Organizações Rurais & Agroindustriais, 25(2023), e1954
eISSN: 2238-6890

ANALYZING ECOSYSTEM SERVICES VALUATION METHODOLOGIES: A SYSTEMATIC REVIEW

Analisando as metodologias de valoração de serviços ecossistêmicos: Uma revisão sistemática

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ABSTRACT
One of the environmental challenges is the preservation and maintenance of the environment. In view of this, the gains are valid and are considered as auxiliary mechanisms to the tangible goods and services promoted by the ecosystems, which can be considered efficient for the control of tangible goods and services. Therefore, the objective of this article is to systematically review which methodologies have been used to value ecosystem services and theirs. This applies specifically: to studies that value the eco-services studied, using only practical methods studied. For that, a systematic review was elaborated, using as databases: Web of Science and Scopus, illustration of gray literature. The results of the analysis found the valuation of ecosystem services using methods still used, in addition, general studies are still incipient more than a statistical methodology. It can be seen that the complexity of giving value to services depends on a set of measurements, due to its complexity. From the elaboration of this study, it is expected that the readers can succinctly know the existing methodologies on the subject, still encourage creativity for the elaboration of new methodologies of monetary valuation. Finally, that this theoretical study contributes to enhance the importance of the subject, extending to the public power as a motivation for the emergence of public policies on the subject.

RESUMO
Um dos desafios seculares ambientais, é a preservação e a manutenção do meio ambiente. Diante disso, atribuir valor monetário aos bens e serviços tangíveis e intangíveis promovidos por ecossistemas pode ser um mecanismo eficiente para comprovar ganhos mútuos, auxiliando na tomada de decisão. Portanto, o objetivo desse artigo é revisar sistematicamente quais metodologias têm sido utilizadas para a valoração de serviços ecossistêmicos e suas limitações. Isso se aplica especificamente: aos estudos que valoram os serviços ecossistêmicos quantitativamente, utilizando apenas métodos monetários. Para tanto, foi elaborado uma revisão sistemática, utilizando as bases de dados: Web of Science e Scopus, excluindo a literatura cinza. Os resultados revelaram que a valoração de serviços ecossistêmicos empregando métodos monetários ainda é incipiente, além disso, geralmente os estudos contém mais de uma metodologia, inclusive análise estatística. Pode-se observar que a complexidade em dar valor aos serviços depende de um conjunto de métricas, devido sua complexidade. A partir da elaboração desse estudo, espera-se que os leitores possam de maneira suscinta conhecer as metodologias existentes sobre a temática, ainda incentive a criatividade para a elaboração de novas metodologias de valoração monetária. Por fim, que esse estudo teórico contribua para enaltecer a importância sobre a temática, estendendo ao poder público como motivação para o surgimento de políticas públicas sobre o assunto.

Keywords: Bioeconomics. Natural resources. Environmental impacts. Vegetation. Biodiversity.

Palavras-chave: Bioeconomia. Recursos naturais. Impacto ambiental. Vegetação. Biodiversidade.

Recebido em: 26/07/2022. Aprovado em: 06/02/2023.
Avaliado pelo sistema *double blind review*.
Editor(a) de seção: Caroline Mendonça Nogueira Paiva
DOI: 10.48142/2520231954

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1. INTRODUCTION

In the last century, due to the evolution of the human species, some dilemmas such as food production, preservation of natural resources, food security and sustainable intensification have gained emphasis. Mainly because the survival of humanity depends on the balance between these themes, which is an immediate challenge. However, food systems today have threatened the potential to nurture human health and support environmental sustainability (Van der Werf *et al.*, 2020; Willett *et al.*, 2019). Note that now, the focus of the problem is not population growth, but the ability to keep the biosphere "healthy" through the natural cycle (Hu *et al.*, 2020; Tudge, 2017).

Unfortunately, the data reveals that if the current rates of productive soil loss remain at the same pace in 60 years, the world's topsoil may become unproductive (Maximillian *et al.*, 2019). In addition, it is emphasized that agriculture is responsible for about 24% of all Greenhouse Gas (GHG) emissions, being one of the main drivers of global warming (Smith *et al.*, 2014; Bajželj *et al.*, 2014; Foley *et al.*, 2011). Another worrying fact is that 70% of water is used in irrigated production systems in search of increased productivity (FAO, 2011). Therefore, countries in general are facing continuous degradation and loss of biodiversity.

Thus, over time, it can be seen that the propagation and livelihood of human beings are conditioned to a healthy environment, as well as to sufficient natural resources spontaneously promoted by the environment (Costanza & Daly, 1992). Therefore, from the 90s, the importance of ecosystems for human well-being begins to be recognized, leading to the need to quantify and value a range of goods and services provided to humanity through ecosystem processes, known as ecosystem services (Daily *et al.*, 2009).

Ecosystem services are the benefits that human beings derive from ecosystems. According to the Millennium Ecosystem Assessment (MEA), ystem has four categories: provision (wetland production, supply water, shipping); regulation (flood control, water quality improvement, soil formation and protection, climate regulation, gas regulation); support (habitat and biodiversity) and cultural (recreation and tourism) (MEA, 2005; Fisher & Christie, 2010; Li *et al.*, 2014). In addition, together we enjoy goods and services, direct or indirect from the ecosystem. However, services start to be important and preserved from the moment that value is assigned to them.

Therefore, monetary evaluation can be defined as an attempt to assign quantitative values to goods and services provided by ecosystems (Förster *et al.*, 2019). In that case, the value of any good or service is usually measured in terms of what we are willing to pay for the goods, subtracting the cost of supplying them. However, the value of the ecosystem service ends up not being internalized (Lara *et al.*, 2022). Recent studies on ecosystem services make use of some methodologies, such as, for example, revealed preference (e.g, focus on estimating direct use values) and declared (consists of assessing non-use value. e.g, option and existence) (Ghermandi, 2018; Pandeya *et al.*, 2016). These methodologies are divided into monetary and non-monetary analyzes. Those of a non-monetary nature have been increasing compared to monetary analyzes, as they are less complex.

The monetary assessment methods of the ecosystem services used are, for example, hedonic prices, value transfer, deliberative valuation, contingent assessment and choice experiment. While studies of a non-monetary nature, they seek to evaluate ecosystem services, by exploring observations, narratives, interviews, questionnaires and scenario simulation (Cheng *et al.*, 2019).

The valuation of ecosystem services depends on some premises, such as, for example, the centrality of the market, the utilitarian structure, the substitutability of resources and technological optimism (Chee, 2004). Although the technological capacity and robustness of the market are understood, the utilitarian framework that transcends space needs to be developed in greater

depth. The usefulness that an individual derives from a given ecosystem service depends on that individual's preferences. However, utility cannot be directly measured in order to provide a common metric for expressing the benefits of various services provided by ecosystems.

Worldwide, studies related to ecosystem services mainly use non-monetary methodologies to measure services (Wurster & Artmann, 2014; Xu *et al.*, 2018; Zagarola *et al.*, 2014; Zulma *et al.*, 2016), with the area of I study the following locations: Australia, China, Patagonia and Colombia, respectively, or theoretical studies (Alejandre et al., 2019; Cheng et al., 2019; Cook et al., 2019; Förster et al., 2019; Himes-Cornell et al., 2018; Quintas-Soriano et al., 2016; Scholte et al., 2015). However, despite scientific advances related to ecosystem services, integrated measurement with primary data, due to its scarcity, especially at the local scale, is still a limitation (Pandeya et al., 2016).

Therefore, although theoretical studies have been on the rise in the last five years, there was a need for studies that elaborate methodological surveys, focused on the monetary valuation of ecosystem services, not limiting the analysis by countries or by ecosystem service category, with the objective to avoid negligence in the scope of the results. This becomes essential to compare the methodological limitations that each tool has, being able to assist the decision maker more accurately, since the economic valuation of nature becomes opportune when the management of ecosystems develops synergies between ecosystem services and conservation biodiversity, which can create better environmental and socioeconomic conditions (Adams, 2014). Faced with this need, this study tends to highlight the methodologies used for the valuation of ecosystem services in the scientific literature, demonstrating in a summarized way the state of the art on the subject. Being able to help through the theoretical work a critical look at the empirical methodologies.

Therefore, the objective of this article is to systematically review which methodologies have been used to value ecosystem services and their limitations. This applies specifically to studies that value ecosystem services quantitatively, using only monetary methods. This article is structured as follows: Section 1 presents the introductory part of the study; Section 2 contains material and methods (2.1. Literature search; 2.2. Selection criteria; 2.3. Data extraction) Sections 3 and 4 present the results and discussions; and Section 5 contains final considerations, containing additional limitations and recommendations.

2. MATERIAL AND METHODS

2.1. Literature search

Section 2 will specifically report on the steps defined to prepare the systematic review, using PRISMA (preferred reporting items for systematic reviews and meta-analysis) as a guide (see., Moher *et al.*, 2010). The choice is due to the credibility, acceptability and breadth of the report. The criteria for inclusion and exclusion of articles were defined by the authors of this systematic review, based on the PRISMA guide. This research seeks to verify which methodologies have been used to value ecosystem services, combining the four ecosystem categories defined in (see., Millennium Ecosystem Assessment (MEA, 2005)), with the assessment methods described in (see., Moher *et al*., 2010). The choice is due to the credibility, acceptability and breadth of the report. The criteria for inclusion and exclusion of articles were defined by the authors of this systematic review, based on the PRISMA guide. This research seeks to verify which methodologies have been used to value ecosystem services, combining the four ecosystem categories defined in (see., Millennium Ecosystem Assessment (MEA, 2005)), with the assessment methods described in (see., The Economics of Ecosystems and Biodiversity (Fisher & Christie, 2010)).

Thus, the main steps established to find the sample of articles are described:

i: two databases were defined for the research, being Web of Science and Scopus, starting the search on January 10, 2020. It should be noted that the subject of the study has been published more in international journals, indexed in these two databases, in addition, these bases are influential in the literature, therefore, the choice of both bases.

ii: the following keywords were chosen as keywords:

"cultural ecosyst service*"and Monetar* OR "cultural service*" and Monetar*; "provid* ecosyst* service*" and Monetar* OR "provid* service*" and Monetar*; "support* ecosyst* service*" and Monetar* OR "support* service*"and Monetar*; "regulat* ecosyst* service*" and Monetar* OR "regulat* service*" and Monetar*;*

iii: as a way to reduce the sample of articles, limiting filters are established, such as year (2005-2019), language (English and Portuguese), type of publication (articles) excluding gray literature;

iv: reading the titles, abstracts and methodologies to determine the adequacy of publications for review according to two criteria: studies that value ecosystem services quantitatively, using only monetary methods. In this case, if the methods and categories of ecosystem services are only mentioned, the article is eliminated from the review. It should be noted that systematic, literature, bibliometric and meta-analysis reviews were excluded;

v: complete reading of the articles that fell within the scope of the study (steps i, ii, iii and iv).

Section 2.2 detailed If the sample product found in the two databases, showing the number of articles included and excluded. For this, we propose Figure 1, seeking to illustrate didactically the step by step to reach the final sample of publications.

2.2. Selection criteria

In a first selection, when inserting the descriptors mentioned in (step ii), the total number of 356 publications was found, in which 182 articles correspond to the Web of Science database, while 174 refer to Scopus (Figure 1). Subsequently, with the aid of the StArt tool (State of the Art through Systematic Review) developed by the Software Engineering Research Laboratory (LaPES), Department of Computing, Federal University of São Carlos (UFSCar), duplicate articles between the bases 124 being excluded publications Web of Science and 65 the Scopus, resulting in 189 identical items.

From the sample that remained in the first selection (n = 167), the second is established, in which the titles, abstracts and methodologies are read to select only articles that fall within the scope of the study, that is, eliminate if publications that does not match m the subject of study (ecosystem services), as they are also rejected review articles, bibliometry, review and systematic meta-analysis also being excluded studies using methods that assign values to non-monetary ecosystem services, publications that neglect the description of the methods used to value the services and, finally, the articles that did not value any type of ecosystem services, even mentioning them. Thus, the total number of publications included in the analysis described in this article totaled 48 articles, 13.48% of initial publications.

2.3. Data extraction

For selected publications during the final screening stage, revision or is the full text and extracted qualitative and quantitative data that could be used to compare and contrast the evaluation of studies on valuation of ecosystem services using monetary methods. Individually, for each publication, the year of publication is extracted; most cited articles, number of articles cited by periodicals, geographic distribution of authors and co-authors, word cloud, ecosystem services, service categories evaluated, geographical area where the study was conducted, evaluation methods used. Which will be demonstrated in table and figure form in the results section.

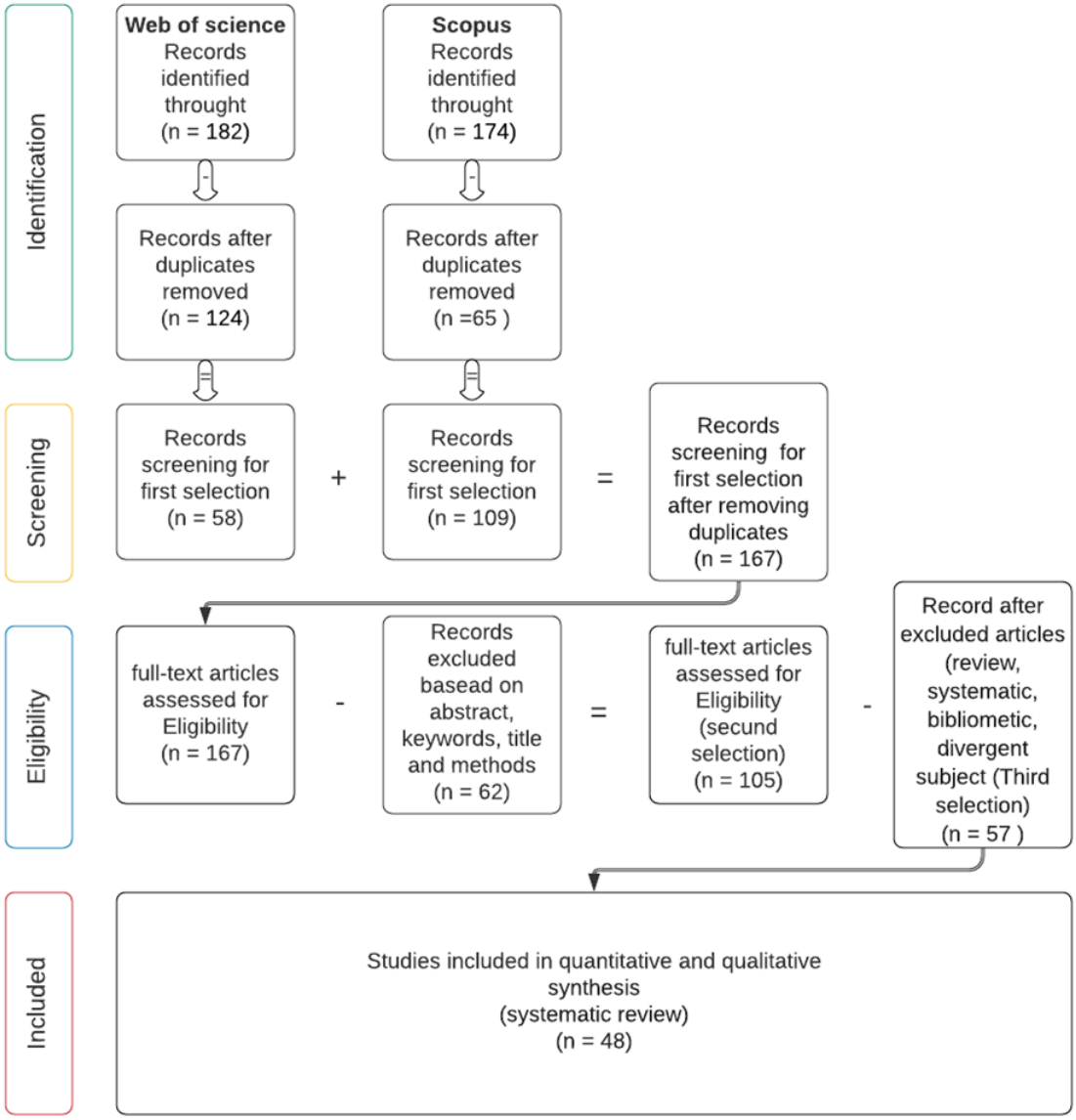

FIGURE 1 – Prisma flowchart for the identification and selection of monetary ecosystem service valuation studies
Source: Research Results (2022)

3. RESULTS

3.1. Quantitative overview of the reviewed articles

This section presents the results after filtering articles in two international databases. For this, a quantitative and qualitative analysis was used, in order to map the scientific production on ecosystem services, focusing in particular on methodological limitations. Thus, after applying filters and criteria described in (Figure 1), the study sample resulted in 48 articles.

In Figure 2, it is possible to observe that the articles on the valuation of ecosystem services using monetary methodologies and methods as a support have suffered peaks of rise and decline since the first years of publication. It should also be noted that the average number of articles published in the years 2015, 2016 and 2019 is 10 articles per year, with the largest volume of published units in 2015, considering the nine years of sample in this study.

As can be seen in Figure 2, the theme of valuing ecosystem services is an incipient and recent issue, this is due to the difficulty in assigning value to intangible goods and services. In addition, it was also analyzed which categories of ecosystem services predominate in the analysis, as classified by MEA (2005). Therefore,

the categories of regulation (n = 17) and cultural (n = 13) stand out in relation to the others, in percentage terms both represent 62.5% of the total publications in the sample, and it is still possible to show in Figure 3 that only 3 articles attribute monetary value to ecosystem services using the 4 categories, due to the complexity of analyzing all categories together.

In addition to the categories of ecosystem services, it is relevant to highlight the journal in which these articles are inserted. For this, the study also portrays the distribution of publications in journals, together with the impact factor. The sample of articles analyzed are disseminated in 27 different international journals, concentrating the publications in the Journal Ecosystem Services and Ecological Indicators with 15 and 3 articles, respectively. When considering the impact factor, both are in the third and sixth position of the ranking, in that order. While the Journal of the Human Environment stands out for having an article published in 2014 with 219 citations, while the Journal of Environmental Management and Ecosystem services follow with 134, 103 and 94 citations (see., Baró *et al.*, 2014; Bastian *et al.*, 2013; Häyhä *et al.*, 2015; Martín-López *et al.*, 2009).

Illustratively, in Figure 4, all the keywords described in the 48 articles are presented, thus, the greater the source of the word, it means that more often it was repeated between articles. As an example, the main words are mentioned: carbon, cost, value, forest and ecosystem service (Figure 5). The tree-shaped design was chosen in order to demonstrate the interrelation of the subject with the environment.

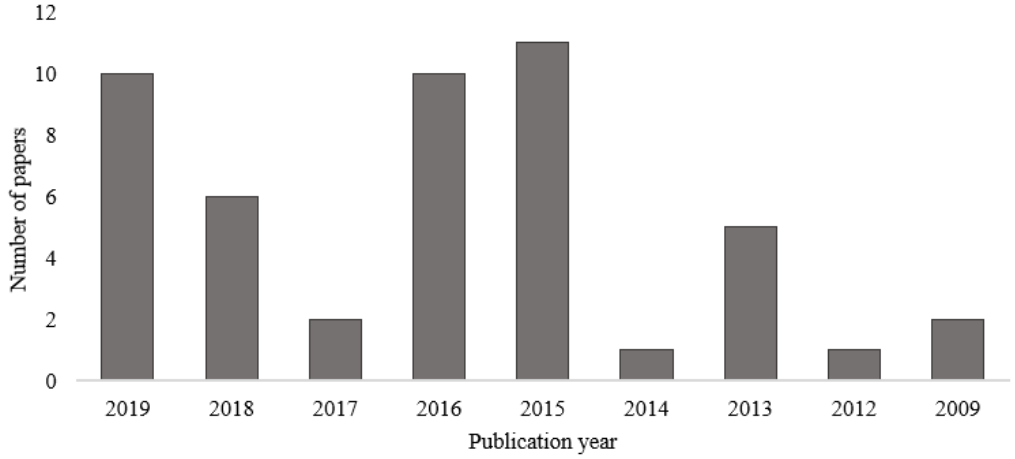

FIGURE 2 – Number of articles per year from 2009 to 2019
Source: Research Results (2022)

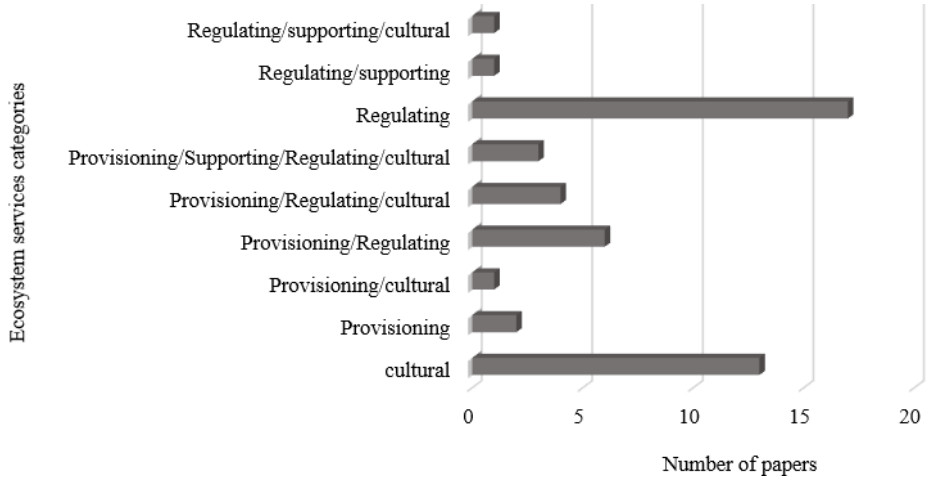

FIGURE 3 – Number of articles published by category of ecosystem services
Source: Research Results (2022)

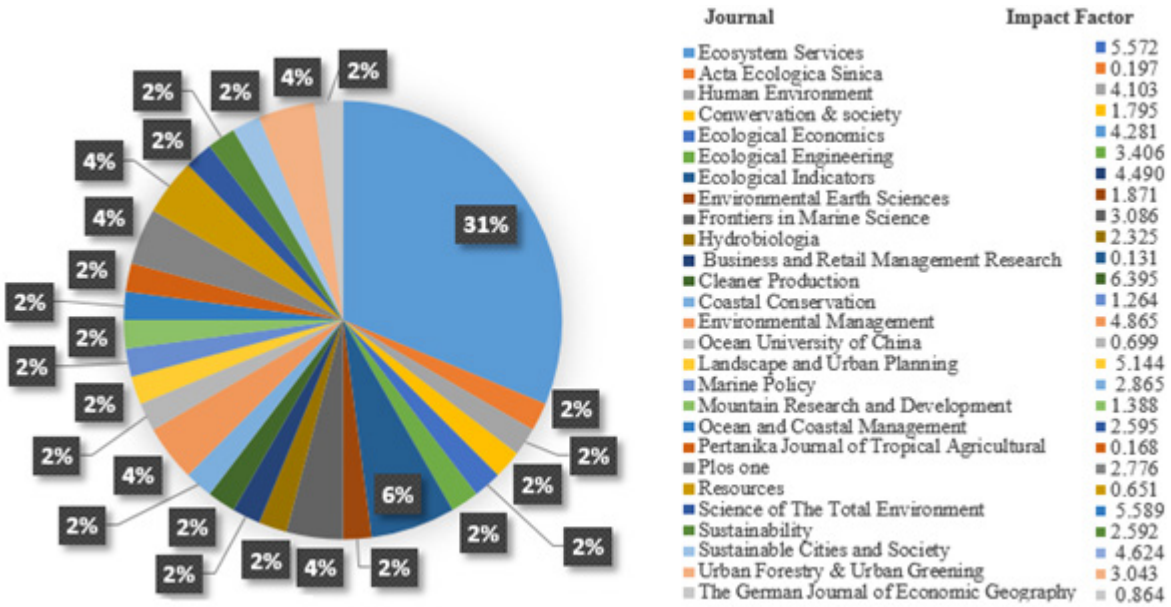

FIGURE 4 – Identification of journals and impact factor in which the articles were published
Source: Research Results (2022)

FIGURE 5 – Word cloud
Source: Research Results (2022)

Then, the relationship between the geographical location of the study and the methods and methodologies applied is identified. The greatest diversity of methods employed is seen among European studies, followed by studies on the Asian continent. It is also observed that statistical analyzes are used to complement the studies. They mention: general linear model (GLM), multi-criteria analyses (MCA), logit and linear regression models e semi-parametric model. See in Figure 6.

3.2. Specific qualitative view of the methods and methodologies of the reviewed articles

Although the number of articles since the initial sample has been reduced, there are still 48 articles left. Table 1 specifically identifies some information about

the articles in which the analysis will be explored. It should be noted that most articles were published by more than 3 authors, with ecosystem services being valued in both urban and rural areas. Most monetary values prevail in studies focused on analyzing agriculture, forestry, marine services and urban parks. Regarding the origin of the data, the primary sources are smaller, due to the difficulty in collecting robust data, with historical series and comparable elements, thus, data of primary origin derive from experiments in their majority.

Although non-monetary evaluations predominate in the literature, there is an incentive to advance research using monetary methods and methodologies. Since measuring the value of an ecosystem service can support the conservation of natural resources, implying, for example, payments for ecosystem services (PES) (Muradian *et al.*, 2013), however, this benefit alone is not enough to attract owners, as the range of benefits provided by ecosystems and biodiversity still needs to be valued.

Thus, studies that value ecosystem services use more than one methodology. In fact, the methodologies defined by Fisher and Christie (2010) are the minority used in the studies of this review, for example, the revealed preference methodologies (Market price, Travel cost, Hedonic pricing and Benefits/Value transfer), as well as those of declared preference (Deliberative valuation, Contingent valuation and Choice experiment), as can be seen in Table 2.

Table 2 was constructed to demonstrate the use of methods and methodologies by category of ecosystem services, in order to verify which service was monetized. It appears that methodologies already applied in financial studies such as Net Present Value, Opportunity Cost and List of Costs and Benefits are adapted to value natural resources, being environmentally useful. In fact, Market price, Travel cost and i-tree Eco/Cool/Hydro dominate the methodologies of systematic review under evaluation.

On the other hand, Table 3 contains the methodologies and methods used in studies carried out in the rural area, briefly describing their definition and limitations. It is observed that the methodologies are repeated, thus, the discussion of this study is concentrated on the 13 methods and methodologies described in Table 3. It is known that the number of these is not the same as the sample selected for this review, totaling 26 units.

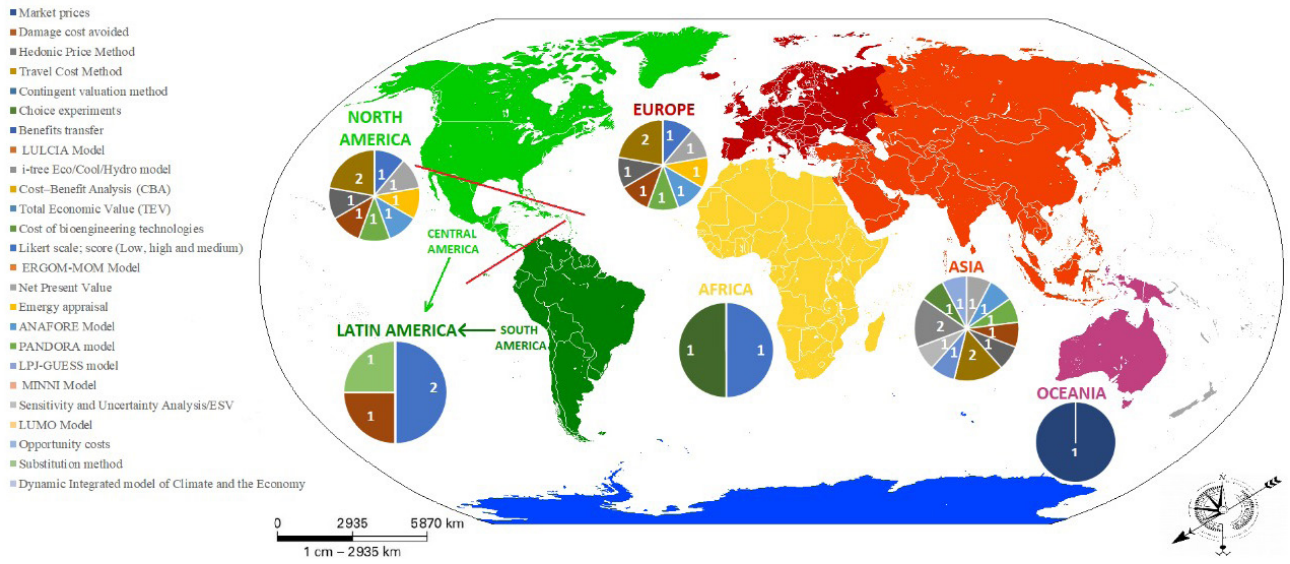

FIGURE 6 – Relative frequency of using assessment methods and methodologies by region
Source: Research Results (2022)

TABLE 1 – Description of the sample of articles selected for analysis and some specificities such as: study location, specificity location study, data source and region

Id	Reference	Study location	Specificity location study	Data source	Region Continua
1	Castillo-Eguskitza *et al.* (2018)	Spain	biosphere reserve	primary	countryside
2	González-Díaz *et al.* (2019)	Spain	forest	secondary and primary	countryside
3	Baulcomb *et al.* (2015)	Turkey	marine and coastal	primary	urban areas
4	Cao *et al.* (2015)	Brazil, Italy, Thailand and USA	forest	secondary	countryside
5	Martin *et al.* (2016)	Latin America	marine and coastal	secondary and primary	urban areas
6	Parsa *et al.* (2019)	Iran	urban forest	primary	urban areas
7	Tardieu *et al.* (2013)	France	terrestrial transport	primary	urban areas
8	Mayer & Woltering (2018)	Germany	parks	primary	urban areas
9	Vermaat *et al.* (2015)	Europe	river	secondary	urban areas
10	Häyhä *et al.* (2015)	Italy	forests	secondary and primary	countryside
11	Ajwang' Ondiek *et al.* (2016)	Kenya	agriculture	primary	countryside
12	Allin *et al.* (2017)	Russia and Poland	marine and coastal	secondary and primary	countryside
13	Wam *et al.* (2016)	Nordic countries	forest	secondary	countryside
14	Langemeyer *et al.* (2015)	Spain	parks	primary	urban areas
15	Baró *et al.* (2014)	Spain	forest	primary	urban areas
16	Ghermandi & Fichtman (2015)	North American	water treatment systems	secondary and primary	urban areas
17	Groshans *et al.* (2019)	USA	livestock wheat and cotton	secondary	countryside
18	Meehan *et al.* (2013)	USA	watersheds	secondary	no
19	Martín-López *et al.* (2009)	Spain	natural protected areas (NPAs)	primary	no
20	Li & Meng (2012)	China	marine	secondary and primary	no
21	Schaubroeck *et al.* (2016)	Belgium	forest	secondary	countryside
22	Pelorosso *et al.* (2016)	Italy	landscape	secondary	metropolitan area
23	Riley *et al.* (2018)	USA	forest	secondary	urban areas
24	Bernués *et al.* (2019)	Europe	agriculture	primary	countryside
25	Pouso *et al.* (2018)	Spain	beaches	secondary and primary	urban areas
26	Bayer *et al.* (2015)	Global	global	secondary	no
27	Czembrowski *et al.* (2016)	Polish	urban green spaces	primary	urban areas
28	Ghermandi *et al.* (2018)	South Florida	wetlands	primary	urban areas
29	Cahyandito & Ramadhan *et al.* (2015)	Indonesia	agriculture	secondary and primary	countryside
30	Sumarga *et al.* (2015)	Indonesia	agriculture	secondary	countryside
31	Nyelele *et al.* (2019)	New York	parks and playgrounds/ restoration areas/streets	secondary and primary	urban areas
32	Aevermann & Schmude (2016)	Germany	urban green spaces	secondary and primary	urban areas
33	Manes *et al.* (2016)	Italian	forest	secundary	urban areas
34	Shi *et al.* (2009)	China	marine	secondary and primary	no
35	Belcher *et al.* (2019)	Singapore	landscape	secundary	Conclusão urban areas

Continue...

TABLE 1 – Continuation

Id	Reference	Study location	Specificity location study	Data source	Region Continua
36	Yushanjiang *et al.* (2018)	China	national Natural Reserve	secundary	no
37	Yeo *et al.* (2013)	Malaysia	urban trees	primary	urban areas
38	Bastian *et al.* (2013)	Germany	agriculture	secondary and primary	urban areas
39	Kenter *et al.* (2016)	United Kingdom	marine	primary	no
40	Soy-Massoni *et al.* (2016)	Spain	agriculture	secondary and primary	urban areas
41	Tyllianakis *et al.* (2019)	United Kingdom	marine	secondary and primary	no
42	Sangha & Russell-Smith (2017)	Australian	indigenous areas	secondary and primary	countryside
43	Ruijs *et al.* (2013)	Europe	agriculture	secundary	countryside
44	Sil *et al.* (2016)	Portugal	park	secundary	countryside
45	Mikhailova *et al.* (2019)	USA	forest	primary	countryside
46	Zarate-Barrera & Maldonado (2015)	Colombia	marine	secondary and primary	no
47	Dai *et al.* (2019)	China	parks	secondary and primary	urban areas
48	Ganguly *et al.* (2018)	India	marine	secundary	no

Source: Research Results (2022)

The methods presented in Table 3 are the main methods used to value ecosystem services. In the next section, the applicability of these methods in the reviewed works will be discussed.

4. DISCUSSION

The irrelevance attributed to the biophysical components of the economy in conventional economic models, can be considered a critical point, while for the ecological economy a motivation. Expressing the produced capital monetarily can be a common way of understanding the value of natural capital, since number is a common variable for individuals (Costanza *et al.*, 2017). Estimating the economic value of the environment can explain externalities in cash previously overlooked or disguised in decision making.

Environmental valuation arises to try to attribute a balance between natural and economic capital, and this relationship can be achieved using environmental accounting. Therefore, the difficulty in creating complete methods and methodologies that are efficient enough to consider, the economic, environmental and biophysical value cannot be found in this review. This is because most ecosystem services cannot be compared with manufactured capital, since in the capital market, the environmental variable is practically insignificant to the decision maker (Costanza, 2014).

Thus, the 26 methodologies used to meet the objectives of the 48 articles analyzed in this study are also limited, so much so that the authors seek to use more than one methodology in their respective analyzes. An example is the Market price methodology used in several research objects biosphere reserve, forest and agriculture, however the values of ecosystem services are created from a single variable, it is known that the market price is changeable daily, causing a bias to the decision maker.

TABLE 2 – Description of methodologies, category of ecosystem services and ecosystem services used in each journal

		Methods or methodologies																								
		Market prices	Cost of damage avoided	hedonic price	Travel cost	Contingent value	Choice experiment	Transfer of benefits	LULCIA model	i-tree Eco/Cool/Hydro model	Cost-benefit analysis	total economic value	Cost of bioengineering technologies	ERGOM-MOM model	Net present value	Emergy assessment	ANAFORE model	PANDORA model	LPJ-GUESS model	MINNI model	Sensitivity and uncertainty analysis	LUMO model	Opportunity cost	Substituition	Dynamic Integrated of Climate and the Economy model
Category of ecosystem services	**Ecosystem services**														13	20					34;36				
Provision	food	1;5;9;11;44a						44			18;29;30				13		21					38			
	wood	1;9;10;44						42			30														
	fresh water	1;10;44																							
	raw materials										30					20									
	quality products						24														36				
Regulation	air quality			27							18;23										34				
	climate (carbon sequestrion)	5;9;10;45;46	2;44				17		4	6;15;31;32	7;23;30;41					20	21			33	34;36		43		48
	nutrient	9								15;31;32									26						
	eutrophication													12											
	erosion control							44	4													38			
	water regulation							42																	
	water purification					24			4		18														
	habitat for species														20										
	hydrogeological protection												10								36				
	sedimentation													12											
	desnitrification													12											
	processing of NH3																21								
	enhanced removal of particulate matter																21								
	fertility soil						24																		
	pest control and eradication										29														
	stormwater runoff reduction									31;32															
	groundwater recharge									32															
	waste treatment																				34;36				
Support	nutrient cycling																								
	biodiversity support						24	42							20						36		43		
	soil conservation														20						36				
Cultural	tourism				14;19;28							10			20										
	recreation			35	8;14;25	16;37	3				29;30	10			20						36			47	
	aesthetic pleasure				14	37;39																			
	biodiversity conservation				19	39	9											22					43		
	religion/spiritual				19																				
	balanced place				14																				
	education					16;40									20										
	landscape					37	24																		
	recreation			35		37																			

[a]The number corresponds to the identification of the analyzed article (see., Table 1)

Source: Research Results (2022)

TABLE 3 – Description of the methodologies and methods of the articles that used the rural area as the location of the study area as the location of the study area

		Methodology or method		
Reference	Study location	Methodology	Description	Limitation
Castillo-Eguskitza et al. 2018	biosphere reserve	Market prices	This method aims to estimate the economic value of ecosystem goods and services, traded on the market.	Limited to market goods and services; Market prices can be distorted e.g. by subsidies. Most ES not traded in markets.
Gonzalez-Diaz et al. 2019	forest	Damage cost avoided	A rational approach, presented as risk decisions, with the objective of estimating the maximum monetary value that is spent to avoid the environmental damage that has occurred or its consequences could reduce their well-being.	Difficult to relate damage levels to ecosystem quality.
Cao et al. 2015	forest	LULCIA model	It aims to measure the impacts of land use, in particular by obtaining ecosystem services directly related to this variable.	The method applied without the aid of other tools is inefficient in analyzing the details of ecosystem services, being incomplete for the valuation.
Häyhä et al. 2015	forests	Total Economic Value (TEV)/Cost of bioengineering technologies/Market prices*	The TEV approach encompasses all components of utility derived from ecosystem services using money or any other market-based unit of account as a common unit of measurement (Pearce, 1993). The cost of bioengineering technologies is based on the cost to replace a given service with a technological substitute.	A limitation of the TEV approach is that it estimates the total annual value or total value that would be lost if all the services disappeared.
Ondiek et al. 2016	agriculture	Market prices*		
Allin et al. 2017	marine and coastal	ERGOM-MOM Model	It is a model created from the principle of thermodynamics, specific biochemistry, but auxiliary for monetary measurements.	Inefficient tool to value ecosystem services, without an auxiliary monetary methodology. Specifically in this study e.g. (Total Economic Value (TEV)).
Wam et al. 2016	forest	Net Present Value	Especially when dealing with environmental assets, the NPV is the amount that can be recovered in the coming days, using the projections of those returns from asset use (inputs (inputs) and revenues (harvests)).	It is generally difficult to assign value to ecosystem services, as their marketing is unusual. The use of this method is ideal especially for simulating scenarios, assigning an estimated value to the asset's value.
Groshans et al. 2019	livestock wheat and cotton	Choice experiments	Assess ecosystem non-use values, but can also be used to estimate generated use values ecosystems.	Potential bias in response, hypothetical market (not observed behaviour), resource intensive; Expensive and technically difficult to implement.

Continua...

TABLE 3 – Continuation

		Methodology or method		
Reference	Study location	Methodology	Description	Limitation
Schaubroeck et al. 2016	forest	ANAFORE Model	It is a method of environmental value or impact of ecosystem services, using scenario simulation.	One of the limitations is that it does not take into account all the externalities of an agricultural system, not being used for complex agricultural systems.
Bernués et al. 2019	agriculture	Choice experiments*		
Cahyandito and Ramadhan et al. 2015	agriculture	Cost–Benefit Analysis (CBA)	CBA, is simply systematic thinking about decision-making. It is a process for identifying, valuing, and comparing the costs and benefits of a project, policy, or decision.	One of the shortcomings of this methodology is to assess specific environmental resources, human life and other assets that are difficult to measure. This methodology is ideal for making decisions, as it is still very dangerous, making it difficult to value the service or service.
Sumarga et al. 2015	agriculture	Cost–Benefit Analysis (CBA)*		
Sangha and Russell-Smith, 2017	indigenous areas	Benefits transfer	The method of transferring benefits uses only values estimated in other evaluation studies, which are carried out similar goods or services and then compiles to give value to clusters of variables, but uses statistical methods as support.	The method is still relatively new and standards for its application have not yet been widely adopted.
Ruijs et al. 2013	agriculture	Opportunity costs	The opportunity cost when related to the object of this research, reflected in monetary terms as compensation between services due to a marginal change in land use.	Limitation refers to the fact of the benefits considered estimated at present value, or that favors the present generation.
Sil et al. 2016	Park	Market prices*/Damage cost avoided*/ Benefits transfer*		
Mikhailova et al. 2019	forest	Market prices*		

Source: Research Results (2022)

Studies that used the Market price and Benefits transfer methodologies tend to be less complex, due to the speed with which an assessment can be completed, requiring the least time and lower costs. Ajwang' Ondiek *et al.* (2016) concludes with his work that by leveraging some ecosystem services on his property, economic benefits are obtained, mentioning some provision services that added value, rice (US $ 602.49) and fish (US $ 1,039.50). In addition, the market price also serves for the valuation of carbon stocks (Mikhailova *et al.*, 2019). In Brazil, a study was carried out to estimate the willingness to pay for the Environmental Reserve Quota (CRA) unit, verifying that the maximum disposition that would be paid by the CRA would be R$ 217.53 per hectare per year (D'Araujo & Alves, 2022).

While the Benefit transfer method is a procedure for estimating the value of an ecosystem service, transferring available information from existing studies to future studies, being able to appropriate the value to the new estimated reality, this means that there is an adaptation of values. That said, one of the concerns is biased estimates that the use of this methodology can lead to decision makers (Richardson *et al.*, 2015).

Sil *et al.* (2016) shows that land use has a major impact on the supply of ecosystem services, so the region interferes positively or negatively in monetary gains, that is, the change in the landscape in the mountainous region in Portugal impacts on the categories ecosystems of provisioning and regulation.

The study by Bernués *et al.* (2019) was more comprehensive than both studies (Ajwang' Ondiek *et al.*, 2016; Mikhailova *et al.*, 2019), as the study area includes agro-ecosystems in the Mediterranean, Atlantic and Alpine regions, in addition to using Choice experiments method also tests the mixed logit model to simulate scenarios. Monetary valuation with the methods chosen for the analysis is highly context-dependent, so it can help prioritize ecosystem service, but the extrapolation of economic values can be misleading.

The Damage cost avoided method aims to measure costs to avoid damages due to lost services, based on the assumption, being a methodological limitation. Instead, Net Present Value, Opportunity costs and Cost – Benefit Analysis (CBA) are non-subjective economic-financial methods, as they serve as a framework for capital investment decision makers. However, they do not consider biophysical externalities, requiring auxiliary models, such as: LULCIA model, Cost of bioengineering Technologies, ANAFORE and ERGOM-MOM, recently created. These models are not monetary methodologies suggested by Fisher and Christie (2010).

Consequently, the emergence of new environmental valuation models is related to national and international agreements, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. With the Clean Development Mechanism (CDM), projects aimed at carbon sequestration grew considerably in developing countries in the late 1990s (Boyd & Krupnick, 2009; Mori-Clement, 2019). In addition, in 2005 the United Nations launched the REDD (Reducing Emissions from Deforestation and Forest Degradation) program. Shortly thereafter, the 2030 agenda emerged, the Forest Code, Law 12.651/2012, the National Biodiversity Policy (PNE) and the Water Producer Program.

Finally, after presenting the results and discussion, the innovative contribution of the study is to briefly illustrate the state of the art in a figure, addressing the key points outlined in this systematic review, focusing on the presentation and methodological limitations encountered. Figure 7 is composed of a timeline showing the initial and final year of the articles in the sample. In addition, the methodologies and methods are presented, relating them to the categories of ecosystem services and the region where they were developed. It should be noted that the font size of the continents expresses the volume of methods and methodologies used in them.

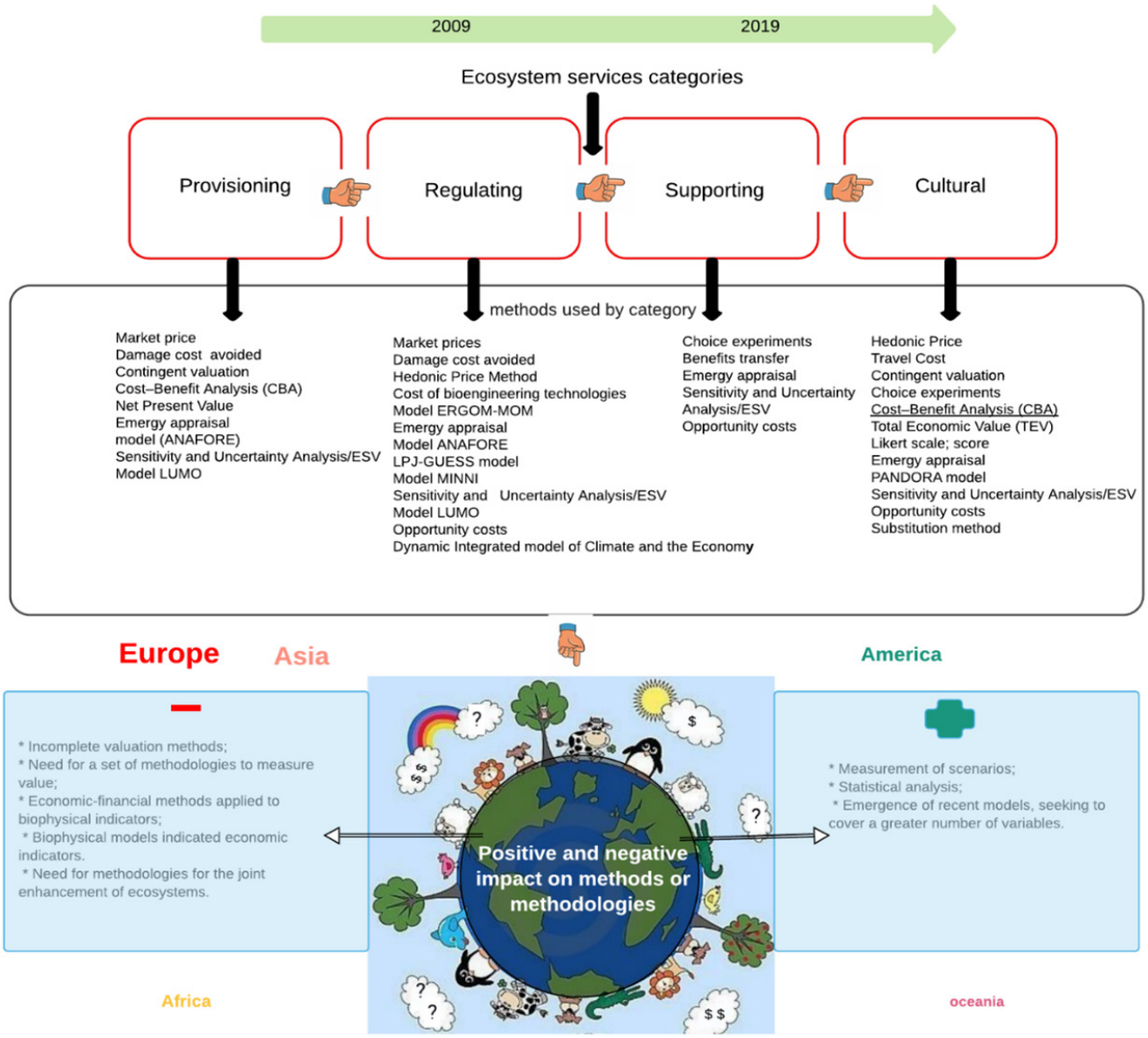

FIGURA 7 – State of the art
Source: Research Results (2022)

It is noted that, as graphically presented in Figure 7, the sample selected in this article includes studies in the most varied continents, however, despite the scope in terms of the area in which the studies were carried out, incomplete methods were still used to value ecosystem services, requiring of more complete methodologies or even the joint employability of these methodologies. A positive point to be highlighted is that the authors of the analyzed works were concerned with analyzing scenarios and some type of statistical application.

CONCLUSIONS

This study made it possible to map the state of the art on ecosystem services in order to verify the methodological limitations applied in their valuation. It can be observed that the quantitative monetary valuation is recent in relation to non-monetary. This is confirmed in studies that aimed to measure ecosystem value through monetary and non-monetary methodologies (Czembrowski *et al.*, 2016; Wam *et al.*, 2016) not discarded from the sample.

The analysis allows to identify that the works are being developed mainly in the European continent, especially in Spain, Portugal and Italy, with source of primary and secondary data. In addition, the study sample started in 2009, continuing for ten years. In general, the studies make use of methodologies and can be divided into three groups, namely, those recommended by TEEB (The Economics of Ecosystems and Biodiversity): Market prices, Damage cost avoided, Contingent valuation, Hedonic price and Benefits transfer) ; the economic-financial methodologies: Net Present Value, Opportunity cost and Cost-Benefit Analysis and recent models seeking to contemplate incipiently the biophysical and economic aspects: Land Use Life Cycle Impact Assessment (LULCIA), i-tree Eco / Cool / Hydro model, Model ERGOM-MOM (Ecosystem Regional Ocean), Analysis of Forest Ecosystems (ANAFORE) model and Land Use Change Modeller (LUMO) model.

Thus, the evolution of methods and methodologies requires a joint effort by scientists and public institutions, seeking to demonstrate positive monetary gains that ecosystems can promote if combined with technological innovations, and types of productive management. Finally, future studies can be prepared based on this review; a meta-analysis is recommended, as the sample set of articles has variables that are monetarily discriminated. Still, the inclusion of new databases can complement the delimitation of the state of the art of the theme discussed here.

ACKNOWLEDGEMENT

This study was funded by the Coordination for the Improvement of Higher Education Personnel — Brazil (CAPES) Finance Codes (88882.457565/2019-01).

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