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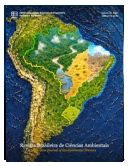

A bibliometric review of ecosystem services and coastal zones: diagnoses and trends

Análise bibliométrica acerca de serviços ecossistêmicos e zonas costeiras: diagnósticos e tendências

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ABSTRACT

Bibliometric analysis is an instrument used to quantify scientific production on a given topic. This type of analysis can be applied to show trends in an area of study. This review aims to examine how scientific production on ecosystem services, coastal zones, and ports is being carried out, identifying trends and gaps. The guiding questions of the work focused on the growth of production, the ports as focal points, the ecosystems studied, the methodologies used, and which ecosystem services were the focus of discussion. Searches on catalog platforms were made to determine how many articles would be considered for analysis, and after filtering, 91 articles were examined. The main results show that the years 2014 and 2018 were the peak of publications; the United States of America is the country that presented most publications with 19 papers; ports appear in just over 20% of the analyzed works, and beaches and marine environments, such as the continental shelf and slopes, are focus of discussion. More than 50 ecosystem services were found in the analysis, with "food" and "recreational values" being the most studied services. With the decade of the oceans, there is a tendency for the growth of scientific production, maintaining the relevance of the themes, particularly when studied together.

Keywords: benefits; environments; recreational values; beaches; papers.

RESUMO

A análise bibliométrica é um instrumento utilizado para quantificar a produção científica sobre determinado tema. Esse tipo de análise pode ser usado para mostrar tendências em uma área de estudo. Esta revisão examina como está sendo realizada a produção científica sobre serviços ecossistêmicos, zonas costeiras e portos, identificando tendências e lacunas. As questões norteadoras do trabalho focaram no crescimento da produção, nos portos como pontos focais, nos ecossistemas estudados, nas metodologias utilizadas e em quais serviços ecossistêmicos eram foco de discussão. Foram feitas buscas em plataformas de catálogos para determinar quantos artigos iriam para a análise e, após filtros, 91 artigos entraram em exame. Os principais resultados mostram que os anos de 2014 e 2018 foram os principais em termos de quantidade de publicações; Estados Unidos da América foram o país que apresentou mais publicações, com 19 artigos; os portos aparecem em pouco mais de 20% dos trabalhos analisados; as praias e os ambientes marinhos, como a plataforma continental e os taludes, são os ambientes mais estudados. Mais de 50 serviços ecossistêmicos foram encontrados na análise, sendo "alimentos" e "valores recreativos" os mais estudados. Com a década dos oceanos, há uma tendência de crescimento da produção científica, mantendo a relevância dos temas, principalmente quando estudados em conjunto.

Palavras-chave: benefícios; ambientes; valores recreacionais; praias; artigos.

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Introduction

Ecosystem services are benefits that humans derive from the ecosystem (MEA, 2005; Díaz et al., 2018; Hernández-Blanco and Costanza, 2019). However, to understand how the discussion about the problematics of ecosystem services is configured in a contemporary way, especially associated with sustainable development and environmental preservation, we must reflect back a few decades. The first time the concept of ecosystem services was shown dates to the late 1960s, with King (1966) and Helliwell (1969), when those themes related to their economic value.

The sustainable development debate stimulated the scientific community to discuss ecosystem services, which had been incipient till then. Until the 1990s, the terminology was already adopted but without a formed concept or proper categorization. The first efforts to conceptualize it started from the economic sphere and afterward from the ecological, with the first sphere still having greater participation in the debate.

The relationship between ecosystem services and human well-being was already evident as stated by de Groot (1987). Despite the concepts, categories, and functionality not being arranged, the effort began to create parameters and relationships of how such services behaved and how they were affected by incipient environmental degradation.

Costanza et al. (1997) assessments covered four pillars concerning the environment, such as function, risk, impact, and management, in addition to the contribution of each pillar to the functioning of an ecosystem and, consequently, to the provision of an ecosystem service.

The theme gained prominence at the turn of the 21st century, from the Millennium Ecosystem Assessment (MEA), between 2001 and 2005. MEA had the collaboration of several entities to study what were the ecosystem services and their importance for economic development, as well as for the generation of well-being and life in society, as it triggered the alarm for what, years later, would be called the global warming (Marzec, 2018).

As a result, ecosystem services were considered as any benefit that people receive from ecosystems (MEA, 2005). Other definitions that can be used are those of Fisher et al. (2009, p. 645), who classified ecosystem services as "the aspects that human beings use to produce human well-being", and of The Economics of Ecosystems and Biodiversity (TEEB, 2010, p. 37) as "the direct contributions and indirect effects of ecosystems for human well-being".

As of MEA, ecosystem services were conceptualized and categorized, clarifying what was needed to adopt measurements and preventive actions for the environment, to a greater extent, through sustainable development. Ecosystem services were organized into four distinct groups and with different measurements: provision, regulation, support, and culture services (MEA, 2005; Hamaarag, 2018; Haines-Young and Potschin, 2018).

In general terms, provision services are those that produce ecosystem products, such as water, energy, and fuel. Regulation services are linked to ecosystem maintenance processes, such as erosion control, storm protection, and water quality. Support services are the basis for other services, as they support the functioning of ecosystems, such as habitat provision and nutrient cycling. In addition, culture services are related to how ecosystems influence the plurality of society, culture, religion, and leisure (MEA, 2005).

From this panorama, the study on the quantification of production on ecosystem services becomes viable due to the significant increase of the theme's relevance in the global scenario, in the sustainable development, and in climate change agendas. Thus, this work permeates the systematic review of studies carried out on ecosystem services.

In addition, the work focuses on coastal zones and all environments that are in contact with and dependent on the relationship with coasts since the Earth's population is concentrated, to a great extent, in these zones. The relationship between the environment and ports covers several themes, from the port area used for the sustainable development of a region to the economic impact of the activities developed there.

Therefore, the main goal of this paper was to quantify the works being produced based on the relationship between ecosystem services and coastal zones and wonder if ports activities are the main question in those papers. Besides that, analyze how the scientific community is treated, which environments are the focus of discussion, and which methods are used.

Methods

In order to ensure an efficient systematic review, a search on two different platforms was carried out (Donthu et al., 2021), and the platforms chosen were Scopus and Web of Science. To guide this bibliometric research, the following questions were made: 1. How much has scientific production grown about ecosystem services and coastal zones throughout time after the publication of MEA? 2. How many papers deal with port problems? 3. Which environments are the focus of discussion about ecosystem services and coastal zones? 4. Which ecosystem services are studied in papers, and which are a major number of appearances? 5. Which methodologies were applied in those studies?

Those questions, after discussion and research, led to the keywords "ecosystem services", "coastal zones", "environment" and the exclusion word "not a river". The search happened on 21 August, 2021. A total of 492 papers were found: 308 on the first platform and 184 on the second. Data were organized using Zotero software.

Exclusion criteria were applied to select the papers. Repetition between platforms, papers before 2005 (the year of MEA, an important milestone for the standardization of concepts and categories), inadequate themes (papers that included the term 'ecosystem services' in the title, abstract, or keywords, but whose primary focus did not revolve around ecosystem services), those papers that were not found in the English language, or were unavailable in complete form.

After following all those criteria, 91 papers were selected and read to answer the questions raised before. To respond to those questions, a matrix was created to fill in the key points in all papers

read (Supplementary Material). To organize all the information, categories were established to quantify, measure, and categorize the content.

The categories were title, authors, first author's country, year of publication, number of institutions, institutions, main institution, journal, partnership between countries, scale, environment, port presence, keywords, provision services presence, provision services, regulation services presence, regulation services, support services presence, support services, cultural services presence, cultural services, and methods.

Following the MEA (2005), categories of ecosystem services and methodologies helped understand the way scientific studies approach the key questions in this paper.

Methodology categories:

1. Revision: It exists in material, consisting mainly of books, scientific papers, and legal documents. It allows the researcher to cover a phenomenal variety and a wide range. The advantage of this method is that a search problem is very dispersed in space data (Ocaña-Fernandez and Fuster-Guillén, 2021).
2. Identification: Gil (1985) certifies that, in this type of method, facts are perceived directly, without any intermediation. In this case, there is a decrease in subjectivity. Nothing else is a use of senses to solve all research problems.
3. Evaluation: Sufian et al. (2011) describe it as a simultaneous collection of information, characteristics, and results from a defined point of view. These definitions focus on the objectives, concerns, and perspectives of the interesting parts of the research. In addition, it enables the identification of priorities from the assessment that have positive impacts on a study area.
4. Modeling: This type of method is described differently in the scientific literature. Madear and Madear (2021) say that a model is an abstraction capable of solving a complex problem, helping people to understand certain structures and behavior of original systems.
5. Case Study: This method empirically investigates a contemporary phenomenon in two ways, depth and context, especially when the limits between the phenomenon and the context are not evident (Priya, 2021; Yin, 2014).
6. Planning: Scherer et al. (2012) affirm that planning is about finding answers and solutions with civil society, aiming at concerted actions, challenging what was previously diagnosed. This results in management to be developed by competent institutions.
7. Valuation: Motta (1997) proves that valuation determines how better (or worse) people's well-being will be considering the changes in the number of goods and ecosystem services. For that, this method will match that goal as it becomes capable of capturing those different parts of economic value to an environmental source (Dhivya et al., 2023).

Ecosystem services categories:

1. Provision: This category includes those products guaranteed by ecosystems, like food, raw materials for fuel or energy sources, genetic resources, etc. Their sustainability pattern should not be classified by the amount that these services are offered, but as an analysis of their limitations to support human activities without losing their properties to ensure operation (MEA, 2005).
2. Regulation: These are ecosystem processes that provide regulation, such as air quality maintenance, climate regulation, erosion control, water purification, disaster protection, etc. Unlike provisioning services, analysis should be done on the predisposition to regulate certain services (MEA, 2005).
3. Support: It is primordial for the functionality of other services. It differs from others due to impacts since it is indirect, and the consequences are long-term. Clear examples are oxygen production, soil formation, nutrient cycling, provision of habitat, etc. (MEA, 2005).
4. Culture: It involves plurality and diversity through the influence of the ecosystem on the multiplicity of different cultures, religious and spiritual values, and education, for example. This type of service is related to human actions and behavior, as human perception of institutions and social patterns results in different ways of measuring cultural ecosystem services. Hence the difficulty in measuring the grades of these services (MEA, 2005).

Results

The 91 publications in this review were published between 2005 and 2021 (the period of the research on the platforms) and the peak of publications occurred in the years 2014 and 2018 (Figure 1). Most publications (50%) were based in four countries: the United States (19), the United Kingdom (14), Brazil (7), and Australia (6) (Figure 2). Over 40% of the publications were based in the Americas, 30% in Europe, approximately 25% in Asia, 10% in Oceania, and 5% on the African continent.

The publications were distributed in several journals; the main ones were Marine Policy (13), Ocean and Coastal Management (10), and Ecological Economics (7). Of the total number of publications, 53% had a contribution from scientists of two or more countries, and 47% had only one country on the list of scientists.

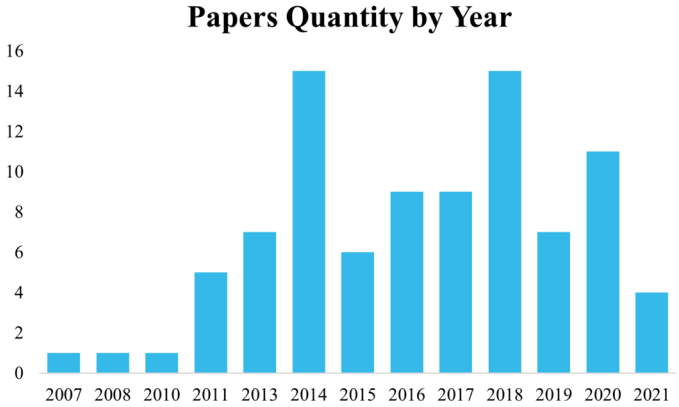
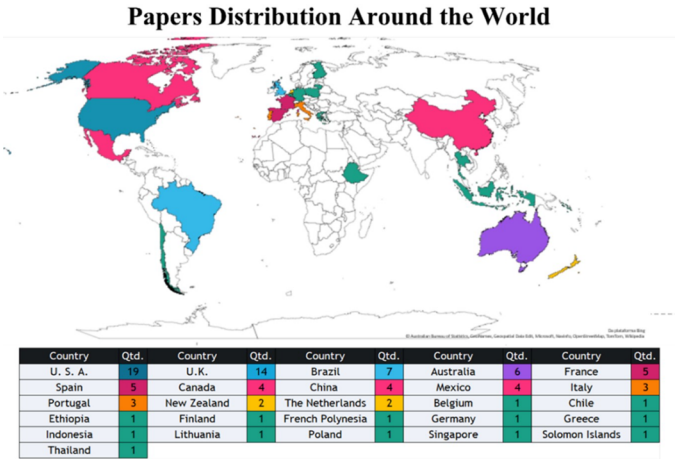


Figure 1 – Quantity of papers published between 2005 and 2021.

There were 50% of papers focusing on the regional scale, 29% on the global scale, and 21% on the local scale.

The most relevant keyword presented in this research was "ecosystem service" (Figure 3), with 39 repetitions in 91 papers. This demonstrates how studies are guided to analyze the relations between services and environments. The other four more relevant keywords were coastal management, climate change, valuation, and economic value, showing how the studies trend in the scenario proposed in this bibliometric review.

The question "How many papers work about port problems?" was answered when the data was collected throughout the bibliometric review. Of the 91 publications, only 23% treated ports and their problems as a protagonist, or a secondary issue. For that, it is important to show the relevance of studying how the impact of port activities has changed the environment and, consequently, ecosystem services.



Country	Qtd.	Country	Qtd.	Country	Qtd.	Country	Qtd.	Country	Qtd.
U. S. A.	19	U.K.	14	Brazil	7	Australia	6	France	5
Spain	5	Canada	4	China	4	Mexico	4	Italy	3
Portugal	3	New Zealand	2	The Netherlands	2	Belgium	1	Chile	1
Ethiopia	1	Finland	1	French Polynesia	1	Germany	1	Greece	1
Indonesia	1	Lithuania	1	Poland	1	Singapore	1	Solomon Islands	1
Thailand	1								

Figure 2 – World's distribution of papers published.

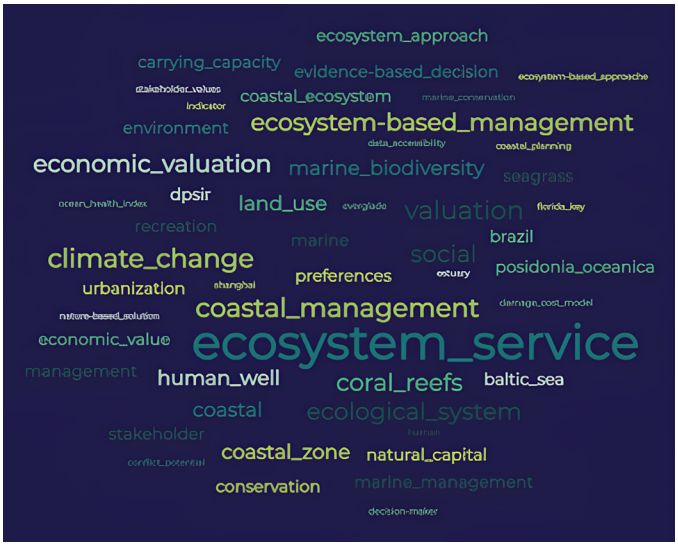


Figure 3 – Word cloud about the keywords in this bibliometric review.

Beaches are the environment that appeared most in the 91 papers worked on in this study, representing 36% of all environments (Figure 4). The beaches were cited in studies of all ecosystem services categories. The marine environment (continental platform and slopes) was present in studies working on the conditions to provide food, habitat, and some of the regulation services (such as climate regulation, storm protection, and air quality). Those studies showed a variety of problems, from erosion on beaches with the high process of urbanization to the recreation conditions on these beaches and how these impacts the presence or absence of people using that space.

The estuaries were mentioned in 13% of all the papers, and coral reefs in 8%. The latter are strictly related to providing habitat to species all around the globe. Mangroves and bays were cited in 6% and 4% of the papers, respectively, and are connected to provide services and support services. The beaches are connected to cultural services.

In 91 papers, the studied environments (represented in Figure 4) performed in varied combinations. It is possible to see in Figure 5, the way ecosystem services were treated in these relations. Beaches are commonly associated with the culture services, but all four categories were highly represented. Furthermore, beaches appeared in ten combinations, four of which did not have all the categories of ecosystem services.

Marine environments (continental platforms and slopes) were the second type that stood out in the study. Regulation and provision of services were the focus of discussion in treating marine areas. In estuary areas, regulation services were the main category; in coral reefs, provision and regulation services were tied in importance. Culture services featured as the main category in bays and mangroves.

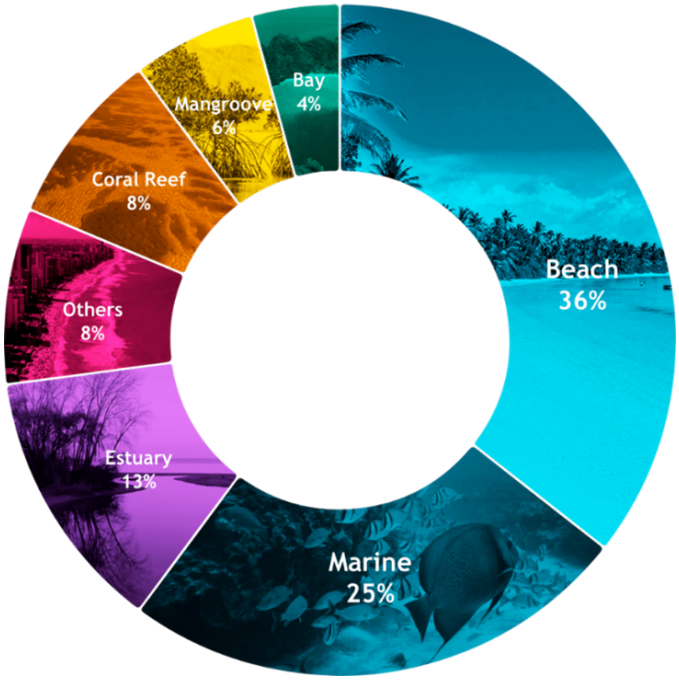


Figure 4 – Environments worked on the papers in the bibliometric review.

The supporting services appeared as the most influential in "others", which included wetlands, urban areas, and freshwaters.

The presence of specific ecosystem services is of great importance to this study. The two most relevant ecosystem services in the sample were "recreation values and food" (Figure 6). Recreation values are related to the capacity of the environment to create conditions for human activities, such as playing sports, relaxing, sunbathing, etc. Food is associated with the conditions of the environment to provide food for all species depending on them, from microorganisms to human beings.

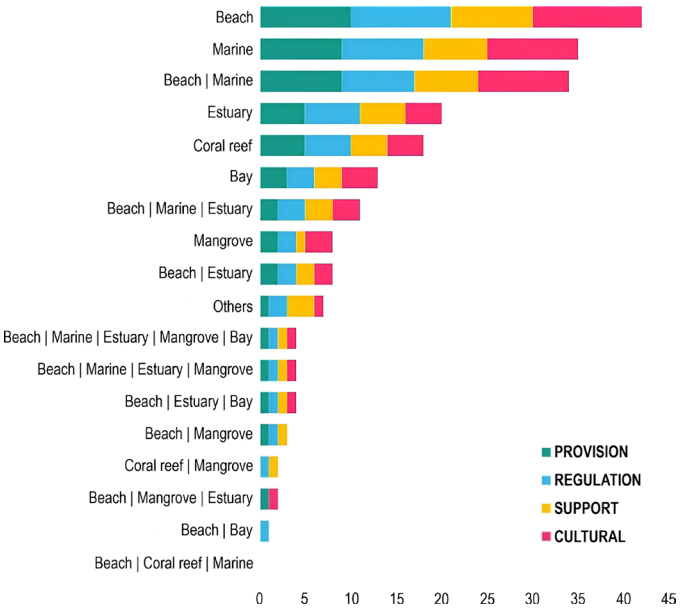


Figure 5 – Relation between the environments and their combinations with the categories of ecosystem services.

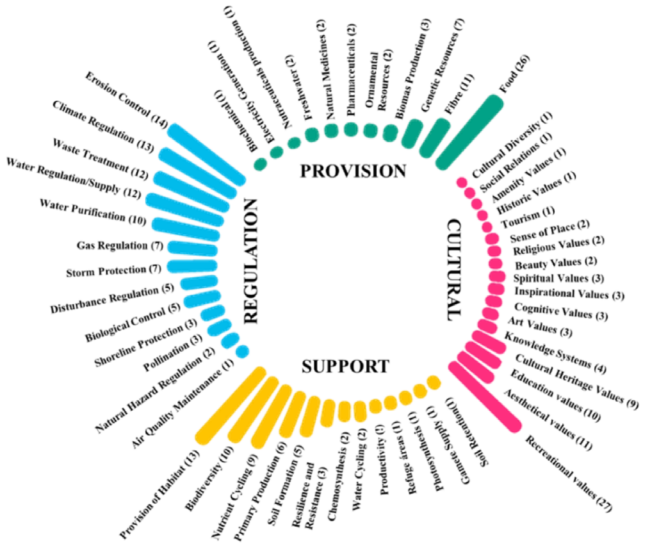


Figure 6 – Representation of all the ecosystem services that was cited in the bibliometric review.

In the next analysis, only those services appearing more than ten times in the 91 papers were selected. Besides, over 60 ecosystem services were listed in the 91 papers, but only 12 were cited more than ten times (Figure 7). The category that had more repetitions was the regulation service, with five services listed. Support and provisioning services had only two services mentioned in this sample. The concern about the changes caused by human activities may have been one of the regulation services to have more range in this example.

Relating the categories of ecosystem services to all the countries that published at least one paper on those keywords, we obtained some answers. The five continents were divided into three blocks: Americas, Europe, and Africa/Asia/Oceania.

In America (Figure 8), only five countries appeared in the research. The United States had the highest number of appearances regarding ecosystem services, with regulation as the main category. In Brazil, regulation and culture services had the same number of mentions in the papers. The Mexican papers spoke more about provision, but the Canadian and Chilean papers had the same amount of each ecosystem service category.

On the European continent (Figure 9), eleven countries were identified in our research. The United Kingdom, France, and Portugal had the highest number of papers containing the keywords. The British papers had more emphasis on provisioning and cultural services, French papers had an equal distribution between all those categories, and Portuguese papers highlighted provisioning and cultural services as well.

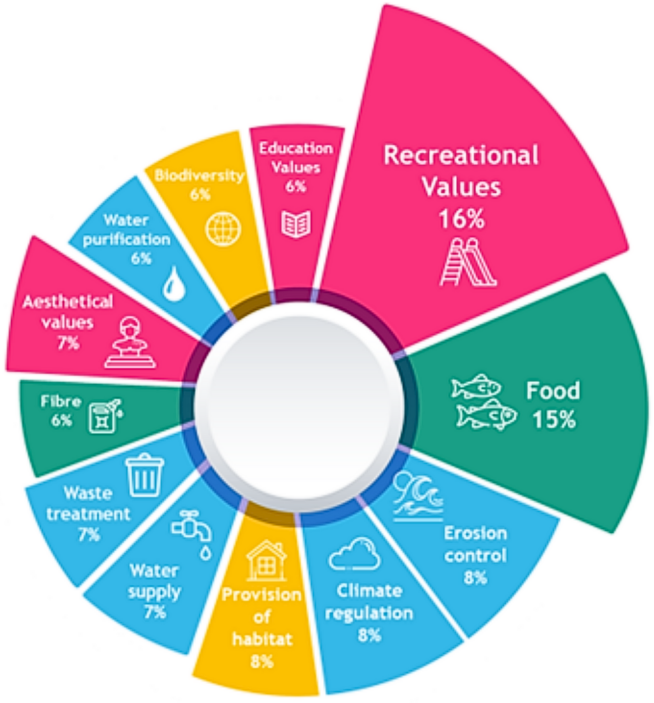


Figure 7 – Principal ecosystem services mentioned in the bibliometric review.

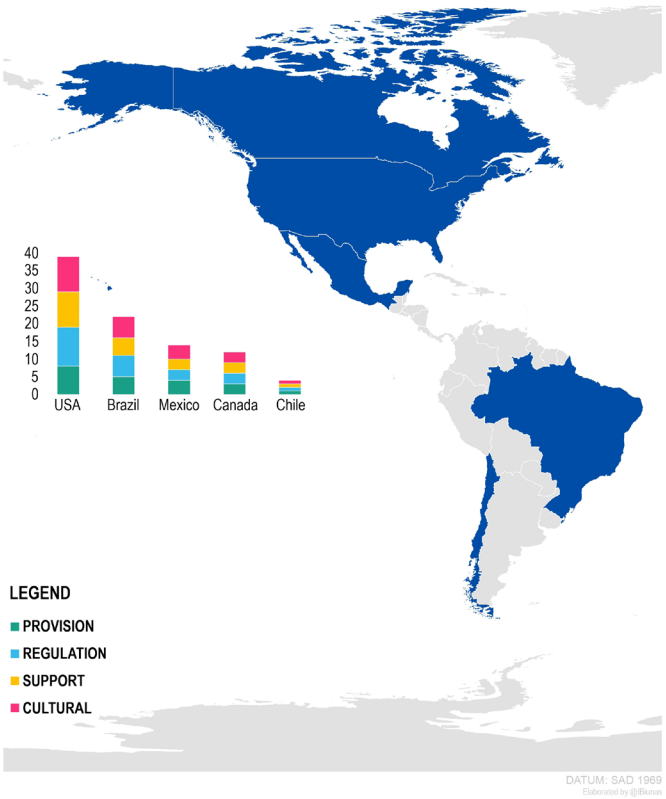


Figure 8 – Relationship between categories of ecosystem services and American countries.

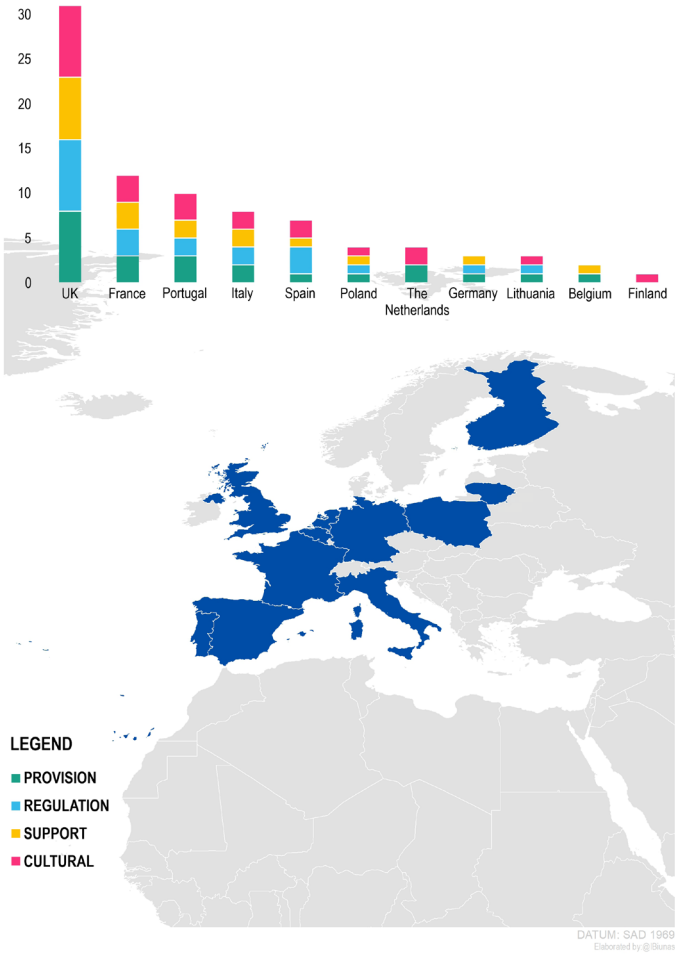


Figure 9 – Relationship between categories of ecosystem services and Europe's countries.

Some countries did not have all four categories in their papers. This is the case of The Netherlands (which had only provision and culture services), Germany (with support, regulation, and provision services), Lithuania (with regulation and culture services), Belgium (with support and provision services), and Finland (which only presented culture services).

In the last block of countries (Figure 10) — Africa, Asia, and Oceania — only nine out of more than one hundred countries appeared in the research, being one in Africa, four in Asia, and four in Oceania. Four of the nine countries mentioned all four categories in their papers: Ethiopia (the only African country), China (with regulation services as the major category), Australia (highlighting culture services), and New Zealand (with a regular distribution between regulation, support, and culture services).

Indonesia and Singapore (in Asia) only worked with culture and regulation services, French Polynesia with provision, and the Solomon Islands with regulation. These countries only appeared once in the research. The Thai papers worked with support, regulation, and provision services.

In the 91 papers, the methods were variable depending on which ecosystem services were treated. Some papers had more than one method. Almost half of the papers (41/91) treated case studies (Figure 11) and those were spread in the four categories of ecosystem services, but highlighting the culture services. Same case as those papers that had revision as a method, including systematic, literature, and documentary. Those studies were related to all categories. Thirty-one papers treated modeling as a method of how ecosystem services are impacted in the context of human activities.

The papers that have "identification" as a method (12/ 91), to identify goods and/or services distributed in the particulate study areas, are related to provision and regulation services, showing low participation of the method in the papers. Valuation appeared in 20 papers, and it is important because those papers reflect the impact of human activities on the value of those environments and the cost of preparing for those damages.

Discussion

As a starting point, it is reasonable to assume that the theme of ecosystem services combined with coastal zones has been gaining strength since the 2010s, almost ten years after the publication of the MEA. The first peak of scientific publications happened in 2014, two years after the launch of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and this may be a reason for the increased scientific interest in these two areas.

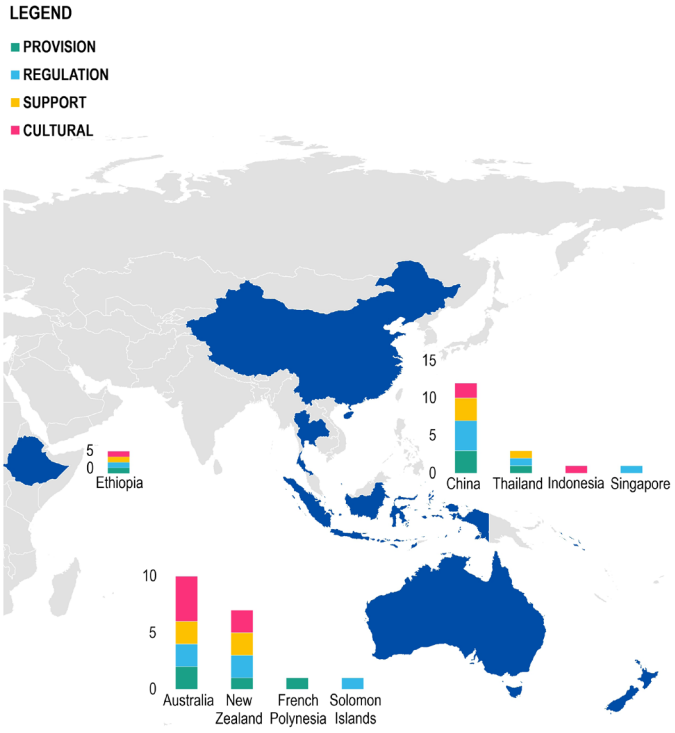


Figure 10 – Relationship between categories of ecosystem services and Africa's, Asia's, and Oceania's countries.

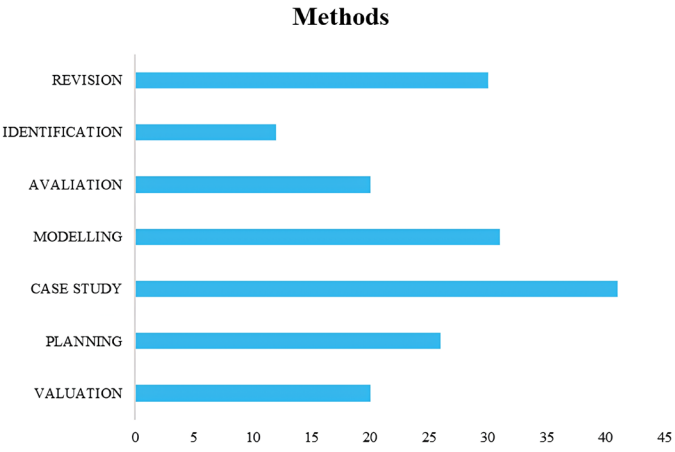


Figure 11 – Methods used in the papers studied in this bibliometric review.

The IPBES was created to scientifically base the information generated by the complex relationship between biodiversity, ecosystem services, and the population, to insert such themes into decision-making among various stakeholders (Finlayson, 2018).

The year 2020 was the third with the highest number of publications about the two main topics in this bibliometric review (Figure 2). However, we could assume that the coronavirus pandemic affected the final number of publications in that year. The pandemic adversely affected scientific output, shutting down most research laboratories. This means that 2020 could have been a year with more publications.

The lack of papers combining the two main topics on port pressure in ecosystem services is a relevant point to be discussed. Asmus et al. (2018) discussed the importance of coastal management in decision-making on coastal zones and the actors inserted there; in the case of the study area of the work in question, the example of the Port of Imbituba, in Santa Catarina state was used. Andrade et al. (2018) specifically addressed the importance of studying the pressures exerted by port complexes on ecosystem services and offered solutions to minimize such pressures.

The gap observed in this bibliometric review is evident and shows the lack of studies on a global scale on the impacts of port activities on adjacent environments when it comes to ecosystem services, fundamental to the functionality of all ecosystems and the generation of benefits for human beings, which was observed in Rova et al. (2018).

The provision of habitat and food for species present in these environments (and others such as coral reefs, estuaries, and mangroves) was noted by Mehvar et al. (2019) and Hope et al. (2020). Their works addressed the essentiality of these ecosystem services and how the provision of benefits is fundamental for human beings.

The environments worked within the context of this bibliometric review represented different ways of exploring their relationship in the coastal zone with ecosystem services. The beaches had the greatest coverage among the 91 works studied. Papers such as Elliff and Kikuchi (2015) and Xu et al. (2016) explored beaches in all categories of ecosystem services. Specifically, Ahtiainen et al. (2019) studied how humans see beaches as places of refuge, especially when they are linked to culture services.

The identification of ecosystem services on beaches is presented in Solé and Ariza (2019) and de Alencar et al. (2020). In these works, it is possible to observe the difference in the offer of services in different parts of the world, which depends on the approach of the categories. These works that serve as an inventory more frequently explored the provision and regulation services.

Often allied to beaches, marine environments appeared significantly in the articles selected for this bibliometric analysis. The way they were approached is often related to climate regulation and the role of marine environments in erosion regulation (Clay et al., 2020).

Of the seven methods addressed in this work, case studies appeared in greater quantity related to the four categories of ecosystem services. These data showed the variety of studies related to the central themes and how the environmental agenda has evolved over the years, especially since the publication of the MEA (2005). Papers such as Shan and Li (2020), Chen et al. (2021), and Silva et al. (2021) reflected the diversity of topics on ecosystem services.

The papers linked to planning were often related to regulation, support, and provision, as they are most often the idea of integrated coastal management, trying to find solutions to reduce human impact on

the natural environment, avoiding the loss of ecosystem services and, consequently, the benefits generated by them. Papers like Asmus et al. (2018) and Drakou et al. (2017), addressed these issues.

The monetary value of ecosystem services and the importance of their preservation is an issue addressed even before the publication of the MEA (2005). Costanza et al. (1997) had already addressed the need to conserve services and how financially harmful the reduction in their provision was.

Papers such as Carss et al. (2020) and Wu et al. (2021) addressed this relationship between monetary value and ecosystem services in all categories cited in this study. This shows the possibility of the financial and environmental link and the future damages caused if human interference in natural environments continues in the same place, as already mentioned.

Conclusion

This bibliometric study shows some diagnoses of how research on ecosystem services and coastal zones has evolved over almost 20 years. With the beginning of the oceanic decade, there is a trend of continuous increase in the volume of research and in the interconnection of both topics as they are extremely important for the quality of human life since most of the planet's population resides in coastal areas.

The relationship between the pressures that port activities exert on coastal environment and, consequently, on ecosystem services is not widely addressed in the articles selected for the research. The lack of work on this connection between ports, coastal zones, and ecosystem services may soon be used in the scientific field, since port activity is one of the most important in global trade, and the changes caused in areas close to these complexes are known to be harmful to the environment.

Several environments were worked on among the 91 articles in this bibliometric research. Beaches are the most frequent environment of all, as well as marine environment (continental platforms and slopes). Mangroves, estuaries, coral reefs, and bays are also mentioned in the studies. These studies are related to different types of ecosystem services and work in the most diverse aspects, from the perception of visitors to the modeling of seas and oceans.

Europe and the Americas proved to be the main research centers on these topics, with the United States and the United Kingdom leading in the quantity of published works. In these countries, regulation and culture ecosystem services stand out in the number of appearances in the works.

More than 50 ecosystem services were accounted for in this survey. The main services in the works selected in this bibliometric research are the provision of habitat, food, recreation, climate, and erosion regulation. This shows the researchers' concern about recent environmental problems and the role of human beings in interfering with environmental balance.

The four categories of ecosystem services are represented throughout this study. However, regulation services appear more equitably, demonstrating the variety in research on such categories. Provision, support, and culture services appear with at least one service in greater prominence than the others, respectively food, habitat, and recreation.

Case studies are the most frequent methodological category within the works selected for this research and are integrated at the local scale in their areas of study. Reviews (whether literature, systematic or documentary) are often linked to works that deal with coastal planning and management, to provide solutions to the environmental crisis that has been occurring in this last century.

In general, it is possible to observe how scientific research behaved after the publication of the MEA and how it evolved with the conventions published since then, such as IPBES and the Common International Classification of Ecosystem Services (CICES). Topics on ecosystem services and coastal zones will continue to be relevant, due to projections on the rise in mean sea level and the consequences for human life, jeopardizing the benefits provided by ecosystem services.

Linked to the oceanic decade, the projection is the intensification of the debate on the importance of these services for the maintenance of the environments inserted there, such as the basic maintenance of living conditions in coastal zones, in large coastal urban centers, as well as in less pressured environments, which may also suffer from an environmental imbalance soon.

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