
State of the art of ecosystem services research at the global level: a multiscale quantitative review

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Abstract: A literature review focused on ecosystem services (ES) research on a worldwide level was performed. The work considered a quantitative analysis based on text mining. Digital information derived from more than 13,000 scientific papers was processed. Temporal trends of ES, the primary research interest, and specificities of different contexts were depicted. Based on a multiscale approach, the above parameters were defined for the global level, regions of the world and countries. The results focused on the relation among ES issues with: 1) techniques for the monetary quantification of ES; 2) the investigation of payments for ecosystem services at a regional scale; 3) the analysis of sustainability pillars. The applied methodology was an updatable and flexible approach useful for the quantitative literature review of specific ES branches, as well as for gap analysis. The final remarks concentrated on future improvements to facilitate the widespread and user-friendly diffusion of the method.

Keywords: ecosystem services; quantitative literature review; text mining; economic evaluation; geographic analysis; multiscale approach; sustainability pillars; payments for ecosystem services; PES; decision support system; socio-economic improvement of developing countries.

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1 Introduction

In recent years, strong interest has arisen in the study of the multifaceted topic of ecosystem services (ES). The most widely accepted definition of ES is that depicted in the millennium ecosystem assessment (MEA) (2005). In this document, ES are defined as ‘the benefits people obtain from ecosystems’, including provisioning, regulating, cultural and supporting services. Beyond the MEA categorisation, several authors have outlined certain difficulties in ES delineation and nebulous interdisciplinary terminology (see e.g., Flint et al., 2013; Kindler, 2016). Among them, Danley and Widmark (2016) stressed how “the term ES scarcely provides specificity or clarity for how to approach environmental science or what aspects of the environment are important for study”. Finding an answer to the above troubles is of particular importance to developing theoretical and practical studies with a common denominator, representing the future direction of ES research (Zhongyuan and Hua, 2011; Volk, 2013) and implementing participatory approaches in the field of ES planning and management (Zajickova and Martens, 2007).

Literature reviews attempt to solve these problems by providing a comprehensive picture of the state of the art for a specific subject. By means of literature reviews, the research status of ES was widely analysed throughout the world. One of the first state-of-the-art analysis of ES modellisation was carried out by Grossmann (1994). Among pioneering papers on ES evaluation for decision making, Bingham et al. (1995) developed a report to understand how various concepts of ES value are structured, how they relate to each other, and how they can guide practitioners and policymakers toward a more integrated valuation process. At the end of the 1990s, Costanza et al. (1997) implemented ES monetisation at a global scale. More recently, Balvanera et al. (2012) developed a large literature review about ES in Latin America, focusing on carbon and water services as well as on payments for ecosystem services (PES). The importance of

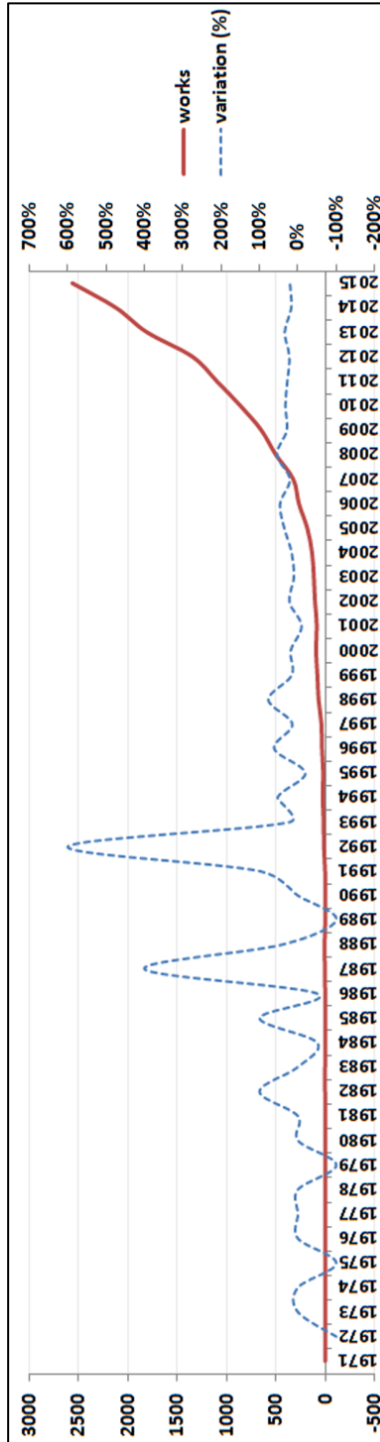
mapping ES was highlighted by reviewing the scientific publications at a global level (Malinga et al., 2015) or taking into account participatory approaches in geographic information system (GIS) analysis (Brown and Fagerholm, 2015). An additional example can be depicted in de Araujo Barbosa et al. (2015) focusing on the spatially explicit remote sensing assessment and valuation of ES. Mach et al. (2015) attempted to perform a science-based evaluation of ES tradeoffs using estuaries' seagrass and shellfish as a case study. Roy et al. (2012) systematically assessed how the benefits and costs of urban trees vary across different cities, geographic scales and climates. A detailed literature review of decision support systems for quantifying, modelling, and mapping ES was developed by Bagstad et al. (2013). ES literature reviews can also be differentiated according to the investigated environment. For example, the role of urban green infrastructure and agroforestry systems (farmland and forest ecosystems) were explored in Wang et al. (2014) and Fagerholm et al. (2016), respectively. Furthermore, a review of the state of the art highlights results from the monetary evaluation of ES (Quintas-Soriano et al., 2016), the relation among ES and human well-being linked to social values and benefits (Schmidt et al., 2016) and the influence of an ecosystem and landscape on educational insights (Mocior and Kruse, 2016).

In the interest of tractability and repeatability, most of the abovementioned works are not included in the literature reviews books, reports and presentations (i.e., grey literature). In addition, one of the more common methods to select scientific peer-reviewed papers seems to be the use of electronic databases e.g., ISI Web of Science, Scopus, Google Scholar, and BIOSIS Citation Index with the application of specific keywords and/or scripts in relative field tags. Literature analysis can also be carried out by means of quantitative reviews that facilitate an objective categorisation of works and items in numerical terms (see, e.g., Luederitz et al., 2015; Labrière et al., 2015; Lee and Lautenbach, 2016).

The main complication for so-defined approaches occurs in the case of a large amount of scientific production, such as in the field of ES. As matter of fact, for the general argument of 'ecosystem services' or for a branch of it, an enormous number of scientific papers can exist and drastically increase during a short period, as shown in Figure 1. Therefore, the easy comparison and updating of research as well as the avoidance of double accounting of papers' (Gavel and Iselid, 2008) can be complicated by the use of dissimilar keywords, scripts and electronic database among studies.

Against this background, the primary objective of a literature review – i.e., to define and to limit the problem on which you are working – appears very problematic. To cope with the concern of processing a high number of manuscripts, text mining – a particular typology of quantitative analysis – can be useful. Text mining reduces the information of large texts, providing a more straightforward understanding of complex data and an automated information achievement from textual data sources (Berry and Kogan, 2010; Ogiela, 2013). Text mining has been widening applied for different text derived from interviews (Parr et al., 2011; Bories et al., 2014), scientific discourses (Tonta and Darvish, 2010; Plumecocq, 2014), media publications (White, 2013; Fløttum et al., 2014), and news articles (Rivera et al., 2014). Currently, to the best of the author's knowledge, text mining has rarely been used to simplify the literature review on ES scientific manuscripts (Tamaddoni-Nezhad et al., 2013).

Figure 1 Total number of works related to ES (from web of science platform) and yearly variation (see online version for colours)



Given these premises, the focal aim of the paper is to develop an intuitive and flexible method that will drive the user through logical steps of literature review for ES scientific papers. This work seeks to implement an updatable database with literature analysis based on a multiscale approach. In particular, a text mining technique able to develop a quantitative analysis of ES literature from national to global levels will be carried out on a text corpus. To demonstrate its usefulness, the technique will be applied in the present work to define:

- 1 A general framework of ES research at the global level.
- 2 A country-based analysis of the occurrence of ES related papers.
- 3 The examination of applied techniques for the monetisation of ES and the PES issues as well as additional specific insights at a regional scale.

In Section 2, methodological aspects of the technique are provided. In Section 3, the results are presented. The last section highlights the discussion and final remarks of the research.

2 Methodology

2.1 Corpus preparation

The first step of the work was the selection of an adequate electronic database from which to extract information. Based on the statements of Falagas et al. (2008), the comparison of databases developed by De Groot and Raszewski (2012) and empirical samples, the Web of Science (WoS) catalogue was chosen for the analysis of ES subjects. Only one electronic database was selected to avoid double accounting of scientific publications. Then, the scripts for the extraction of the text corpus (hereafter identified as corpus) were implemented. The corpus included the ES domain, which could be analysed at worldwide level or downscaled by means of a multiscale approach as reported in Figure 2. That categorisation was based on the classification of countries by major areas (continents) and regions of the world – including Antarctica – (United Nations, Department of Economic and Social Affairs, Population Division, 2013). The relevance of examined issue in political and practical terms stresses the importance of the evaluation scale in the assessment of ES. The implementation of guidelines at a large scale requires different input compared with small-scale analysis. The application of tools able to support a multiscale evaluation is thus necessary to facilitate the decision-making process. A multiscale approach has already been applied in environmental research. For example, Walsh et al. (2001) defined the link between the scale of observation and dynamic variability of human populations and environmental variables. Multiscale methodologies have also been applied to model species distributions in complex environmental systems (Hopkins and Burr, 2009).

To expand the search query in respect to available literature (see e.g., search terms in Balvanera et al., 2012; Malinga et al., 2015), the following script (S_{ES}) was used for the identification of the ES domain: $TS = ('ecosystem\ services' OR 'ecosystems\ services' OR 'ecosystem\ goods\ and\ services' OR 'ecosystems\ goods\ and\ services' OR 'ecological\ services' OR 'ecological\ goods\ and\ services' OR 'environmental\ services' OR 'environmental\ goods\ and\ services')$, where TS represents the topic tag in the WoS

advanced search. Countries, regions and major areas were identified not only with respective names but also with the introduction of adjectival and demonymic forms (Central Intelligence Agency, 2016). The scripts for each area were derived as in the next rules:

$$S_n = S_{ES} \cap S_{N,n} \quad (1)$$

where S_n is the script for the extraction of the ES dominion for country n and $S_{N,n}$ is the script for the identification of the name, adjectival and demonymic equivalent for country n .

$$S_r = S_{ES} \cap S_{R,r} \cap S_n \quad \forall n \in r \quad (2)$$

where S_r is the script for the extraction of the ES dominion for region r and $S_{R,r}$ is the script for the identification of the name, adjectival and demonymic equivalent for region r .

$$S_c = S_{ES} \cap S_{C,c} \cap S_r \cap S_n \quad \forall r \in c \quad \forall n \in r \quad (3)$$

where S_c is the ES dominion extraction script for continent c and $S_{C,c}$ is the script for the identification of the name, adjectival and demonymic equivalent for major area c .

The resulting scripts are reported in Appendix 1. The extracted corpus was limited to publication in English prior to 2016 to make the database easily updatable. As a matter of fact, in the corpus, each area (country, region or continent) is straightforwardly identifiable by means of a specific header (i.e., * ****name).

The corpus was pre-processed through disambiguation, lemmatisation and lexicalisation. Disambiguation allows us to simplify words with the same graphic form but different meanings. In lemmatisation, words with the same root or similar meaning are encoded in a new form that sums occurrences (e.g., from ‘environmental services’ or ‘ecosystem good and services’ to ‘ecosystem services’). Lexicalisation allows users to trace repeated segments back to a single form (e.g., from ‘ecosystem services’ to ‘ecosystem_services’).

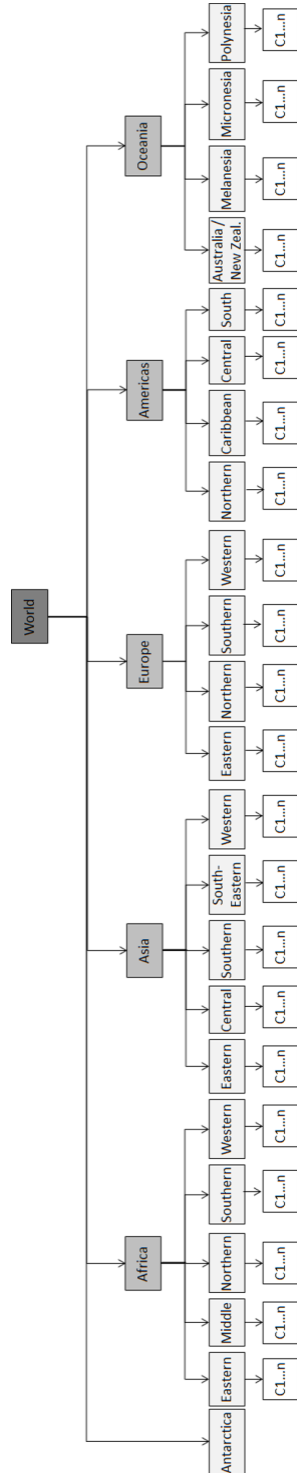
2.2 *Quantitative review*

The corpus was imported as a.txt file, and text mining was performed by means of the software T-Lab, a tool based on the lexicometric approach (Bolasco, 1999).

Text mining consists in a series of statistics-based approaches that allow us to derive quantitative information from text. Text mining involves the process of deriving patterns within the corpus and analysis of the output. Typical text mining applications include text clustering, text categorisation, sentiment analysis and concept extraction.

Different analyses were performed at diverse scales to show potential uses of the database. Studied topics related to ES at the global level were investigated by means of multidimensional scaling approach (MDS), a graphical representation of relationships among lemmas presented in the literature (Sammon, 1969). Through the application of Sammon’s (1969) algorithm, the MDS map permits users to reduce a high-dimensional space represented by similarity matrices to a low-dimensional space.

Figure 2 Representation of the multiscale approach



The number of works related to the whole scientific production (TP_c) as well as the number of works linked to ES for each country (ESP_c) were extracted. Then, the normalised value of the ES production (NP_c) with respect to total scientific literature was quantified for each country by means of equation (4). In this way, the implemented instrument can be applied to reveal potential gaps in the current scientific research and localisation of academic interest for ES issues.

$$NP_c = 1 - \frac{TP_c - ESP_c}{TP_c} \quad (4)$$

A specific quantitative literature review was performed on a regional scale to account for the frequency of applied methodologies suitable for analysing the economic dimension of ES. The classification of the above methods was based on Koundouri et al. (2016) and on King and Mazzotta (2000). For each region, the occurrence of publication involving each economic technique with respect to all papers considering ES was computed. Regional level was also selected to achieve the occurrence analysis of PES studies. The final elaboration realised on a regional scale was the analysis of emerging themes that can be defined as specific topics investigated in a particular text (in our case geographic context). The procedure consists of the following steps (for more detail see T-Lab manual):

- 1 The construction of a co-occurrence matrix.
- 2 Data analysis using a probabilistic model that uses Latent Dirichlet allocation and Gibbs sampling.
- 3 The description of themes by means of the probability of their characteristic words, either 'specific' or 'shared' by two or more themes.

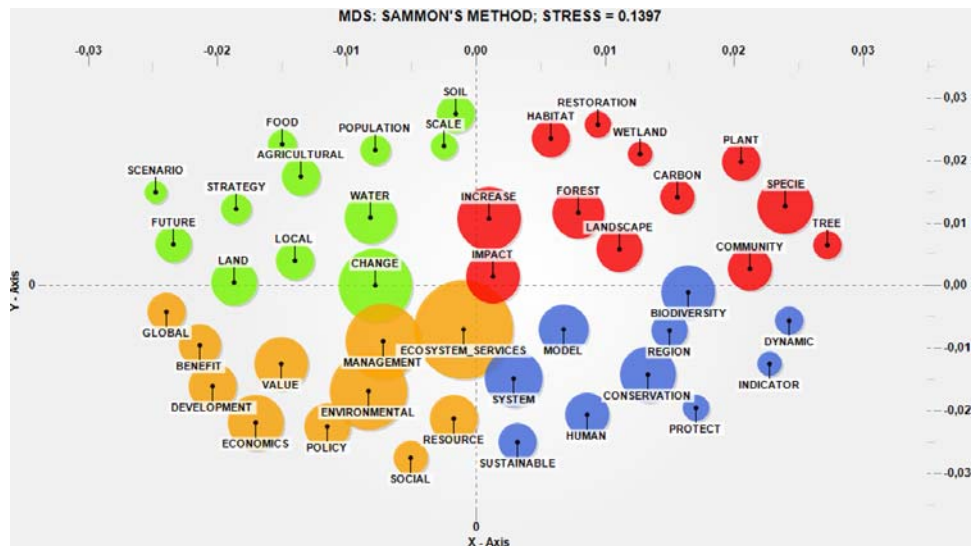
3 Results

The application of script S_{ES} deals with the total number of works concerning ES, which is equal to 13,107 (with removal of duplicates). The MDS results are reported in Figure 3.

The stress index of MDS output (0.14) depicts a fair correlation between the input matrix and Sammon's map (Wickelmaier, 2003). The map shows how the research interest has mainly concentrated on some subjects. In the first quadrant, the importance of 'impact' assessment on ES was revealed; furthermore, the investigations seem to mostly focus on 'forest' and 'landscape' environments. A prevalence of studies based on regulating and supporting services was stressed here (see e.g., the lemmas 'habitat', 'carbon', 'specie'). The second quadrant demonstrates how a particular attention was paid to four additional classes of topic. The first one is represented by provisioning services described by terms such as 'food', 'agricultural', 'water' and 'soil' linked to 'population'. Then, the influence of potential 'change' on ES was explored. In this case, 'change' can be primarily interpreted as land use change or a global increase in economic and societal prosperity as confirmed in Delphin et al. (2016) and Laforteza and Chen (2016), respectively. Scale issue are also reported with 'scale' and 'local'/'global' (third quadrant) lemmas. Eventually, scenario analysis as well as future trends of ES were determined (see 'scenario', 'future', 'strategy'). The third and fourth quadrants express the weight of management and conservation activities as well as the evaluation of

sustainability in an ES framework. Here, the reference is to the three pillars of sustainability, i.e., environmental, economic and social pillars, including in those criteria technological, political and cultural insights (Hacking and Guthrie, 2008). In the third quadrant, proper ‘management’ strategies seem to be strictly related to ES maintenance and improvement. Moreover, the sustainability pillars are consistently evaluated. It is worth noting how ‘environmental’ issues reach a consistent weight (see circle size) compared to the ‘economic’ and ‘social’ pillars. Indeed, in the first phase of complex system analysis, a simplification and focus on ecological (and, thus, on economic) aspect seem to be necessary. Subsequently, the evaluation shifts to the social pillar and it is accompanied with an augmented analysis of complexity as confirmed in other sectors (Cambero and Sowlati, 2014; Diaz-Chavez, 2006). This aspect seems to be proven by the lemmas ‘system’ as well as ‘dynamic’ shown in fourth quadrant. A final remark has to be placed on the quantification of ES. The terms ‘model’ and ‘indicator’ can in fact be associated with generic lemmas ‘benefit’ as well as ‘value’.

Figure 3 Multi-dimensional scale representation of ES topic (see online version for colours)



The structure of the corpus allows us to downscale the analysis at different levels. To reveal the gap in scientific literature and to localise the consistency for production of ES studies, a frequency assessment for each world country is depicted in Figure 4 and in Figure 5.

Figure 4 reports the total number of academic works linked to ES. The results highlight how the majority of papers are concentrated in northern America (USA and Canada), Central America (Mexico), Southern America (Brazil), northern, western and southern Europe, South Africa, China, India and Australia. Intuitively, a preliminary evaluation seems to be directly related to the high number of published papers per nation with the amount of expenditures on research and development (R&D) (OECD, 2016).

Table 1 Partitioning of ES works, and weight of treated topic per region

Region	ES works	Sustainability pillar			Methods for monetary quantification					PES	
		Environmental	Economics	Social	Benefit transfer	Market price or market-based	Contingent valuation	Choice modelling	Cost benefit or cost effectiveness		
Antarctica	33	76.7%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Australia and New Zealand	726	94.9%	58.2%	26.9%	0.0%	5.0%	2.3%	2.4%	7.4%	1.4%	1.4%
Central America	749	100.0%	55.1%	26.9%	0.0%	4.0%	1.5%	1.0%	5.1%	8.3%	8.3%
Central Asia	38	48.3%	51.7%	41.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eastern Africa	452	76.8%	55.4%	32.2%	0.0%	0.0%	0.0%	0.0%	4.4%	8.0%	8.0%
Eastern Asia	1,859	91.7%	67.8%	19.5%	0.0%	0.0%	3.9%	0.0%	4.3%	3.2%	3.2%
Eastern Europe	282	99.1%	74.2%	27.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Caribbean	312	100.0%	74.6%	43.9%	0.0%	7.8%	0.0%	0.0%	6.0%	9.6%	9.6%
Melanesia	42	73.5%	91.2%	32.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Micronesia	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Middle Africa	72	38.8%	35.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Northern Africa	37	100.0%	63.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Northern America	2,007	74.9%	49.8%	17.5%	0.5%	1.4%	1.6%	0.0%	3.5%	0.9%	0.9%
Northern Europe	1,118	78.2%	52.4%	25.1%	0.0%	0.0%	3.5%	2.8%	6.9%	2.1%	2.1%
Polynesia	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
South America	893	100.4%	54.6%	26.7%	0.0%	1.2%	4.0%	0.8%	4.4%	3.1%	3.1%
South-Eastern Asia	438	100.0%	76.5%	31.3%	0.0%	2.7%	3.2%	0.0%	5.1%	2.7%	2.7%
Southern Africa	465	51.0%	72.7%	27.3%	0.0%	0.0%	0.0%	0.0%	7.2%	0.0%	0.0%
Southern Asia	368	95.1%	73.6%	28.1%	0.0%	0.0%	5.4%	0.0%	0.0%	0.0%	0.0%
Southern Europe	769	100.0%	57.9%	29.6%	0.0%	0.0%	7.4%	2.1%	3.2%	0.0%	0.0%
Western Africa	161	84.3%	57.9%	26.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Western Asia	185	100.0%	55.6%	22.8%	0.0%	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%
Western Europe	868	82.8%	41.3%	17.3%	0.0%	0.0%	4.6%	2.5%	7.5%	1.2%	1.2%
<i>Average</i>		<i>76.8%</i>	<i>54.5%</i>	<i>21.9%</i>	<i>0.0%</i>	<i>1.0%</i>	<i>1.8%</i>	<i>0.5%</i>	<i>2.8%</i>	<i>1.8%</i>	<i>1.8%</i>

Some areas stress a deficiency of work on ES. Among them, Africa reveals a strong gap in ES scientific production, in particular for the northern zone. In Europe, the same status can be depicted in the countries of ex-Yugoslavia. Asia is lacking of ES papers in the central and western parts, specifically identified with the Arabian peninsula, Syrian Arab Republic, Iraq, Kazakhstan, Turkmenistan, Uzbekistan and Afghanistan. Those localisations are mainly concentrated in areas characterised by socio-political weaknesses; in particular, a relation seems to emerge with the occurrence of wars in the last 25 years.

An interesting output is revealed from the normalised value of papers on total scientific production (Figure 5). The equatorial countries followed by tropical ones appear to be the region with the main significance of ES studies. Particular emphasis is depicted in Latin America and the Caribbean – with the highest scores reached by Turks and Caicos Islands and Costa Rica – southern and eastern Africa and south-eastern Asia (see e.g., the relevance registered for Indonesia). In general, ES is of great importance in minor islands and states with high natural capital. ES sees less attention in respect to the whole scientific production in the geographical range including northern Africa, western and central Asia, Mongolia, Russia and some developed countries i.e., Japan, Democratic People's Republic of Korea and Denmark. Detailed amounts of papers and normalised papers per country and region are reported in Appendix 1.

In the regional-level analysis, a focus on both methods for ES economic evaluation and PES is provided. Table 1 indicates how the majority of economic evaluations seem to be carried out by means of cost-benefit analysis that involve medium- to long-term forecasting.

From a methodological point of view, stated preference techniques, such as contingent valuation or choice modelling, have been prevalently applied in respect to revealing preferences methods. Contingent valuation (mainly implemented through the willingness-to-pay approach) is followed by market price (or market-based) tools. Choice modelling is an additional method presented in the literature for ES evaluation. In general, ES monetisation is presented in only 6.1% of the total works denoting how the quantification of ES can follow both biophysical and monetary data, but the first is currently the usual option (Cordier et al., 2014). Benefit transfer has reached a significant value only in North America. This aspect confirms the importance of a consistent number of case studies already analysed to have a valuable sample of similar examples. Another emerging result is the significance of market-based techniques in such regions as Australia and New Zealand, Central America, Caribbean, South America and South-Eastern Asia. The results linked to travel cost, as well as hedonic price methods, are not reported because they are associated with ES valuation in a trivial number of papers. The stated preference method obtains a strong influence in European regions, particularly in southern, northern and western Europe. At least one example of the methodology for ES monetisation was expressed in 17.1% of scientific works for Australian and New Zealander region, followed by Western Europe (14.6%), the Caribbean (13.7%) and Southern Europe (12.7%).

An interesting output is related to the frequency of PES research in different regions. The above topic is mainly represented in the Caribbean, Central America as well as Eastern Africa following the importance of ES studies in respect to total scientific production (NP_c). As matter of fact, the correlation between the number of PES studies and the amount of paper concerning methods for ES economic evaluation is quite low (R^2 : 0.22). As a consequence, a relevant production of works for the monetisation of

environmental benefits does not directly indicate a real market of them. PES implementation seems to have higher importance in developing countries to promote local socio-economic advances.

Sustainability pillar evaluation confirms previous assertion: in general, the greater importance of environmental issues is followed by economic and social ones (apart from Melanesia and Central Asia).

Appendix 2 highlights the emerging themes related to ES works for each region of the world. In other terms, evidence of specificity to stress typical subjects of diverse areas was sought. Among several outputs that can be derived from Appendix 2, a focus on economic and sustainability issues was carried out. Financial subjects seem to be specific for region, such as Eastern Europe, where the analysis of financial aspect of project related to ES is highlighted (see e.g., terms 'business', 'finance', 'fund', 'budget', 'revenue'). They also appear with a certain relevance in North and South America with lemmas such as 'effectiveness', 'financial' and 'invest' or 'PES', 'market' and 'poverty', respectively. It seems to confirm how a specific goal of PES implementation in developing countries is socio-economic improvements of single contexts. In addition, the Caribbean region stresses emerging themes linked to economic parameters (e.g., 'commodity' as well as 'bank'). Techniques related to the monetisation of ES appear as specificities in south Asia ('market-based') or southern Europe ('market price', 'WTP'). Sustainability issues as well as the evaluation of the ES framework as a complex system were explicitly reported in the south Asian context with lemmas such as 'ecological', 'sustainable', 'social', 'socio-economics', 'integrate' and 'complex'. Similarly, the southern African area expressed specific terms linked to the above subject ('environmental', 'dynamic', 'trade-offs'). Additional insights can be found for Southern Europe, where particular emphasis seems to be given to ES for touristic and recreational aspects. In this territory, research reveals emerging themes such as sustainability evaluation of protected areas ('sustainability', 'SCIs') as well as the importance of cultural heritage and landscape perception ('heritage', 'culture', 'aesthetic'). Specificity for Western Africa is depicted in REDD policies and carbon sequestration.

4 Discussion

The domain of ecosystem services has been thoroughly investigated in the last few decades. As expressed by Figure 1, the argument was analysed from the early 1970s with a particular emphasis starting from the end of the 1990s. This is probably due to the growing interest for that subject as well as the influencing paper in Nature by Costanza et al. (1997) on ES monetary evaluation. Multi-dimensional scale assessment depicts various topics on which the scientific literature has concentrated. In general, it can be affirmed how the interest and the studies were moved, or integrated, from an environmental based evaluation to socio-economic ones with a major focus on the complexity and interrelation of the analysed systems. The quantitative appraisal of ES research at a country scale highlights how the great number of papers is concentrated on developed nations, but the weighted number of works with respect to the total scientific production seems to be strictly dependent on natural capital. More natural capital follows the tropical as well as equatorial zones; in those areas mainly developing countries can be represented, and ES analysis seems to reach a consistent importance, not only to give a

picture of either ecosystem state or goods and services potentially provided from them but also to depict a useful path for local development. As a matter of fact, PES studies mainly involve the nation with a valuable score in normalised ES paper. The absence of correlation among a number of papers in which ES economic quantification was carried out and a number of papers debating the topic of PES demonstrated how often – in this sector – research output and the real market are not strongly linked; the above aspect stresses a lack of innovation and technology transfer. A few works related to monetisation of ES are presented in the literature compared to the total scientific production. It seems to confirm the numerous limits of the methodologies for quantifying ES from an economic perspective with respect to biophysical indicators. Several authors depicted and discussed the above weaknesses (among them see Maguire, 2009; Brander and Koetse, 2011; Armbrrecht, 2014), and suggestions for improvement were proposed (see e.g., Gsottbauer et al., 2015). From a methodological point of view, monetisation techniques are prevalently based on stated preferences methods, such as Contingent Valuation or Choice Experiments, culminating in cost-benefit analysis. Additional approaches, such as revealed preference procedures, have been less applied.

One of the main advantages of the proposed methodology can be depicted in the application of specific scripts able to include a large number of works with respect to already available search queries. The scripts permit us to take into account a comprehensive amount of scientific papers concerning the topic of ES in both general terms and for specific geographic contexts. This last aspect enables a multiscale analysis from global to local (national) levels. The output of the present research can be easily updated and compared with future work (e.g., through the integration of text corpus with data of following years) to assess trend analysis and scientific interest modification.

The suggested technique exhibits weaknesses that have to be considered in future analyses. First, the adopted search queries considered only the title, abstract and keywords of scientific papers/chapters and not the full text. Full text could not be evaluated because in this case, single lemmas could be inserted in the general context or discussion. In addition, full text scripts do not guarantee specificity of the treated topic. Furthermore, the grey literature should be introduced to expand ES evaluation. Applied simplification (grey literature exclusion) currently permits defining a homogenous method that is widely usable and ensures data provenance. Ecosystem services are a quite recent matter in scientific discourse. In general, it can be considered as an updating of other terminological statements, such as ‘multifunctionality’ (Huang et al., 2015). Consequently, several works have taken into account ES without explicitly using the expression of ‘ecosystem services’. In addition, singular ES treatment can occur (e.g., in works focused on ‘water regulation’ and ‘biodiversity maintenance’).

A quantitative review and text mining approach can face difficulties in some literature interpretation in the case of:

- 1 negative or positive acceptance of a particular lemma
- 2 the combined analysis of environmental services/disservices
- 3 the investigation of trade-off among ES.

Particular attention has to be paid to the geographic identification of case studies as well. In fact, the examined areas could be uniquely identified as sub-national contexts; this circumstance is still rare in international scientific papers.

5 Conclusions

The proposed technique allows us to collect a large number of scientific works and to analyse them by means of quantitative methods. The text mining approach facilitates the investigation of implemented corpus in numerical and statistical ways. In particular, the suggested framework seems to be a useful pathway to carry out a literature review in the case of a great quantity of digital data.

The above considerations stress the potential implications of the present study for academics and practitioners. The scientific research community can benefit from the output of this work, taking into account the trend of ES analysis as well as the gap in the scientific literature at different scales. Future research seems to be oriented to the treatment of ES as complex and integrated systems. Particular attention should be paid to techniques able to evaluate ES with mixed methods and dynamic approaches. For example, more emphasis could be given to methodologies, such as multicriteria analysis that can integrate in a unique framework both biophysical and economic indicators. The dynamic trend and temporal variation of ES can be computed by means of system dynamics models (Limburg et al., 2002; Vidal-Legaz et al., 2013). Uncertainty quantification should be introduced in the above simulations to strengthen the results and provide evidence scenario analysis. In this way, greater consistency with the economic quantification of ES and – subsequently – PES schemes, can be defined. Gap analysis is another suggestion for further research topics. Additional studies could be in fact concentrated on countries with a few number of scientific analyses of ES (see results related to Figures 4 and 5) or on the social implication of ES maintenance and management, specifically in a region with a particular lack on this subject (see e.g., Middle and Northern Africa in Table 1). Eventually, the PES market can be strongly analysed in different major areas of the world. In particular, Asia and Africa could benefit from more insights of these investigations (see the last column of Table 1).

This study can be useful for increasing the attention of policy makers and decision makers to take effective actions to sustain the performance of ES. A preferred PES scheme could be investigated in the context of particular specificities related to ES. Some examples arising from results that should be examined in depth include:

- 1 The activation of the particular ES market related to landscape benefits and natural heritages in Southern Europe.
- 2 The integration of the carbon sink market in Western Africa.
- 3 The reinforcement of biodiversity-related market in Central America.

These regions and, in general, areas with particular peculiarities can be considered as a case study to transfer best practices in other territories. Attention remark should be paid to definition of guidelines to improve socio-economic conditions in developing countries. In this sense, several parameters could be integrated with each other to highlight zones where ES can act as a promoter of well-being (e.g., the frequency of ES studies, the gap in socio-economic evaluation or the average gross domestic product (GDP) per capita can be considered in future analyses). A suitable background can in fact be depicted to make ES maintenance/management or PES implementation, a proper path for local development.

A final remark is concentrated on future potential methods and tools to manage and analyse a large amount of data. Future trends seem to be directed to big data (BD) evaluation, where BD is digital information characterised by significant growth in the volume, velocity and variety of data (Dumbill, 2012). BG has been applied in the ES framework in a few works (see e.g., Lynch et al., 2015; Cord et al., 2015). Unless there is a wide availability of web technologies for environmental BG management (Vitolo et al., 2015), currently the main problem seems to be the absence of a user-friendly application extensively usable for a quantitative literature review, as well as text mining analysis.

Appendices/Supplementary materials are available on request by emailing the corresponding author at sandro.sacchelli@unifi.it.

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