintenance, pollination, pest and disease control, etc.
– Cultural: they include recreation, entertainment, education, scientific, aesthetic, heritage, spiritual and religious, symbolic, bequest and existence services.

The choice of CICES classification is explained by the fact that it has been recently revised to be adapted to the changing needs of ecosystem accounting and to better support the related scientific literature.

Considering that in many of the examined works ecosystem services belonging to two or more macro-categories were simultaneously evaluated, it was necessary, for the purpose of the study, to also include their groupings: PR (Provisioning + Regulation and Maintenance), PC (Provisioning + Cultural), RC (Regulation and Maintenance + Cultural) and PRC (Provisioning + Regulation and Maintenance + Cultural).

The adopted classification for the monetary valuation of the FES in the papers under analysis is based on the prevalent use of methodologies for goods traded on the market or for goods without market (such as public goods in general or natural or environmental resources).

The first macro-category includes some appraisal methods generally applied in the main stream doctrine, that is to say the market value (market price), the cost value (cost approach) and the value of the replacement or substitution cost.

The second category, in conceptual contrast with the first one, includes those methods which are essentially based on the consumer sovereignty principle, but differing in the way in which their preferences are identified.

All the methods not attributable to the previous categories have been grouped into a single item, called "others".

Subsequently, the collected data were processed in order to obtain information regarding the distribution of works by year and by geographical area, with particular attention to European countries, the economic evaluation methodology used for each macro-category and by grouping of ecosystem services.

TRENDS OF SCIENTIFIC RESEARCH PRODUCTION ON FES

Description of the data set. In the period 1997–2019, scientific research produced a total of 93 papers that evaluated in economic terms the various ecosystem services provided by the forest (Figure 1).

As can be seen from Figure 1, in the period between 1997 and 2005, there were annually few papers on the two search engines (at most 3 articles). 2005 was the year when many researchers began to take an interest in the problem, following the publication of the results of the "Millennium Ecosystem Assessment", which highlighted the rate of degradation of ecosystems and encouraged the attention of the scientific community to the subject. The number of economic studies on evaluation remained almost constant annually until 2014, while from the following year there was an increase in the scientific production, with an annual number of works comprised between 7 and 13.

It should be noted that the number of scientific articles in the Scopus database is by definition lower than or at most equal to that of the Google Scholar indexed works. The explanation of this trend is that not all scientific journals are accredited by Scopus, unlike Google Scholar which adopts less restrictive criteria for their inclusion in the database.

Mengist and Soromessa (2019), in a somewhat similar study, using Scopus and Science Direct as search engines and analysing a shorter period (2005–2018), found 41 scientific articles on FES economic valuation.

Considering that the incidence of papers in the first sub-period – between 1997 and 2004 – is rather limited both in numerical and percentage terms (only 11.8% of the total), and that in the present work we also analysed 2019 papers while Mengist and Soromessa (2019) had to stop in 2018, for the shared investigated period (2005–2018) the significant numerical difference of 28 papers between the two surveys (69 articles against 41) is almost exclusively due to the choice of the search engines made by the authors, and as far as Google Scholar

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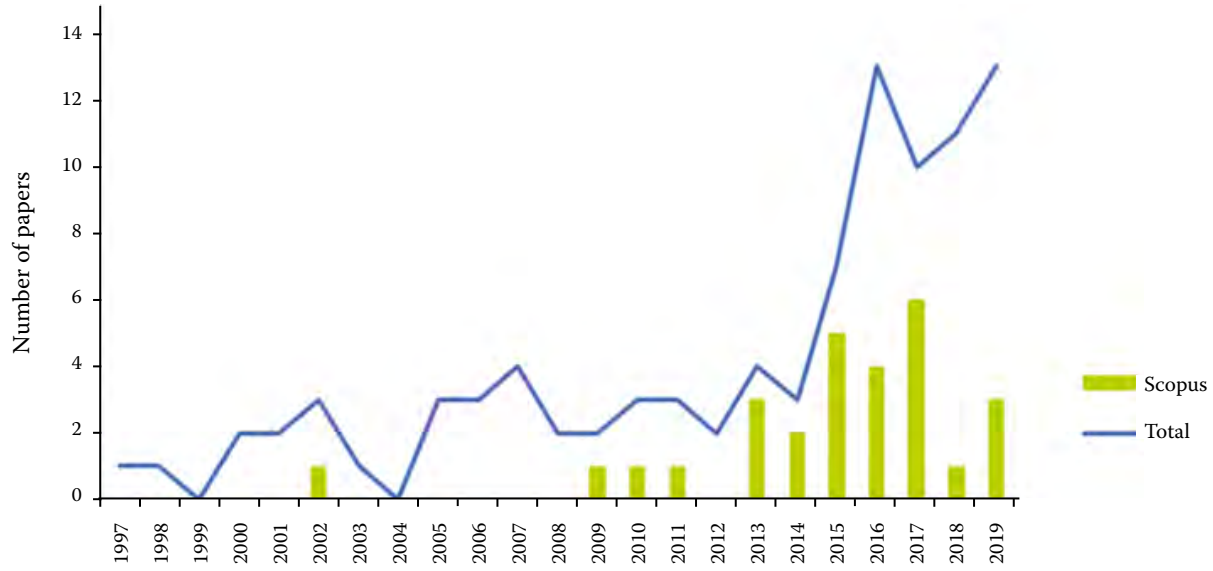

Figure 1. Trend of forest ecosystem services (FES) papers in the period 1997–2019

is concerned, you can find all the scientific production of a certain period of time, while on Science Direct there are only publications in journals that meet certain requirements.

On a world level (Figure 2), Europe (46.24% of the dataset, equal to 43 papers) and Asia (37.63%, equal to 35 papers) are the continents that have involved a greater number of research papers on the economic evaluation of the FES in the examined period, followed by America (12.90%, that is 12 studies) and Africa (3.23%, corresponding to 3 studies), while in Oceania no study has been carried out on FES.

It has to be noteworthy to remark that the investigated studies are only those ones dealing with FES individually valuated in economic terms.

In the work of Mengist and Soromessa (2019), on the other hand, Asia is the most represented continent in the dataset (44% of the total), followed by Europe (22%) and America (17%).

The breakdown by continent of the 28 Scopus scientific papers sees Europe in the first place with 14 articles, followed by Asia with 10, then by the American continent with 3 and finally by Africa, which contributes just 1 study.

The situation is quite different if we consider the percentage incidence of Scopus works in the total of articles by continent; in fact, the Scopus database contains 33.3% of the works whose case studies are located on the African continent, followed by Europe (32.6%) and Asia (28.6%); the American continent contributes only 25.0% of the works to Scopus.

As regards the distribution of scientific works in European countries, it can be observed that the EU-28 – the analysis refers to the pre-Brexit period, therefore the United Kingdom was also part of the EU – contribute most to the increase in the number of researches on the economic evaluation of FES, intercepting a total of 43 articles; non-EU countries (Norway and Switzerland) were involved in a total of 3 papers (Figure 3).

These results are probably to be related both to the policies implemented by the EU that have encouraged scientific research and to the extent and characteristics of the forests in the different countries.

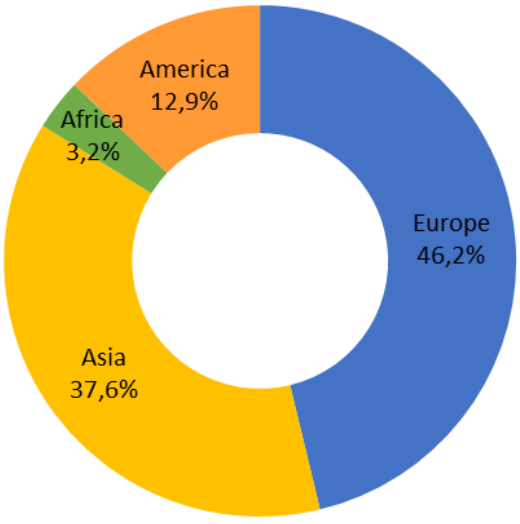

Figure 2. Breakdown of papers by continent

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Italy is the country showing the highest number of publications (8), followed by Finland and Sweden (4 articles), in the fourth place we find Spain and Germany (3 works), whereas in all other countries the number of scientific articles is between 1 and 2.

The scientific production concerning Romania, Slovakia, Poland, Czech Republic and Lithuania is fully included in the Scopus database; Italy follows with over 60%, Denmark and Slovenia with 50% and finally Spain with 33% of the studies. All the other countries are not represented in the Scopus database.

Distribution of papers by CICES macro-category and evaluation approach. Within the database, the economic evaluation concerned almost uniformly a single macro-category (49.5%) or a grouping of different macro-categories (50.5%) of the FES.

In detail, the studies analysed to a greater extent the FES falling within the PRC group (26 papers), followed by PR, RC and PC groups with 10, 6 and 5 articles, respectively (Figure 4). Several European case studies fall into the first group of macro-categories, where Italy is the most frequently represented country. The FES belonging both to the RC and PC groups are mainly evaluated in Asian countries.

With reference to the individual macro-categories, cultural services were the most frequently studied with 25 articles, mainly from EU countries, followed by regulation and maintenance ones with 16 articles, especially dealing with areas from Asia, and more specifically from China. Finally provisioning services are singularly investigated in only 5 papers concerning Asian and American case studies.

In most cases, the studies have taken into consideration more than one ecosystem service within the same macro-category, especially in the context of "Regulation and Maintenance".

Among the "Provisioning" services, the most frequently evaluated are the production of wood and firewood, non-wood forest products (mushrooms, wild herbs, wild berries, game, etc.) and drinking water supply, while the economic evaluation of fish

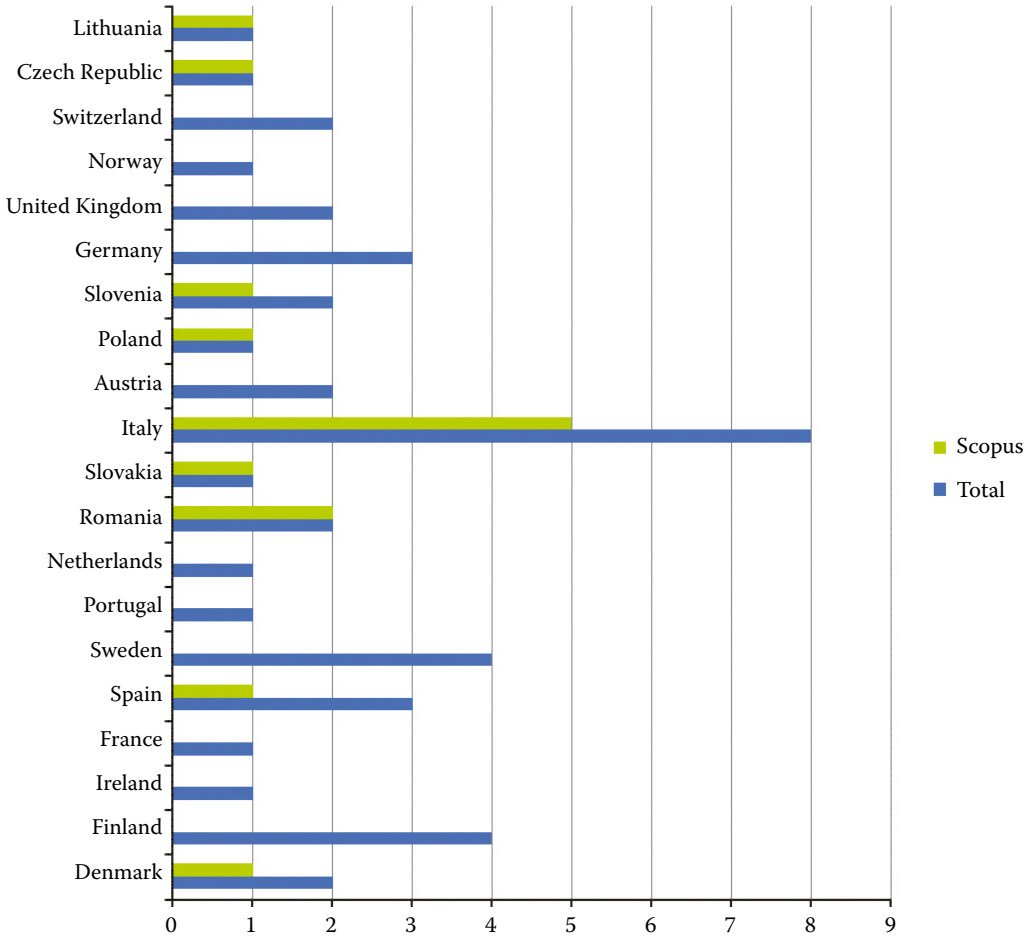

Figure 3. Breakdown of papers by European countries

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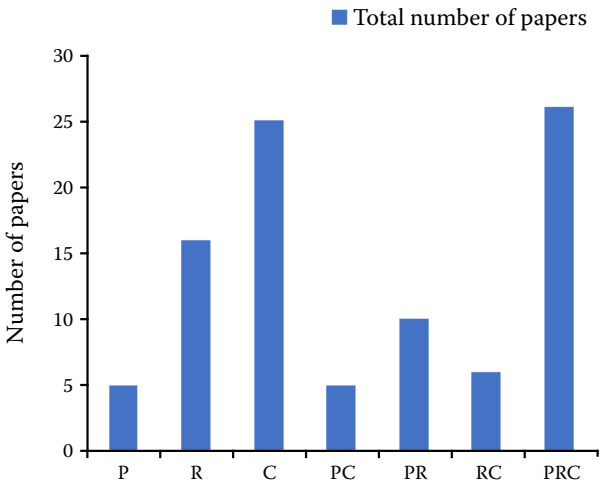

Figure 4. Number of papers by CICES (Common International Classification of Ecosystem Services) Version 5.1 macro-category and grouping

P – Provisioning; R – Regulation and Maintenance; C – Cultural; PC – Provisioning + Cultural; PR – Provisioning + Regulation and Maintenance; RC – Regulation and Maintenance + Cultural; PRC – Provisioning + Regulation and Maintenance + Cultural

production (aquatic fish and crustaceans) is by far the most observed in coastal or river areas of Indonesia, Malaysia, Brazil and China.

With reference to the FES falling within the "Regulation and Maintenance" macro-category, carbon sequestration, water conservation, soil protection, erosion prevention are the most common services analysed in the studies.

The most commonly studied services in the "Cultural" macro-category are mainly represented by the recreational ones, followed by the aesthetic (scenic beauty), cultural, existence, bequest and religious services.

The above results for the various macro-categories of FES are consistent with those obtained by Mengist and Soromessa (2019).

As previously noted, in many works of the dataset several ecosystem services were valued simultaneously using different economic methods, therefore the total of the adopted evaluation methods is greater than the overall total of the examined works.

Table 1 examines the economic valuation methods according to the "market goods", "goods without market" and "others" denominations, for each macro-category of ecosystem service. The market price and cost value methods were found in the dataset for market goods; for non-marketed goods, both the disclosed preference methods, such as the travel cost method (TCM) and the hedonic price method (HPM), and the expressed or declared preference methods, such as the contingent valuation method (CVM) and the choice experiment method (CEM), and finally the benefit transfer method.

In this work, the following techniques are classified as "others": the cost-benefit analysis (CBA), a methodology widely used in the analysis of the economic convenience of public utility projects, the gross domestic product (GDP), an indicator of the economic wealth within a single country. The input-output matrix that determines the reciprocal interrelationships between the sectors producing goods and services and those that use them as inputs in their production processes, and finally, the production function.

In general terms, the economic evaluation of ecosystem services in the dataset was mainly (55.6%) based on the application of the methods traditionally used for the evaluation of market goods, and more in detail on the market price and on the cost value, which together account for 52.6% of the total of 171 methods applied to the case studies of this paper. Among the other methods, the contingent valuation is also fairly present, since it is applied to 20.5% of the investigated services.

In the monetary evaluation of provisioning services it is highlighted that the most commonly used techniques (60% of the total) are those traditionally applied to private goods. In particular, the market price was the most frequently adopted criterion, as the services falling into this category have the availability of a reference market, with the consequent possibility of using the prices that the market expresses at that given moment for valuation purposes. This makes the evaluation process more transparent and difficult to be questionable.

Even the regulation and maintenance services were more frequently (almost 73% of the total methods) evaluated with the use of traditional methods, and in particular the cost value criterion (i.e. the "replacement cost") accounts for 50%, followed by the market price with an incidence of 23% in the total. On the other hand, the methodologies expressly conceived for the valuation of non-market goods (non-market goods) make up just over a quarter (27.3%) of the total within the investigated dataset.

Unlike the previous macro-categories of FES, for the evaluation of Cultural services (C) the most frequently used methods are – in order of decreasing

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Table 1. Valuation methods in the dataset of papers

Ecosystem service	Non market goods					Private goods		Other	Total
	contingent evaluation	choice experiment	travel cost	hedonic price	benefit transfer	market price	cost		
P	1	–	–	1	–	2	1	–	5
R	4	–	–	–	2	5	11	–	22
C	11	7	7	–	–	–	2	–	27
PC	2	–	1	–	–	3	1	–	7
PR	3	–	–	–	1	7	3	2	16
RC	3	1	2	1	2	4	7		20
PRC	11	1	6	1	8	26	18	3	74
TOT	35	9	16	3	13	47	43	5	171

P – Provisioning; R – Regulation and Maintenance; C – Cultural; PC – Provisioning + Cultural; PR – Provisioning + Regulation and Maintenance; RC – Regulation and Maintenance + Cultural; PRC – Provisioning + Regulation and Maintenance + Cultural; TOT – total number of valuation methods

importance – the contingent evaluation (CVM), the choice experiments (CEM) and the travel cost (TCM), traditional expressions of scientific studies on non-market goods, with an overall weight equal to 92.6% of the total.

With regard to the situation concerning the various categorical groupings, market price and cost value are by far the most commonly used methods in the monetary valuation of ecosystem services, followed by contingent valuation (CVM), for each macro-category grouping.

CONCLUSION

The number of documents relating to ecosystem services as of January 1, 2020 was 16 673, of which only 8.3% concerned the forestry sector; focusing the analysis only on articles in scientific journals written in English and providing an economic evaluation of a single ecosystem service, the number dramatically went down to 93 articles, equal to 6.7% of the initial documents on the FES.

The scientific production on the economic evaluation of the FES shows a significant percentage increase starting from 2015, so much that in the last five years it reports as much as 58.0% of the total number of the analysed period. Our study found a small number of articles dealing with such a key topic, especially in consideration of the long period of data observation.

Cultural services were the most frequently studied at the level of the single CICES macro-category; within the same macro-category, especially in the area of Regulation and Maintenance, more than one ecosystem service was evaluated.

Among the FES, the most frequently evaluated in the Provisioning macro-category were those attributable to the *Biomass and Water* division, while the *Genetic Material* division of the whole biota has been little studied. With reference to the FES falling within the "Regulation and Maintenance" macro-category, the most recurrent services in the investigated studies were those included in the *Regulation* division, even if the *Transformation of biophysical and chemical inputs into ecosystems* (carbon sequestration) division is present in most research papers.

The most commonly studied services in the "Cultural" macro-category are mainly represented by those falling within the *Direct* division, in situ (outdoor recreation), although a fair number of articles were observed that evaluated services of the Indirect division, remote.

Ultimately, there was very little attention from the scientific community to the evaluation of some FES such as pollination, seed dispersal, conservation of genetic resources, bio-reclamation, pest control.

In relation to the geographical distribution of the investigated case studies, from FAO (2020) it was observed that at a continent level there is a general correspondence between the number of the papers dealing with a macro-category and the forest area managed according to one of the six main forest objectives (production, soil and water protection, biodiversity conservation, social services, multiple use and others) listed in the report.

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Besides, there is a total lack of case studies on FES economic valuation concerning six countries (Russian Federation, Brazil, Canada, Australia, Democratic Republic of the Congo, and Peru) which account overall for nearly 50% of world forest area (FAO 2020).

With reference to the valuation methodologies, in addition to those already consolidated and widely applied to private and public assets, a fair incidence of the benefit transfer method was observed (7.6% of the total) in case studies concerning mainly Asian and Eastern European countries, maybe due to a lack of public funds for carrying out a primary data collection through sample surveys.

In conclusion, this study firstly aimed to quantify and categorize scientific articles concerning the economic evaluation of FES. As a second objective, it provides an overview of recent international developments about the methodologies for the valuation of different ecosystem services, highlighting the approaches adopted to assess the FES value in monetary terms.

Moreover, the study may provide support to the decisions of forest stakeholders in defining strategies, policies and forest management with a view to the ecosystems sustainability and social well-being.

An improvement of this research could be effectively achieved by extending the survey to other search engines (Science Direct, Web of Science) in order to obtain a more complete database containing the results of the economic evaluations of FES attained by various authors.

The findings of these next analyses could represent both a starting point for new economic studies and a support for decision-makers in a political process of adjustment and/or determination of payments for ecosystem services (PES) in those territories where the need for monetary remuneration of the benefits produced by forests towards local communities might come to light.

In this context it is desirable that in the near future there will be a greater political will at the international level in financing economic research in the field of FES.

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