Ecosystem services research trends in Indonesia: a bibliometric analysis

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Abstract. *Firdaus N, Supriatna, Supriatna J. 2022. Ecosystem services research trends in Indonesia: a bibliometric analysis. Biodiversitas 23: 1105-1117.* Among the world's mega-biodiversity countries in the tropics, Indonesia has experienced the most severe deforestation in recent decades. It is alarming that the rate is potentially disrupting the future provision of ecosystem services. On the other hand, there is a paucity of research on ecosystem services in Indonesia, and its current state is unknown. This study provided an overview of ecosystem services research trends in Indonesia from 1998 to 2020 using bibliometric and science mapping analysis of 298 published works from the Scopus database. Since 2013, publications on the topic have increased and grown exponentially, with environmental science dominating the subjects, followed by agriculture and biology, and the social sciences. Biodiversitas and Ecosystem Services are the most prolific journals for publishing results, while Science and Ecological Economics have the most citations. Being the most productive in publications, Indonesia and the United States are also engaged the most in research collaborations. Ecosystem services research in Indonesia is closely linked to biodiversity, deforestation, and oil palm. Furthermore, oil palm, sustainability, and land-use change are promising topics to address in the coming years. This study suggests that the dynamics of ecosystem services research in Indonesia call for further developments in improving the quality of impactful research through interdisciplinary approaches, international collaboration, and the engagement of diverse stakeholders and policy-makers related to the field, to increase the benefits of sustainable ecosystem services in the future.

Keywords: Bibliometric, ecosystem services, Indonesia, research foci, science mapping

INTRODUCTION

Natural ecosystems, as a biodiversity entity, are essential for providing direct and indirect benefits, defined as ecosystem services, which include conditions, processes, and components required for the sustainability of life on earth (Costanza et al. 1997; Daily 1997; Turner and Daily 2008; Chen et al. 2020). The Millennium Ecosystem Assessment (MA) classified these services as provisioning, regulating, cultural, and supporting services (MA 2005). Ecosystem services result from interactions and interdependence among ecosystem components, namely biophysical, socio-economic, and cultural aspects. Therefore, they are fundamentally beneficial for supporting human wellbeing as an integral part of the ecosystem (Cardinale et al. 2012; Costanza et al. 2014). It is reported that two-thirds of the utilized global ecosystem services have degraded faster than the recovery period (MA 2005). This state poses a threat to the future flow of ecosystem goods and services in many regions, notably in the tropics (Estoque and Murayama 2016; Li et al. 2016; Cruz-Garcia et al. 2017; Turubanova et al. 2018; Wade et al. 2020). Especially in the land ecosystem, the rapid growth of the global population causes anthropogenic pressure on nature by altering land use through rapid fragmentation, degradation, and deforestation (Newbold et al. 2015; Aznar-Sánchez et al. 2018; Acharya et al. 2019).

Indonesia is one of the world's most populous and ranks third among the mega-biodiversity countries of the tropics (Vollmer and Grêt-Regamey 2013; Rintelen et al. 2017; Soemodinoto et al. 2018). Between 1990 and 2005, Indonesia lost 21.32 million hectares (Mha) of forest cover out of 121.40 Mha in 1990 (Hansen et al. 2009). It is still occurring, with 91 Mha of forest cover left in 2015 (Food and Agriculture Organization [FAO] 2015). Furthermore, between 2001 and 2017, the average forest loss in Indonesia was 1.39 Mha per year, with an annual increase of 0.075 Mha (Chen et al. 2019). This phenomenon placed Indonesia as a country with the highest deforestation rate than any other region in the world in the last three decades (Newbold et al. 2015; Van Der Plas et al. 2016; Austin et al. 2019). However, deforestation in Indonesian tropical rainforests is a matter of concern since tropical rainforests have a substantial impact on climate regulation, nutrient cycles, freshwater supplies, conserving biodiversity, as well as mitigating natural disaster impacts (Ninan and Kontoleon 2016; Aznar-Sánchez et al. 2018; Dwiyahreni et al. 2021). In turn, it will also disrupt the provision of the ecosystem's goods and services globally (Turubanova et al. 2018; van der Laan et al. 2018). Therefore, this concern encourages demands for more sustainable ecosystem management to safeguard the ecosystem services flow (Sumarga and Hein 2016; Zafirah et al. 2017; Wood et al. 2018; Ayompe et al. 2021) in order to achieve the fifteenth

goal of the Sustainable Development Goals (SDGs), which deal with protecting, restoring, and promoting sustainable use of terrestrial ecosystems, sustainably managing forests, preventing desertification, halting and reversing land degradation, and halting biodiversity loss.

Concerning the global ecosystem crisis and increasing awareness of ecosystem services' significance, the establishment of major international initiatives, including MA in 2001 (MA 2005), followed by The Economics of Ecosystems and Biodiversity (TEEB) in 2007, and The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2012, have helped to standardize definition, classification, and assessment of ecosystem services globally (Costanza et al. 2017; Pauna et al. 2018). Furthermore, the ecosystem services concept has attracted attention as a beneficial instrument for evaluating, defining, and predicting the interdependencies between natural ecosystems and human interests from global scholars and policy-makers (Busch et al. 2012; McDonough et al. 2017).

Ecosystem services have been the subject of extensive academic discourse and analysis and have driven the rapid increase of global scientific publications during the last two decades (Zhang et al. 2019). Accordingly, some research reviews of literature on ecosystem services have been conducted in many countries worldwide (Alamgir et al. 2014; D'Amato et al. 2016; Jiang 2017), at the regional (Balvanera et al. 2012; Wangai et al. 2016; Shoyama et al. 2017) and global level (Vihervaara et al. 2010; Costanza and Kubiszewski 2012). However, there is a paucity of ecosystem service research in Indonesia, and its current state is still indefinite. To fill this gap, bibliometric analysis and a science mapping approach were performed based on publication data from the last 23 years (1998-2020) to overview and identify research foci and current prospects in ecosystem services research in Indonesia. Therefore, this analysis aims to: 1) investigate the annual research trends related to ecosystem services in Indonesia over the last two decades; 2) provide an overview of ecosystem service research in Indonesia based on journal productivity, Scopus subject areas, countries' networks, and keywords; and 3) evaluate and map countries' collaboration networks and keywords in ecosystem services research in Indonesia.

This research will be relevant for practitioners, researchers, and policy-makers, particularly those involved in the ecosystem services field, identifying current research trends, comprehending the most prominent research lines, and deliberating on developing policies about ecosystem services.

MATERIALS AND METHODS

Research design

Bibliometric analysis is a set of statistical procedures used to analyze the text and information connected with existing literature in certain domains (Daniels and Thistlethwaite 2017). For the last five decades, many researchers have applied this method for comparative analysis of journals, research institutions, and authors to acquire a better understanding of growth trends in particular topics, the structure of scientific research, and collaboration between disciplines (Gutiérrez-Salcedo et al. 2018; Szomszor et al. 2021; Wirth et al. 2021).

A bibliometric analysis was performed in this research by modifying the method proposed by previous studies (Wang et al. 2014; McDonough et al. 2017; Aznar-Sánchez et al. 2019; Liu et al. 2019; Kandel et al. 2021). In addition, a science mapping analysis of the extensive research literature database was also conducted to acquire interpretation that is more manageable by emphasizing relationships between research components as the primary analysis unit in the study (Cowhitt et al. 2020). The variables involved in this work are the number of annual publications, Scopus categories of subject fields, publication journals and citations, the collaboration between countries, and authors' keywords.

Data source

A research dataset was extracted and constructed from the Scopus platform, one of the major online databases for academic publications and citations (McDonough et al. 2017; Aznar-Sánchez et al. 2019). Currently, it collects about 76 million documents with more than 23,000 peer-reviewed journals, grouped into 27 main subjects and more than 300 minor subject fields (http://www.scopus.com). Therefore, Scopus provides broader coverage and more choices than other bibliographic databases, particularly in ecosystem services. Furthermore, its extra features will benefit users who need data extraction in various formats for data visualization and processing and further analysis with another software application (Aleixandre-Benavent et al. 2018; Gutiérrez-Salcedo et al. 2018).

Searching strategy

The systematic search in Scopus was performed on the title, abstract, and keywords. An initial search was conducted in two stages to compare annual publications on global scale and in Indonesia. First, for global coverage, the following terms were used: "ecosystem services," "environmental services," and "ecological services" as search queries. Second, the term "Indonesia" was then added to the terms above. In addition, to obtain relevant results on the dataset, Boolean logic operations were applied, including "OR" and "AND" in the search query.

Searching for the database was conducted during December 2020-January 2021, in articles published between 1998-2020. The initial year of the articles' search was set for 1998, a year after the publication of two seminal works in ecosystem services (Costanza et al. 1997; Daily 1997), in which the ecosystem service framework (MA 2005) originated. These were then followed by rapid growth of ecosystem services studies from many areas (Vihervaara et al. 2010; Costanza et al. 2017).

Only original articles published in English were included in the analysis, considering that such publications have been rigorously reviewed to confirm the quality of the data and conclusions and the broader target of the publications. The data were downloaded in the comma-delimited text (CSV) format. Items with duplication were

screened using add-in features on the worksheet application. Furthermore, if a particular result was still doubtful, the corresponding paper was downloaded and read carefully. At this step, the data entry with duplicates and unfulfilled criteria were excluded from the dataset. These steps were applied chronologically to ensure the data relevancy to the topic, omit duplicate records, and improve data quality. The final dataset for further analysis in this work comprises 298 articles.

Data analysis

After processing the appropriate data from the Scopus database, a descriptive analysis was performed on the number of annual publications, the subject category, the most productive journals, and the most-cited journal articles using Microsoft Excel (version 2013). Meanwhile, to understand the relationship between research components, a science mapping analysis of the bibliometric network of research collaboration (countries) and research hotspots (keywords) was performed using VOSviewer (version 1.6.17).

VOSviewer is a network analysis-based software that allows users to visualize various types of bibliometric networks and maps, considering the factors of common occurrence (Pauna et al. 2018; Eck and Waltman 2019). In the research, a science-mapping approach is conducted through co-authorship and co-occurrence analysis to create bibliometric maps, which show: 1) the co-authorship network between countries whose researchers are affiliated; and 2) the network of keywords' co-occurrence. In each map, the connecting line called a link displays the relationship between components (Pauna et al. 2018). The thickness of each link shows the occurrence frequency of a component's unit simultaneously in the research network called the total link strength. Furthermore, the number of articles or frequency of keywords displayed in a varied circle size determines the unit size according to its weight. Then, the circle's position and color of different items in network mapping are used to classify the sample unit into a similar cluster (Anand and Gupta 2020; Mishra et al. 2021; Rosato et al. 2021). The calculation method used in this analysis is a fractional calculation method and for data normalization by the Linlog/Modularity method (Eck and Waltman 2019). In addition, some previous studies (Perianes-Rodriguez et al. 2016; Maula et al. 2018; Zhang et al. 2019) showed that fractional counting is preferred to full counting since it delivered count of co-authored publications to each author fractionally and provided more accurate results. Further information on the statistics and methodologies used in VOSviewer can be obtained from Eck and Waltman (2019).

RESULTS AND DISCUSSION

Publication growth on ecosystem services

The initial Scopus database search yielded 22855 articles on ecosystem services published worldwide between 1998 and 2020, while approximately 17000 publications were recorded in the same database between 1997 and 2017 (Costanza et al. 2017). Clearly, the annual publications show steady growth during the observed period, ranging from 42 to 3425 articles, and the average annual publication reaches 1039 articles per year. Meanwhile, about 298 articles, or 1.3% of global publications, were associated with Indonesia. The growth of publications related to ecosystem services in Indonesia and the global publications comparison is shown in Figure 1.

During the 1998-2007 period, only 19 articles on ecosystem services in Indonesia were recorded in the dataset. The initial publication was in 1998, listed in the Scopus database, discussing the economic value of ecosystem services (Abramovitz 1998). Surprisingly, there was no article found in 2000 and 2004. Over the period, the number of annual publications has increased, and reached the peak in 2017 with 41 articles. The highest percentage of publications was recorded in the last eight years between 2013 and 2020, which reached 84% of total publications on the topic. This analysis, in general, shows an accumulative increase more than two-fold in the number of articles by a 5-year interval (Figure 1). Furthermore, the trend of publications shows that an exponential growth ($R^2 = 0.89$) has been achieved since 2013 (Figure 1).

This research has revealed the development of ecosystem services studies in Indonesia over the past two decades, from 1998 to 2020. Ecosystem services topic is relatively new and emerging but has been effectively campaigned by recognized international agencies and supported by dedicated funding bodies (Brunet et al. 2019) to raise greater awareness of the global ecosystem crisis. This would have a good impact on ecosystem services in attaining the relevant SDGs in the future (MA 2005; Hernández-Blanco et al. 2020). Therefore, this topic has grown steadily during the last few decades and has received more interest from researchers and policy-makers worldwide (Rillig et al. 2015; Hossain et al. 2018).

Between 1998 and 2020, the number of articles on the topic increased from 42 to 3245 globally and rose from one to 41 in Indonesia, demonstrating the increasing importance of this issue in the global research landscape. The final number of papers included in the analysis is 298 articles published in 146 peer-reviewed journals, which were selected based on specified criteria. Furthermore, there has been an exponential increase in article publishing, which is expected to continue in the forthcoming years.
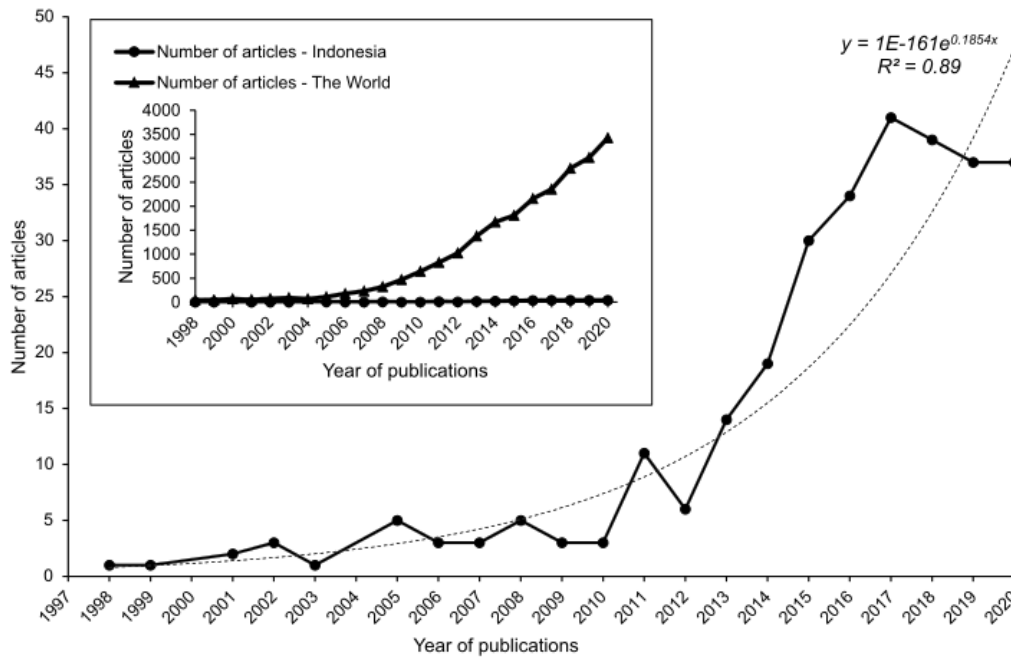
Figure 1. Publication growth trends related to ecosystem services in Indonesia in 1998-2020 (interpolation of Scopus data)

Global initiatives such as MA, TEEB, and IPBES (TEEB 2010; Vihervaara et al. 2010; Costanza et al. 2017; Bongaarts 2019) have been helpful in effectively promoting and mainstreaming the concept of ecosystem services as a valuable instrument for defining, assessing, and predicting interrelationships between humans and their natural environment and as an approach to sustainable ecosystem management in achieving SDGs. Since then, it has become a topic that attracts immediate attention and is addressed globally (McDonough et al. 2017; Zhang et al. 2019). It was shown in the high increase in the number of publications in ecosystem services worldwide since its first mention (Costanza et al. 2017). However, this was not the case in Indonesia. There were several years delayed following the publication of MA before various research on ecosystem services in Indonesia were conducted and published in scientific journals. Similar conditions are also reported from other developing countries (Christie et al. 2012; McDonough et al. 2017; Kandel et al. 2021).

It is hard to pinpoint the cause of this discrepancy; nonetheless, it is assumed to be linked with inadequacies related to researchers' resources and financial assistance (Lakitan et al. 2012; Katsnelson 2016). Furthermore, a lack of support for scientific-based decision-making in government policy practices, as well as a lag in concept implementation (Christie et al. 2012; Kandel et al. 2021), have an indirect effect on the imbalanced representation of ecosystem services studies from developing countries (Tydecks et al. 2018). Despite this, some of those developing countries, including Indonesia, have the world's highest biodiversity, which is associated with the provision of essential ecosystem services (Daily and Matson 2008; Acharya et al. 2019) thus need better attention from the global society as well as from the country itself. Some attempts have been made to achieve this, but they have not

been entirely successful, such as international collaborations in research among academics, governments, or non-governmental (Lakitan et al. 2012; Hossain et al. 2018). In addition, domestic counterparts of local researchers or residents still need to be rigorously trained to achieve an enhanced quality of research and publications (Christie et al. 2012).

Main subject field in ecosystem services studies in Indonesia

The temporal dynamics of article publications between 1998 and 2020 based on the subject categories provided by Scopus are shown in Figure 2. Articles related to the subject of environmental science dominated most of the period, with 201 articles or 33.6% of the total categories (Figure 2). Then, agricultural and biological science with 157 articles (26.3%), followed by social sciences with 87 articles (14.5%), and biochemistry, genetics and molecular biology with 37 articles (6.2%). Finally, earth and planetary science with 24 articles (4%). Meanwhile, the combination of other subjects reached 15.4% of the total subject categories. However, analysis of the subject categories shows increasing trends in agricultural and biological sciences and also biochemistry, genetics and molecular biology. Nonetheless, neither were able to outnumber environmental science (Figure 2).

Scopus category analysis shows that publications related to ecosystem services in Indonesia are burgeoning and encompass a wide range of scientific disciplines, including environmental science, agriculture and biology, and social science. All of which are also top-ranked in global studies correlated to the topic (McDonough et al. 2017; Aznar-Sánchez et al. 2018; Chen et al. 2020). Furthermore, it indicates that researchers from a variety of disciplines contributed to the publications on the subject.

Since the notion of ecosystem services is interdisciplinary, scientific collaboration is essential for establishing mutual understanding among disciplines and assisting scientists in addressing contemporary challenges encountered in the ecosystem services field (Costanza and Kubiszewski 2012; McDonough et al. 2017; Contandriopoulos et al. 2018).

Main publishing journals and most cited articles

A total of 298 articles recorded in this research dataset were published in 147 peer-reviewed journals. About 135 journals, or 92% of the total, have published less than five over the last two decades, from 1998 to 2020. In comparison, the top 12 journals published around 33% of the total articles analyzed in this research (Figure 3). The two top journals listed as the most productive in publishing ecosystem services topics are Biodiversitas (18 articles) and Ecosystem Services (16).

Analysis of journal publications related to ecosystem services in Indonesia showed that Biodiversitas and Ecosystem Services were the most productive scientific journals publishing the results on ecosystem services topics. Ranked first by the number of publications, Biodiversitas is one of the most prolific journals in Indonesia, whose scope covers the biodiversity of plants, animals, and microbes at any level of life organization (http://biodiversity.mipa.uns.ac.id/d/scopes.htm). Meanwhile, Ecosystem Services, in the second rank, is a prominent journal that integrates the social, economic, and policy fields with ecosystem services as their scientific basis. It has become the most recognized publication place and is among the primary references for the scientific community on ecosystem services (Costanza et al. 2017). However, this result implies that even though the notion of ecosystem services is interdisciplinary (Brunet et al. 2019), biodiversity studies remain dominant within ecosystem service research in Indonesia. In other words, the notion of ecosystem services is inherently related to biodiversity (Pauna et al. 2018; Torres et al. 2021), which influences the published article spectrum.

Furthermore, the citation analysis result shows that each of the most cited articles has at least 100 citations (Table 1). The first most widely cited article, on the other hand, addressed changes in global forest cover (Hansen et al. 2013) and was published in Science, which was not among the most prolific publications on the topic. Then, in Ecological Economics, the second most cited publication highlighted the importance of the value of coasts globally. In addition, with the exception of Ecological Economics, the other most referenced articles in the dataset were published in journals not listed in Figure 3.

Although some journals, including Science and Ecological Economics, are among the most cited, (Table 1), the number of articles they publish on ecosystem service topics is not comparable to the number of citations generated. Hence, their contribution to the amount of information related to the topic is not the same (McDonough et al. 2017). Furthermore, all of the most cited literature in this research dataset requires at least four years to accumulate sufficient citations after publication, which corresponds to the reliability of the bibliometric analysis (Belter 2015; Stephan et al. 2017; Anand and Gupta 2020). However, despite being arguable, the number of citations is frequently used to assess the impact of a publication (Belter 2015) and has become a widely utilized standard indicator in bibliometric analysis (Rogers et al. 2020).
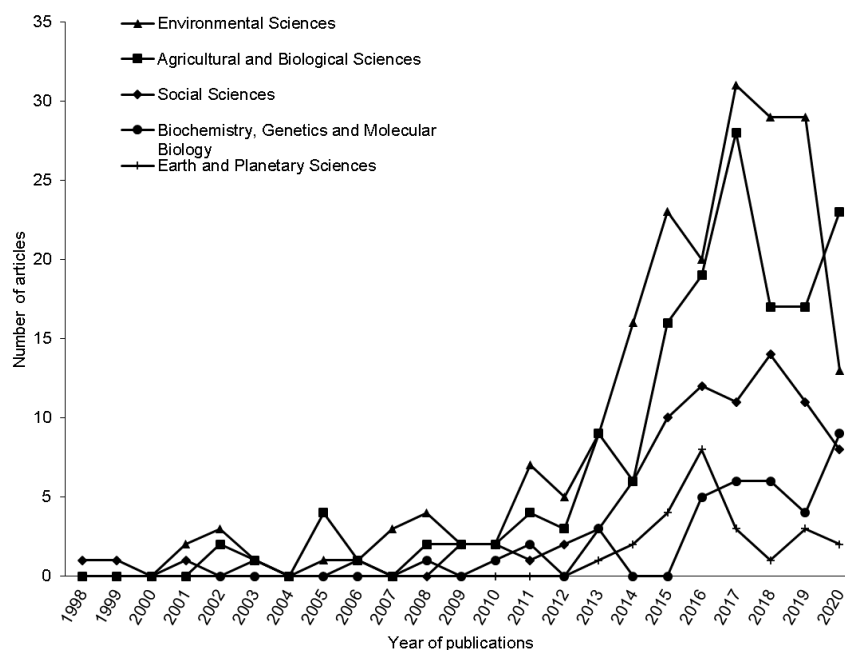

Figure 2. The growth of articles on ecosystem services in Indonesia based on the main subject category in 1998-2020
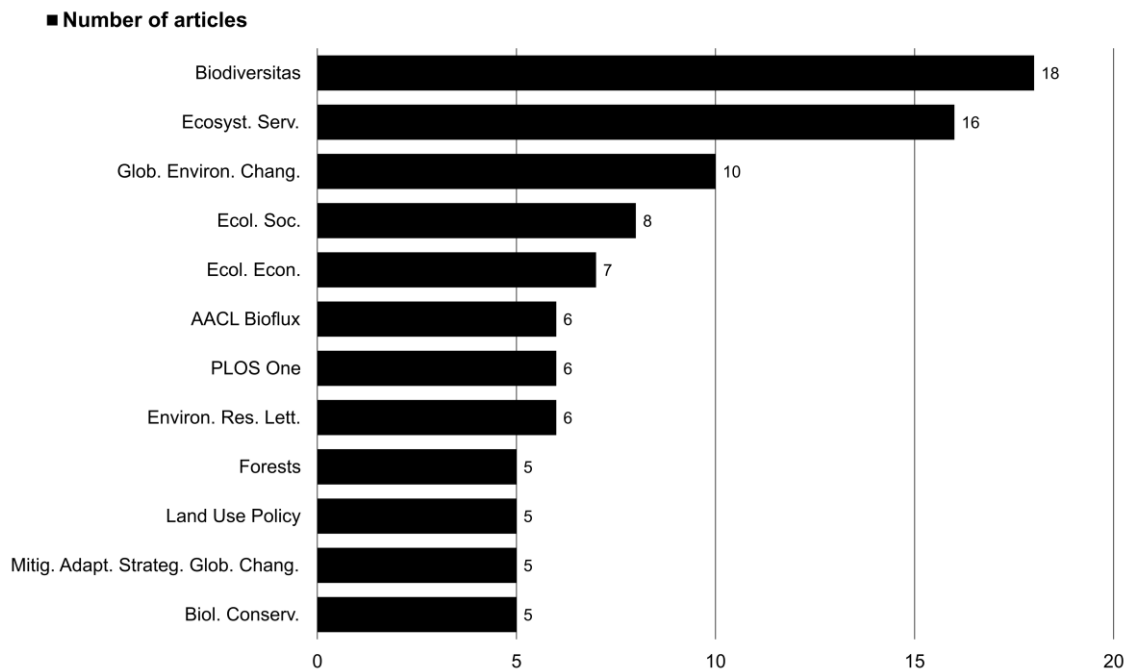
■ Number of articles

Figure 3. The top journals in term of the number of publications regarding ecosystem services in Indonesia in 1998-2020. Abbreviations (in alphabetical order): AACL Bioflux: Aquaculture, Aquarium, Conservation & Legislation - International J the Bioflux Society; Biol. Conserv.: Biological Conservation; Ecol. Soc.: Ecology and Society; Ecol. Econ.: Ecological Economics; Ecosyst. Serv.: Ecosystem Services; Environ. Res. Lett.: Environmental Research Letters; Glob. Environ. Chang.: Global Environmental Change; Mitig. Adapt. Strateg. Glob. Chang.: Mitigation and Adaptation Strategy for Global Change

On the other hand, further analysis revealed no direct connection between the number of citations from specific journals and the most prolific in the field. However, since this kind of literature is probably cited in disciplines related to ecosystem services and many other subjects, the number of citations generated will likely be affected. Furthermore, these findings confirm that the global natural resource crisis is concerning. They have elevated ecosystem services to the status of a fascinating topic that is gaining traction among academics. It also benefits significantly from scholarly publications on ecosystem services (Costanza et al. 2017; McDonough et al. 2017; Zhang et al. 2019), as indicated by an increase in related topic publications in international peer-reviewed journals.

Collaboration of countries in ecosystem services research in Indonesia

As many as 57 countries contributed to the research of ecosystem services in Indonesia between 1998 and 2020. Indonesia earned the first rank, contributing to 201 out of 298 articles (67.45% with at least one author affiliated with the country), followed by the United States (US) with 69 articles (23.15%), and Australia with 52 articles (17.45%) (Table 2). The analysis result in Figure 4 depicts a co-authorship network based on affiliated countries and weighted by the number of co-authored articles by researchers related to ecosystem services in Indonesia.

Authors from each country tend to collaborate with others from favorable countries, resulting in complex collaboration networks.

As illustrated in Figure 4, the color and units (countries) might distinguish three clusters. The first and largest cluster (red color) is led by Indonesia, followed by the US, Australia, and other countries. Then Germany took the lead in the second cluster (green), followed by the others. Finally, France was the leader of the smallest cluster (blue). As a result, Indonesia has been identified as having a strategic position in collaboration networks among countries (Figure 4).

Furthermore, it was found to have considerable collaboration networks with other countries, such as the US, Australia, Germany, the Netherlands, and the United Kingdom (UK). After Indonesia, the US ranked second, followed by Australia. Surprisingly, collaboration on this research topic is less prevalent between Indonesia and its Southeast Asian neighbors, notably Singapore and Malaysia, compared to previously mentioned countries.

However, based on geographical origin among those most productive countries (Figure 4), only one came from Latin America (Peru), two from Africa (Kenya and Cameroon), and most came from Asia (Indonesia, Singapore, Japan, China, and Malaysia). Table 2 shows the top 20 countries in terms of their publications number and organized clusters, as depicted in Figure 4.

Table 1 The ten most-cited journal articles

No.	Year	Title	Journal	Authors	NC
1	2013	High-resolution global maps of 21st-century forest cover change	Science	Hansen et al.	4196
2	2007	The coasts of our world: Ecological, economic and social importance	Ecological Economics	Martínez et al.	409
3	2008	Functional group diversity of bee pollinators increases crop yield	Proceedings of the Royal Society B: Biological Sciences	Hoehn et al.	367
4	2016	Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012	Proceedings of the National Academy of Sciences of the United States of America	Richards and Friess	315
5	2016	Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21)	Global Ecology and Biogeography	Hamilton and Casey	298
6	2011	Combining high biodiversity with high yields in tropical agroforests	Proceedings of the National Academy of Sciences of the United States of America	Clough et al.	230
7	2015	The potential of Indonesian mangrove forests for global climate change mitigation	Nature Climate Change	Murdiyarso et al.	220
8	2011	Community structure and diversity of tropical forest mammals: data from a global camera trap network	Philosophical Transactions of the Royal Society B: Biological Sciences	Ahumada et al.	181
9	2008	The 2004 tsunami in Aceh and Southern Thailand: A review on coastal ecosystems, wave hazards and vulnerability	Perspectives in Plant Ecology, Evolution and Systematics	Cochard et al.	179
10	2013	Bats and birds increase crop yield in tropical agroforestry landscapes	Ecology Letters	Maas et al.	143

Note: NC: number of citation

Table 2. 20 Top countries in contribution to ecosystem services research in Indonesia

Cluster 1			Cluster 2			Cluster 3		
Rank	Country	NA	Rank	Country	NA	Rank	Country	NA
1	Indonesia	201	4	Germany	49	7	France	19
2	United States	67	10	Canada	15	8	Singapore	18
3	Australia	52	12	New Zealand	10	9	Switzerland	18
5	Netherlands	44	13	Sweden	10	17	Peru	5
6	United Kingdom	40	14	China	6	20	Cameroon	4
11	Japan	14	15	Denmark	6			
18	Norway	5	16	Kenya	5			
19	Malaysia	4						

Note: NA: number of articles

Given the nature of the factors implicated in managing ecosystem services, collaboration among the countries participating in the study was also followed by increasing publication trends. Furthermore, based on the co-authorship network analysis, Indonesia demonstrated a significant propensity for establishing international collaboration, mainly with developed countries. For instance, Indonesian researchers preferred to collaborate intensively with their colleagues from the US, Australia, Germany, and the Netherlands. Instead, collaboration with neighboring Southeast Asian countries was more circumscribed. It appears to be related to many factors requiring further development, such as researcher affinity (including educational background and expertise) (Locatelli et al. 2021), capacity building to form international collaboration, access to more advanced research infrastructure, and access to global funding resources. However, these factors are substantial and will affect researchers' ability to construct international collaboration (Contandriopoulos et al. 2018; Tydecks et al. 2018).
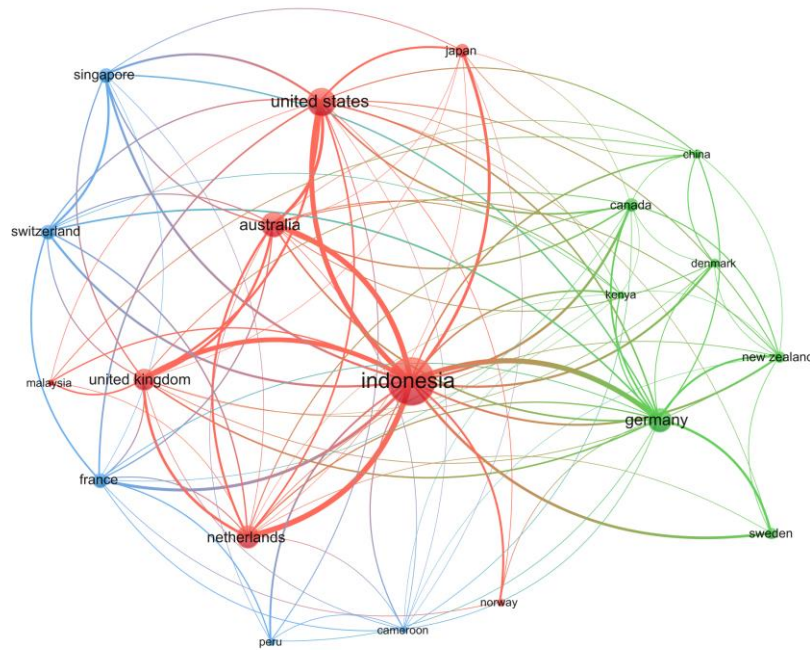
Figure 4. The network of the countries' collaboration in ecosystem services in Indonesia in 1998-2020

Predictably, most of the publications by Indonesian researchers in this dataset were the outcome of collaborative research, primarily with overseas researchers or institutions. It is constant with a prior study (Lakitan et al. 2012) that Indonesian researchers have a greater dependency on international collaborators. However, research collaboration on the topic is imperative to promote natural resource and biodiversity conservation initiatives by increasing the impact of scholarly articles, stimulating scientific innovation, and building effective communication between stakeholders and policy-makers (Perez and Hogan 2018). Nevertheless, it increases the dependence of researchers from developing countries on multinational actors and institutions and probably disregards the context and local dynamics (Chaudhary et al. 2015; Suominen et al. 2019). Furthermore, ecosystem services must be prioritized in the national research agenda, in particular, to emphasize the significance of local dynamics (Kandel et al. 2021). However, conservation activities in natural resources and biodiversity should be fully supported to achieve sustainable ecosystem services in the future (Hobbs et al. 2011; Eastwood et al. 2016; García-Llorente et al. 2018; Wade et al. 2020).

Keywords used in articles

In total, 1001 authors' keywords were used in research on ecosystem services in Indonesia, with roughly 973 keywords (97%) utilized in less than five. It demonstrates the magnitude of the diversity of research foci that have been conducted on this topic (Aleixandre-Benavent et al. 2017; Chen et al. 2020). Figure 5 depicts a network map of the 20 most widely used keywords from 1998 to 2020, based on the keywords' co-occurrence (at least five times)

and the total strength of the link they formed, as shown with circles and links of different sizes. Furthermore, it displays four clusters that are distinguished by their color, which are "ecosystem services" (red), "climate change" (green), "deforestation" (blue), and "oil palm" (yellow) (Figure 5). Almost all the essential keywords within each cluster are linked to two core terms (ecosystem services and Indonesia). Meanwhile, each keyword is linked to at least one other, revealing major research topics of emphasis and issues identified related to ecosystem services in Indonesia.

The two main keywords, "ecosystem services" (used 75 times or in 7.5% of the total articles) and "Indonesia" (57; 5.69%), as the current research's core issue, were inextricably linked with "biodiversity" (20; 2%), "deforestation" (18; 1.8%), and "oil palm" (13; 1.3%), in that order. However, other concepts, such as "conservation" (13; 1.3%), "climate change" (12; 1.2%), "valuation" (10; 1%), "sustainability" (8; 0.8%), and "payments for ecosystem services" (8; 0.8%), have also gained attention in ecosystem services research in Indonesia, indicated by their inclusion in the top author's keywords, as shown in Figure 5. On the other hand, among the top keywords, there were "Kalimantan" (6; 0.6%), "Sumatra" (5; 0.5%), and "Southeast Asia" (6; 0.6%) in different clusters (Figure 5), revealing that research on ecosystem services in Indonesia, at the time of writing, was still primarily focused on Kalimantan and Sumatra. Furthermore, the challenges of ecosystem services that have been investigated in Indonesia over the last two decades are intrinsically linked and have an influence on ecosystem services across the Southeast Asian region.
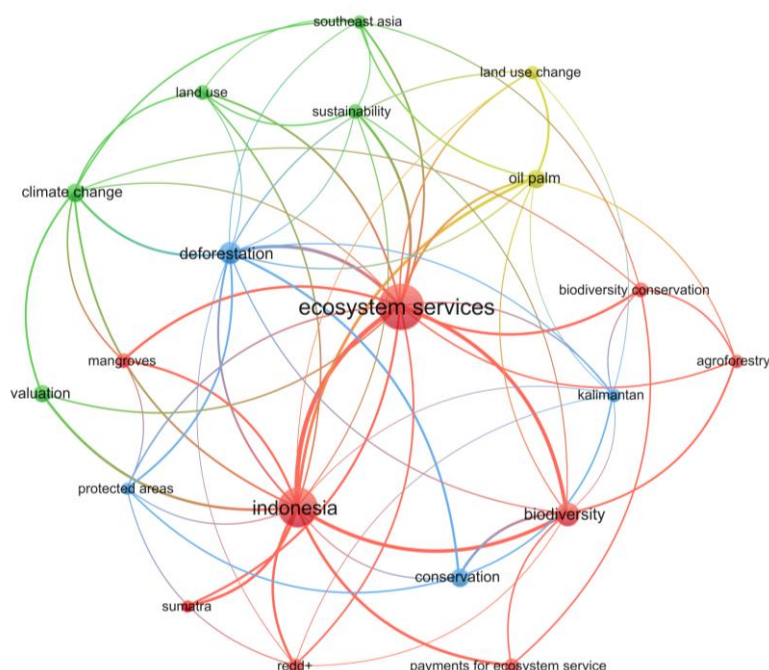
Figure 5. The network of keywords' co-occurrence in the topic of ecosystem services in Indonesia from 1998 to 2020

The result of science mapping on keywords demonstrated that ecosystem services studies in Indonesia are strongly related to biodiversity, deforestation, and oil palm. Furthermore, these relationships indicated that numerous studies on ecosystem services in Indonesia thoroughly examined the biodiversity crisis caused mainly by deforestation, which in Indonesia is particularly associated with oil palm (Sumarga and Hein 2016; Acosta and Curt 2019; Sharma et al. 2019; Nurhidayah and Alam 2020). On the other hand, oil palm was the most significant driver of deforestation in Indonesia, accounting for 23% of the total national deforestation from 2001 to 2016 (Austin et al. 2019).

Throughout the previous decade, Indonesia has become an enthusiastic participant in Reducing Emissions from Deforestation and Forest Degradation and Enhancing Forest Carbon Stocks (REDD+). However, despite the Indonesian government's commitment to REDD+ and its progress, uncontrolled deforestation and degradation of Indonesian forests still occur. As the driving factors of deforestation and degradation cannot be completely reduced, coupled with the poor implementation of related policies, the effectiveness of REDD+ is still questionable (Murray et al. 2015; Nurhidayah and Alam 2020; Dwisatrio et al. 2021). In spite of this, the inclusion of REDD+ among the top-ranked keywords demonstrates the relative importance of REDD+ in the issue of ecosystem services in Indonesia. Thus, the network analysis of keywords has highlighted the key topics that have attracted the considerable attention of the researchers of ecosystem services in Indonesia for the past two decades.

The result also shows that some geographic names are found among the 20 main keywords, such as Kalimantan, Sumatra, and Southeast Asia. Therefore, it is indicated that Kalimantan and Sumatra remain areas of priority for researchers in ecosystem services. Furthermore, the challenges

to ecosystem services in Indonesia over the last two decades are indirectly linked to ecosystem services in the Southeast Asian region and the effects they generate as well.

According to the temporal analysis of the top 20 keywords based on an average of year publications basis, the most significant shift in keywords clusters transpired in 2014-2017, as illustrated in Figure 6. Before 2014, research on the topic emphasized mainly "biodiversity conservation" and "payments for ecosystem services". As of 2014 to 2015, the topic shifted to "valuation". Then, from 2015 to 2016, research concentrated most on "biodiversity", "conservation", and "land use". In addition, in this period, a global initiative, viz. REDD+ emerged as a critical research focus on ecosystem services in Indonesia, although with a minor frequency of occurrence. Therefore, from 2016 to 2017, "deforestation" and "climate change" grew into the major topics. On the other hand, this analysis clearly shows that "oil palm", "sustainability", and "land-use change" have emerged as the new research focus on the study of ecosystem services in Indonesia since 2017 and afterward.

The temporal analysis of keywords revealed that the ecosystem services notion has historically been related to biodiversity conservation (Pauna et al. 2018), and these concepts are at the core of payments for ecosystem services. It is worth mentioning that during the research period, biodiversity conservation and payment of ecosystem services are the fields of frontier research for ecosystem services in Indonesia. Furthermore, in recent years, the topics of oil palm, sustainability, and land-use change have also arisen. Moreover, considering the current progress of economic sound development in Indonesia (Sloan et al. 2018; Supriatna et al. 2020), which indirectly affects the dynamics of ecosystem services globally, these three topics may remain the research foci in ecosystem services, particularly in Indonesia, in the next few years.

Figure 6. The temporal development of the keywords in ecosystem services in Indonesia from 1998 to 2020

However, the current work highlights some limitations that need to be addressed to improve data complexity, coverage area, and the quality and rationale of outcomes for potential enhancement. Firstly, the dataset retrieved from Scopus indexed publications between 1998 and 2020 may not be exhaustive in its coverage of related topics within that period. In this study, Scopus was chosen with the consideration that it is one of the largest databases that compiles a large number of scientific works on ecosystem services (McDonough et al. 2017). Future research needs to examine combining the source with other major databases, including Clarivate's Web of Science, Google Scholar, and Dimension, to obtain more comprehensive data in this field. Secondly, this research dataset is limited to published articles in English. Most Scopus journals and the other previously mentioned databases are published in English, so it might be unfavorable for publications in other languages.

Meanwhile, some relevant publications on this topic are presumably published in languages other than English. Therefore, to avoid bias and gaps in terms of publication language, further research should consider this one of the criteria for compiling the dataset. Finally, some types of publications related to ecosystem services in Indonesia are probably excluded from the screening process for datasets. Other researchers could improve further research by applying rigorous criteria, modifying the search query, expanding the type of publication, and so forth. Therefore, all the data presented in this paper should be interpreted in light of the constraints above.

To sum up, the present work is a helpful initial study to overview studies on ecosystem services in Indonesia over the past two decades using bibliometric and science mapping analysis. Despite certain limitations, the present study produced robust and greatly reproducible results. Therefore, this work will assist researchers and practitioners in ascertaining the status of research development in ecosystem services in Indonesia and advancing further related research in this mega-biodiversity country and most vulnerable to anthropogenic pressure.

This research may shed light on ecosystem services research in Indonesia more accurately within the conditions of the bibliometric method that has been performed. The technique allows identifying the most productive journals, subject fields, countries, and the most popular keywords involved in the research topic of ecosystem services in Indonesia. Furthermore, examining the highly cited papers and the co-occurrence of keywords reveals which topics are emphasized the most. In addition, the network analysis results demonstrate a pattern of connectivity among components involved in ecosystem services in Indonesia. However, some critical remarks can be made as follows.

Although the contribution is minor compared to global publication on the topic (Costanza et al. 2017; McDonough et al. 2017), publication in ecosystem services studies in Indonesia has continuously developed and expanded tremendously over the previous decade. However, this growth must be accompanied by an increase in the quantity and quality of research through various strategies, including the involvement of local researchers in research collaboration with international researchers and institutions conducting research in Indonesia and providing research facilities and research funding resources (Christie

et al. 2012; Lakitan et al. 2012; Katsnelson 2016; Hossain et al. 2018).

Biodiversitas and Ecosystem Services were the most productive journals on ecosystem services in Indonesia, while Science and Ecological Economics were the most frequently cited. On the other hand, there was no connection between the most prolific and most-cited journals. Furthermore, Indonesia and the US have published the most articles on this topic and are the most engaged in the research network.

Topics such as biodiversity, deforestation, and oil palm denote the research foci and characterize the current state of ecosystem services research in Indonesia. Among these topics, biodiversity, in particular, closely follows the research trend at the global level. However, certain current and potentially promising topics related to ecosystem services in Indonesia, such as oil palm, sustainability, and land-use change, call for further investigation. Furthermore, future research might consider this work as a starting point. Furthermore, other studies can examine whether the focus on the topic remains or changes in the future within the ecosystem services dynamics in Indonesia.

To the best of found knowledge, this is the first study to perform bibliometric and scientific mapping approaches to overview the development of ecosystem services research in Indonesia. The improvement in interdisciplinary approaches, international collaboration, and the development of research roadmaps for ecosystem services in Indonesia, with the engagement of multiple stakeholders and policy-makers, and the promotion of interdisciplinary scientific research results by researchers, are viable strategies for raising awareness about the critical importance of ecosystem services in the future.

ACKNOWLEDGEMENTS

REFERENCES

Abramovitz JN. 1998. Putting a value on nature's "free" services. World Watch 11: 10-19.

Acharya RP, Maraseni T, Cockfield G. 2019. Global trend of forest ecosystem services valuation - An analysis of publications. Ecosyst Serv 39: 100979. DOI: 10.1016/j.ecoser.2019.100979.

Acosta P, Curt MD. 2019. Understanding the expansion of oil palm cultivation: A case-study in Papua. J Cleaner Production 219: 199-216. DOI: 10.1016/j.jclepro.2019.02.029.

Alamgir M, Pert PL, Turton SM. 2014. A review of ecosystem services research in Australia reveals a gap in integrating climate change and impacts on ecosystem services. Intl J Biodiver Sci Ecosyst Serv Manage 10: 112-127. DOI: 10.1080/21513732.2014.919961.

Aleixandre-Benavent R, Aleixandre-Tudó JL, Castelló-Cogollos L, Aleixandre JL. 2017. Trends in scientific research on climate change in agriculture and forestry subject areas (2005-2014). J Cleaner Production 147: 406-418. DOI: 10.1016/j.jclepro.2017.01.112.

Aleixandre-Benavent R, Aleixandre-Tudó JL, Castelló-Cogollos L, Aleixandre JL. 2018. Trends in global research in deforestation. A bibliometric analysis. Land Use Policy 72: 293-302. DOI: 10.1016/j.landusepol.2017.12.060.

Anand S, Gupta S. 2020. Provisioning ecosystem services: Multitier bibliometric analysis and visualisation. Environ Sustain Indic 8: 100081. DOI: 10.1016/j.indic.2020.100081.

Austin KG, Schwantes A, Gu Y, Kasibhatla PS. 2019. What causes deforestation in Indonesia?. Environ Res Lett 14. DOI: 10.1088/1748-9326/aaf6db.

Ayompe LM, Schaafsma M, Egoh BN. 2021. Towards sustainable palm oil production: The positive and negative impacts on ecosystem services and human wellbeing. J Cleaner Prod 278: 123914. DOI: 10.1016/j.jclepro.2020.123914.

Aznar-Sánchez JA, Belmonte-Ureña LJ, López-Serrano MJ, Velasco-Muñoz JF. 2018. Forest ecosystem services: An analysis of worldwide research. Forests 9 (8): 453. DOI: 10.3390/f9080453.

Aznar-Sánchez JA, Velasco-Muñoz JF, Belmonte-Ureña LJ, Manzano-Agugliaro F. 2019. The worldwide research trends on water ecosystem services. Ecol Indic 99: 310-323. DOI: 10.1016/j.ecolind.2018.12.045.

Balvanera P, Uriarte M, Almeida-Leñero L, Altesor A, DeClerck F, Gardner T, Hall J, Lara A, Laterra P, Peña-Claros M, Silva Matos DM, Vogl AL, Romero-Duque LP, Arreola LF, Caro-Borrero ÁP, Gallego F, Jain M, Little C, de Oliveira Xavier R, Paruelo JM, Peinado JE, Poorter L, Ascarrunz N, Correa F, Cunha-Santino MB, Hernández-Sánchez AP, Vallejos M. 2012. Ecosystem services research in Latin America: The state of the art. Ecosyst Serv 2: 56-70. DOI: 10.1016/j.ecoser.2012.09.006.

Belter CW. 2015. Bibliometric indicators: Opportunities and limits. J Med Library Assoc 103: 219-221. DOI: 10.3163/1536-5050.103.4.014.

Bongaarts J. 2019. 45 Population and Development Review IPBES, 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 680-681. DOI: 10.1111/padr.12283.

Brunet L, Arpin I, Peltola T. 2019. Governing research through affects: The case of ecosystem services science. Sci Public Policy 46: 866-875. DOI: 10.1093/scipol/scz035.

Busch M, La Notte A, Laporte V, Erhard M. 2012. Potentials of quantitative and qualitative approaches to assessing ecosystem services. Ecol Indic 21: 89-103. DOI: 10.1016/j.ecolind.2011.11.010.

Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwani A, MacE GM, Tilman D, Wardle DA, Kinzig AP, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S. 2012. Biodiversity loss and its impact on humanity. Nature 486: 59-67. DOI: 10.1038/nature11148.

Chaudhary S, McGregor A, Houston D, Chettri N. 2015. The evolution of ecosystem services: A time series and discourse-centered analysis. Environ Sci Policy 54: 25-34. DOI: 10.1016/j.envsci.2015.04.025.

Chen B, Kennedy CM, Xu B. 2019. Effective moratoria on land acquisitions reduce tropical deforestation: Evidence from Indonesia. Environmental Research Letters 14: 044009. DOI: 10.1088/1748-9326/ab051e.

Chen W, Geng Y, Zhong S, Zhuang M, Pan H. 2020. A bibliometric analysis of ecosystem services evaluation from 1997 to 2016. Environ Sci Pollut Res 27: 23503-23513. DOI: 10.1007/s11356-020-08760-x.

Christie M, Fazey I, Cooper R, Hyde T, Kenter JO. 2012. An evaluation of monetary and non-monetary techniques for assessing the importance of biodiversity and ecosystem services to people in countries with developing economies. Ecol Economic 83: 67-78. DOI: 10.1016/j.ecolecon.2012.08.012.

Contandriopoulos D, Larouche C, Duhoux A. 2018. Evaluating academic research networks. Canadian J Program Eval 33: 69-89. DOI: 10.3138/cjpe.42159.

Costanza R, D'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R V, Paruelo J, Raskin RG, Sutton P, Van Den Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260. DOI: 10.1038/387253a0.

Costanza R, Kubiszewski I. 2012. The authorship structure of "ecosystem services" as a transdisciplinary field of scholarship. Ecosyst Serv 1: 16-25. DOI: 10.1016/j.ecoser.2012.06.002.

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Farber S, Turner RK. 2014. Changes in the global value of ecosystem services. Global Environ Change 26: 152-158. DOI: 10.1016/j.gloenvcha.2014.04.002.

Costanza R, de Groot R, Braat L, Kubiszewski I, Fioramonti L, Sutton P, Farber S, Grasso M. 2017. Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosyst Serv 28: 1-16. DOI: 10.1016/j.ecoser.2017.09.008.

Cowhitt T, Butler T, Wilson E. 2020. Using social network analysis to complete literature reviews: A new systematic approach for independent researchers to detect and interpret prominent research programs within large collections of relevant literature. Intl J Soc Res Method 23: 483-496. DOI: 10.1080/13645579.2019.1704356.

Cruz-Garcia GS, Sachet E, Blundo-Canto G, Vanegas M, Quintero M. 2017. To what extent have the links between ecosystem services and human well-being been researched in Africa, Asia, and Latin America? Ecosyst Serv 25: 201-212. DOI: 10.1016/j.ecoser.2017.04.005.

D'Amato D, Rekola M, Li N, Toppinen A. 2016. Monetary valuation of forest ecosystem services in China: A literature review and identification of future research needs. Ecol Economics 121: 75-84. DOI: 10.1016/j.ecolecon.2015.11.009.

Daily GC. 1997. Nature's services: Societal dependence on natural ecosystems. Daily GC (Ed.). Island Press, Washington DC.

Daily GC, Matson PA. 2008. Ecosystem services: From theory to implementation. Proceedings of the National Academy of Sciences of the United States of America 105: 9455-9456. DOI: 10.1073/pnas.0804960105.

Daniels J, Thistlethwaite P. 2017. Being a scholar in the digital era Measuring scholarly impact. Ding, Ying; Rousseau, Ronald; Wolfram D (Ed.). Springer International Publishing, Switzerland. DOI: 10.1007%2F978-3-319-10377-8.

Dwisatrio B, Said Z, Permatasari AP, Maharani C, Moeliono M, Wijaya A, Lestari AA, Yuwono J, , Pham TT. 2021. The context of REDD+ in Indonesia: Drivers, agents and institutions [Update edition] The context of REDD+ in Indonesia: Drivers, agents and institutions [Update edition]. DOI: 10.17528/cifor/007952.

Dwiyahreni AA, Fuad HAH, Soesilo TEB, Margules C, Supriatna, J. 2021. Forest cover changes in Indonesia's terrestrial national parks between 2012 and 2017. Biodiversitas 22: 1235-1242. DOI: 10.13057/biodiv/d220320.

Eastwood A, Brooker R, Irvine RJ, Artz RRE, Norton LR, Bullock JM, Ross L, Fielding D, Ramsay S, Roberts J, Anderson W, Dugan D, Cooksley S, Pakeman RJ. 2016. Does nature conservation enhance ecosystem services delivery?. Ecosyst Serv 17: 152-162. DOI: 10.1016/j.ecoser.2015.12.001.

Eck NJ Van, Waltman L. 2019. VOSviewer Manual. Leiden University.

Estoque RC, Murayama Y. 2016. Quantifying landscape pattern and ecosystem service value changes in four rapidly urbanizing hill stations of Southeast Asia. Landscape Ecol 31: 1481-1507. DOI: 10.1007/s10980-016-0341-6.

Food and Agriculture Organization [FAO]. 2015. Global Forest Resources Assessment 2015: Country Report Indonesia. Rome.

García-Llorente M, Harrison PA, Berry P, Palomo I, Gómez-Baggethun E, Iniesta-Arandia I, Montes C, García del Amo D, Martín-López B. 2018. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodiver Conserv 27: 1575-1597. DOI: 10.1007/s10531-016-1152-4.

Gutiérrez-Salcedo M, Martínez MÁ, Moral-Munoz JA, Herrera-Viedma E, Cobo MJ. 2018. Some bibliometric procedures for analyzing and evaluating research fields. Appl Intell 48: 1275-1287. DOI: 10.1007/s10489-017-1105-y.

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman S V., Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, Townshend JRG. 2013. High-resolution global maps of 21st-century forest cover change. Science 342: 850-853. DOI: 10.1126/science.1244693.

Hansen MC, Stehman SV, Potapov PV., Arunarwati B, Stolle F, Pittman K. 2009. Quantifying changes in the rates of forest clearing in Indonesia from 1990 to 2005 using remotely sensed data sets. Environ Res Lett 4: 034001. DOI: 10.1088/1748-9326/4/3/034001.

Hernández-Blanco M, Costanza R, Anderson S, Kubiszewski I, Sutton P. 2020. Future scenarios for the value of ecosystem services in Latin America and the Caribbean to 2050. Curr Res Environ Sustain 2: 100008. DOI: 10.1016/j.crsust.2020.100008.

Hobbs RJ, Hallett LM, Ehrlich PR, Mooney HA. 2011. Intervention ecology: Applying ecological science in the twenty-first century. BioScience 61: 442-450. DOI: 10.1525/bio.2011.61.6.6.

Hossain MS, Pogue SJ, Trenchard L, Van Oudenhoven APE, Washbourne CL, Muiruri EW, Tomczyk AM, García-Llorente M, Hale R, Hevia V, Adams T, Tavallali L, De Bell S, Pye M, Resende F. 2018. Identifying future research directions for biodiversity, ecosystem services and sustainability: perspectives from early-career researchers. Intl J Sustain Develop World Ecol 25: 249-261. DOI: 10.1080/13504509.2017.1361480.

Jiang W. 2017. Ecosystem services research in China: A critical review. Ecosyst Serv 26: 10-16. DOI: 10.1016/j.ecoser.2017.05.012.

Kandel P, Chettri N, Chaudhary S, Sharma P, Uddin K. 2021. Ecosystem services research trends in the water tower of Asia: A bibliometric analysis from the Hindu Kush Himalaya. Ecol Indic 121: 107152. DOI: 10.1016/j.ecolind.2020.107152.

Katsnelson A. 2016. Big science spenders. Nature 537: S2-S3. DOI: 10.1038/537S2a.

van der Laan C, Budiman A, Verstegen JA, Dekker SC, Effendy W, Faaij APC, Kusuma AD, Verweij PA. 2018. Analyses of land cover change trajectories leading to tropical forest loss: Illustrated for the West Kutai and MahakamUlu Districts, East Kalimantan, Indonesia. Land 7: 108. DOI: 10.3390/land7030108.

Lakitan B, Hidayat D, Herlinda S. 2012. Scientific productivity and the collaboration intensity of Indonesian universities and public R&D institutions: Are there dependencies on collaborative R&D with foreign institutions?. Technol Soc 34: 227-238. DOI: 10.1016/j.techsoc.2012.06.001.

Li W, Ciais P, MacBean N, Peng S, Defourny P, Bontemps S. 2016. Major forest changes and land cover transitions based on plant functional types derived from the ESA CCI Land Cover product. Intl J Appl Earth Observation Geoinformation 47: 30-39. DOI: 10.1016/j.jag.2015.12.006.

Liu W, Wang J, Li C, Chen B, Sun Y. 2019. Using bibliometric analysis to understand the recent progress in agroecosystem services research. Ecol Econ 156: 293-305. DOI: 10.1016/j.ecolecon.2018.09.001.

Locatelli B, Vallet A, Tassin J, Gautier D, Chamaret A, Sist P. 2021. Collective and individual interdisciplinarity in a sustainability research group: A social network analysis. Sustain Sci 16: 37-52. DOI: 10.1007/s11625-020-00860-4.

Maula AW, Fuad A, Utarini A. 2018. Ten-years trend of dengue research in Indonesia and South-east Asian countries: a bibliometric analysis. Global Health Action 11: 1504398. DOI: 10.1080/16549716.2018.1504398.

McDonough K, Hutchinson S, Moore T, Hutchinson JMS. 2017. Analysis of publication trends in ecosystem services research. Ecosyst Serv 25: 82-88. DOI: 10.1016/j.ecoser.2017.03.022.

Millennium Ecosystem Assesment [MA]. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC.

Mishra M, Sudarsan D, Santos CAG, Mishra SK, Kar D, Baral K, Pattnaik N. 2021. An overview of research on natural resources and indigenous communities: A bibliometric analysis based on Scopus database (1979-2020). Environ Monit Assess 193: 59. DOI: 10.1007/s10661-020-08793-2.

Murray JP, Grenyer R, Wunder S, Raes N, Jones JPG. 2015. Spatial patterns of carbon, biodiversity, deforestation threat, and REDD+ projects in Indonesia. Conserv Biol 29: 1434-1445. DOI: 10.1111/cobi.12500.

Newbold T, Hudson LN, Hill SLL, Contu S, Lysenko I, Senior RA, Börger L, Bennett DJ, Choimes A, Collen B, et al. 2015. Global effects of land use on local terrestrial biodiversity. Nature 520: 45-50. DOI: 10.1038/nature14324.

Ninan KN, Kontoleon A. 2016. Valuing forest ecosystem services and disservices - Case study of a protected area in India. Ecosyt Service 20: 1-14. DOI: 10.1016/j.ecoser.2016.05.001.

Nurhidayah L, Alam S. 2020. The forest and its biodiversity: Assessing the adequacy of biodiversity protection laws in Indonesia. Asia Pacific J Environ Law 23: 178-201. DOI: 10.4337/APJEL.2020.02.04.

Pauna VH, Picone F, Le Guyader G, Buonocore E, Franzese PP. 2018. The scientific research on ecosystem services: A bibliometric analysis. Ecol Questions 29: 53-62. DOI: 10.12775/EQ.2018.022.

Perez TM, Hogan JA. 2018. The changing nature of collaboration in tropical ecology and conservation. Biotropica 50: 563-567. DOI: 10.1111/btp.12573.

Perianes-Rodriguez A, Waltman L, van Eck NJ. 2016. Constructing bibliometric networks: A comparison between full and fractional counting. J Informetrics 10: 1178-1195. DOI: 10.1016/j.joi.2016.10.006.

Van Der Plas F, Manning P, Soliveres S, Allan E, Scherer-Lorenzen M, Verheyen K, Wirth C, Zavala MA, Ampoorter E, Baeten L, Barbaro L, et al. 2016. Erratum: Biotic homogenization can decrease landscapescale forest multifunctionality. Proceedings of the National Academy of Sciences of the United States of America 113: E2549. DOI: 10.1073/pnas.1605668113.

Rillig MC, Kiessling W, Borsch T, Gessler A, Greenwood AD, Hofer H, Joshi J, Schröder B, Thonicke K, Tockner K, Weisshuhn K, Jeltsch F. 2015. Biodiversity research: Data without theory-theory without data. Front Ecol Evol 3: 251. DOI: 10.3389/fevo.2015.00020.

Rintelen K Von, Arida E, Häuser C. 2017. A review of biodiversity-related issues and challenges in megadiverse Indonesia and other Southeast Asian countries. Res Ideas Outcomes 3 (1): e20860. DOI: 10.3897/rio.3.e20860.

Rogers G, Szomszor M, Adams J. 2020. Sample size in bibliometric analysis. Scientometrics 125: 777-794. DOI: 10.1007/s11192-020-03647-7.

Rosato PF, Caputo A, Valente D, Pizzi S. 2021. 2030 Agenda and sustainable business models in tourism: A bibliometric analysis. Ecol Indic 121: 106978. DOI: 10.1016/j.ecolind.2020.106978.

Sharma SK, Baral H, Laumonier Y, Okarda B, Purnomo H, Pacheco P. 2019. Ecosystem services under future oil palm expansion scenarios in West Kalimantan, Indonesia. Ecosyst Serv 39. DOI: 10.1016/j.ecoser.2019.100978.

Shoyama K, Kamiyama C, Morimoto J, Ooba M, Okuro T. 2017. A review of modeling approaches for ecosystem services assessment in the Asian region. Ecosyst Serv 26: 316-328. DOI: 10.1016/j.ecoser.2017.03.013.

Sloan S, Campbell MJ, Alamgir M, Collier-Baker E, Nowak MG, Usher G, Laurance WF. 2018. Infrastructure development and contested forest governance threaten the Leuser Ecosystem, Indonesia. Land Use Policy 77: 298-309. DOI: 10.1016/j.landusepol.2018.05.043.

Soemodinoto A, Yulianto I, Kartawijaya T, Herdiana Y, Ningtias P, Kassem KR, Andayani N. 2018. Contribution of local governments to a national commitment of the Aichi Biodiversity Target 11: the case of West Nusa Tenggara Province, Indonesia. Biodiversity 19: 72-80. DOI: 10.1080/14888386.2018.1467790.

Stephan P, Veugelers R, Wang J. 2017. Reviewers are blinkered by bibliometrics. Nature 544: 411-412. DOI: 10.1038/544411a.

Sumarga E, Hein L. 2016. Benefits and costs of oil palm expansion in Central Kalimantan, Indonesia, under different policy scenarios. Regional Environ Change 16: 1011-1021. DOI: 10.1007/s10113-015-0815-0.

Suominen A, Seppänen M, Dedehayir O. 2019. A bibliometric review on innovation systems and ecosystems: A research agenda. European J Innov Manage 22: 335-360. DOI: 10.1108/EJIM-12-2017-0188.

Supriatna J, Shekelle M, Fuad HAH, Winarni NL, Dwiyahreni AA, Farid M, Mariati S, Margules C, Prakoso B, Zakaria Z. 2020. Deforestation on the Indonesian island of Sulawesi and the loss of primate habitat. Global Ecol Conserv 24: e01205. DOI: 10.1016/j.gecco.2020.e01205.

Szomszor M, Adams J, Fry R, Gebert C, Pendlebury DA, Potter RWK, Rogers G. 2021. Interpreting Bibliometric Data. Front Res Metrics Analyt 5: 1-20. DOI: 10.3389/frma.2020.628703.

The Economics of Ecosystems and Biodiversity [TEEB]. 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Kumar P (Ed.). Earthscan, London and Washington.

Torres AV, Tiwari C, Atkinson SF. 2021. Progress in ecosystem services research: A guide for scholars and practitioners. Ecosyst Serv 49: 101267. DOI: 10.1016/j.ecoser.2021.101267.

Turner RK, Daily GC. 2008. The ecosystem services framework and natural capital conservation. Environ Resour Economics 39: 25-35. DOI: 10.1007/s10640-007-9176-6.

Turubanova S, Potapov P V, Tyukavina A, Hansen MC. 2018. Ongoing primary forest loss in Brazil, Democratic Republic of the Congo, and Indonesia. Environ Res Lett 13: 074028. DOI: 10.1088/1748-9326/aacd1c.

Tydecks L, Jeschke JM, Wolf M, Singer G, Tockner K. 2018. Spatial and topical imbalances in biodiversity research. PLoS One 13: 0199327. DOI: 10.1371/journal.pone.0199327.

Vihervaara P, Rönkä M, Walls M. 2010. Trends in ecosystem service research: Early steps and current drivers. Ambio 39: 314-324. DOI: 10.1007/s13280-010-0048-x.

Vollmer D, Grêt-Regamey A. 2013. Rivers as municipal infrastructure: Demand for environmental services in informal settlements along an Indonesian river. Global Environ Change 23: 1542-1555. DOI: 10.1016/j.gloenvcha.2013.10.001.

Wade CM, Austin KG, Cajka J, Lapidus D, Everett KH, Galperin D, Maynard R, Sobel A. 2020. What is threatening forests in protected areas? A global assessment of deforestation in protected areas, 2001-2018. Forests 11: 539. DOI: 10.3390/F11050539.

Wang Y, Pan SY, Ke RY, Wang K, Wei YM. 2014. An overview of climate change vulnerability: A bibliometric analysis based on Web of Science database. Nat Hazards 74: 1649-1666. DOI: 10.1007/s11069-014-1260-y.

Wangai PW, Burkhard B, Müller F. 2016. A review of studies on ecosystem services in Africa. Intl J Sustain Built Environ 5: 225-245. DOI: 10.1016/j.ijsbe.2016.08.005.

Wirth W, Lesbarrères D, Ariel E. 2021. Ten years of ranavirus research (2010-2019): An analysis of global research trends. Facets 6: 44-57. DOI: 10.1139/FACETS-2020-0030.

Wood SLR, Jones SK, Johnson JA, Brauman KA, Chaplin-Kramer R, Fremier A, Girvetz E, Gordon LJ, Kappel C V., Mandle L, Mulligan M, O'Farrell P, Smith WK, Willemen L, Zhang W, DeClerck FA. 2018. Distilling the role of ecosystem services in the Sustainable Development Goals. Ecosyst Serv 29: 70-82. DOI: 10.1016/j.ecoser.2017.10.010.

Zafirah N, Nurin NA, Samsurijan MS, Zuknik MH, Rafatullah M. 2017. Sustainable ecosystem services framework for tropical catchment management: A review. Sustainability 9 (4): 546. DOI: 10.3390/su9040546.

Zhang X, Estoque RC, Xie H, Murayama Y, Ranagalage M. 2019. Bibliometric analysis of highly cited articles on ecosystem services. PLoS One 14: 0210707. DOI: 10.1371/journal.pone.0210707.