

# Mapping the Scientific Literature on Mangrove Conservation in Indonesia: A Bibliometric Analysis to Environmental Research

Jazimatul Husna<sup>1\*</sup>, Ima Wijayanti<sup>2</sup>, Liliek Budiastusi Wiratmo<sup>1</sup>, Sri Indrahti<sup>1</sup>, Agus Naryoso<sup>1</sup>, Nor Edzan Che Nasir<sup>3</sup>, Maharani Patria Ratna<sup>4</sup>, Berliana Mulyaning Andini<sup>1</sup>, and Dhaka Raihan Putra Ratarno<sup>1</sup>

<sup>1</sup>Departement of Informations and Culture, Vocational School, Diponegoro University, Indonesia.

<sup>2</sup>Fisheries Product Technology, Fisheries and Marine Sciences, Diponegoro University. Indonesia.

<sup>3</sup>Libraries, University of Malaya. Malaysia.

<sup>4</sup>Applied Foreign Language, Vocational School, Diponegoro University. Indonesia.

**Abstract.** In 2022, the Global Mangrove Alliance (GMA) released the latest map of the world's mangroves. Southeast Asia is home to the most extensive mangrove forests, with Indonesia contributing one-fifth of the world's total mangrove area. Given this, government policies and in-depth studies are needed. The purpose of this study is to contribute to and complement the studies conducted by previous researchers. This study uses the bibliometric analysis methodology with VOSviewer and the biblioshiny package in RStudio. This study investigates the development of international publications and research on mangroves in Indonesia. The methodology and framework were adapted from the bibliometric analysis procedures developed by Donthu in 2021. The published results and findings on mangroves increased by 475%. There is a scientific collaboration between world scientists and Indonesian scientists, for example, the collaboration of Kauffman J.B. Alongi D.M., Murdiyarso D., and Basyuni. The book *World Atlas of Mangroves*, written by M. Spalding et al., and the book *Mangrove Guidebook for Southeast Asia*, written by Giesen et al., have received many citations and have become essential references for many world mangrove researchers. Many Scopus journals that have a high h-Index and ranking (Q) have published publications on mangrove ecosystems in Indonesia, for example, *Biodiversity* (Q2), *AAFL Bioflux* (Q2), and *Ocean and Coastal Management* (Q1). Many keywords related to various aspects of the mangrove ecosystem were found: conservation, biodiversity, blue carbon, ecotourism, climate change, remote monitoring, *avicennia marina*, *rhizophora*, and seagrass.

**Keywords:** Mangrove conservation, Bibliometric analysis, Scientific literature, Environmental research, Indonesia,

## 1 Introduction

Efforts to protect and conserve mangroves in Indonesia are essential for human survival and must be prioritized. The 2022 Global Mangrove Alliance (GMA) Report [1] reveals that Indonesia and other countries such as Brazil, Australia, Mexico, and Nigeria are

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\* Corresponding author: [jazimatulhusna@live.undip.ac.id](mailto:jazimatulhusna@live.undip.ac.id)

home to most of the world's mangroves. Furthermore, the report emphasizes the importance of mangrove forests in supporting the integrity of the local environment.

Mangroves can help people adapt and adapt to climate threats and create a special and unique environment in Indonesia [2], [3]. Mangrove has a valuable natural resource value and can help slow the impact of climate change [4]–[6], protect marine ecosystems [7], filter pollutants [8], [9], protects coastal communities from erosion [10], [11], provides economic value [12]–[15], and is home to various types of animals [16].

Many efforts have been made to identify problems and strengthen the protection and conservation of mangroves [1]. International organizations such as IUCN and the World Bank have played a role in studying and implementing the latest regulations, policies, and strategies to protect and conserve mangroves [12], [17], [18]. In line with this, In 2022, the Global Mangrove Alliance (GMA) published a report highlighting increasing the visibility of mangroves and setting conservation and restoration goals [1]. GMA engages government, academia, researchers, non-profit organizations, and private companies to pool resources, including information technology and funding, through education and training, investment, and the manufacture of mangrove-based products.

However, instead of being considered necessary, many of these efforts need to be improved by human activities, which cause widespread damage to mangroves [1]. Substantial efforts are needed to encourage government commitment and enforce regulations, increase the function and value of mangrove forests, integrate mangrove management, and develop research and innovation [3]. In the context of mangrove conservation, efforts to protect and conserve mangroves in Indonesia must involve various parties and utilize existing resources to maintain the sustainability of this critical mangrove conservation in Indonesia.

The latest report from GMA and the Ministry of Maritime Affairs and Fisheries (KKP) [19] states that efforts to protect and conserve mangroves in Indonesia are an essential part of preserving mangroves in Indonesia and the world. Support from the government, academics, and local communities is needed to achieve the target of restoring 600,000 hectares of mangroves by 2024 [20]. Conservation strategies that involve raising awareness, reducing deforestation, restoring vegetation, improving water quality, and managing sustainable resources have been developed [19].

At the same time, academics can contribute to managing mangrove conservation in Indonesia by conducting research, transferring technology, and providing accurate and integrated data [21]. Bibliometric analysis is used in this study to analyze publications and research trends on mangroves in Indonesia, as well as explore the latest findings that can be applied in efforts to preserve and enhance the development of mangroves in Indonesia.

This study aims to provide an in-depth analysis of mangrove development in Indonesia using a bibliometric analysis method [22], [23]. The three research questions posed by this study are:

- RQ 1. Publications and research conducted by previous mangrove researchers
- RQ2. The development of mangrove research trends in Indonesia, and
- RQ3. Recent findings can be applied to preserving and improving mangrove environmental in Indonesia.

Bibliometric analysis was performed by processing 1,286 documents in the form of international journal articles from the Scopus database published between 2013 and 2022. Quantitative analysis and bibliometric visualization used VOSviewer [24], [25] and the Biblioshiny package in RStudio [26].

This study is divided into four parts : in the first part, we focus on the importance of Indonesian mangroves to the world. In the second part, we explain techniques for tracing, data collection, filtering, and extraction based on the Scopus database. We also conduct a

bibliometric analysis of publications and research on mangrove conservation in Indonesia in Indonesia. In the third part, the analysis results are used to answer research questions and explore the development of mangrove research trends in Indonesia. In the fourth part, a discussion of the analysis results is carried out to look for potential future mangrove environmental research.

## **2 Literature Review**

In this part, Mapping the scientific literature on mangrove conservation in Indonesia is a topic studied in various bibliometric analyses and systematic reviews. We will present previous research that we consider important and still related to this study, namely a bibliometric analysis of mangroves in Indonesia.

The first study, a bibliometric analysis of publishing performance and research trends on mangroves, will be conducted on 2021 by Yuh-Shan Ho and Sharif A Mukul [27] This study analyzes the research results on mangroves and identifies the institutions and authors who are most productive in their mangrove research. However, this research does not focus specifically on mangrove conservation in Indonesia.

The second study was conducted by Sheriza Mohd Maizatul Azwa Radzi, Arnaldo Marín, and Zaiton Samdin [28] 2021. A bibliometric analysis of changes in tropical mangrove forest land use from 2010 to 2020 will be carried out 2021. The study retrieves scientific documents on mangrove land use change using remote sensing from Scopus, the most widely used database for scientific publications. This study does not focus specifically on mangrove conservation in Indonesia.

The third study was conducted by Maria Elisa B. Gerona-Daga and Severino G. Salmo [29] 2022. This study uses bibliometric-based analysis to identify trends and future directions to meet biodiversity goals. The review identified the most relevant institutions and authors in restoration manuscripts in Southeast Asian mangroves, and most of the authors included in the list were from Southeast Asia and affiliated with the top 20 most relevant institutions. This study provides insight into mangrove restoration in Southeast Asia, including Indonesia.

The third research, conducted by Megandaru Widhi Kawuryan, Aqil Teguh Fathani, and Eko Priyo Purnomo et al [15], the findings of this study analyzed 861 articles published until February 2021 in the Scopus database on the sustainability of Indonesia's tourism development, using the VosViewer software to discover trends and their impact. The study results indicate a new gap/novelty for further research related to the themes of sport tourism, mangrove tourism, sharia tourism, and the resilience of Indonesian tourism.

The third previous studies, discussed provide helpful information about mangrove research trends, mangrove conservation, and the sustainability of Indonesian tourism. In this study, we will develop further research based on the arguments and findings found in previous research. Our study discusses sustainable mangrove conservation in Indonesia in the future.

## **3 Materials and Methodology**

### **3.1 Data collection**

The bibliometric analysis methodology is a systematic method used to analyze large volumes of scientific data [30], [31], which have been published in international scientific

journals and other publications [22]. In recent years, bibliometric analysis has been a popular research method approved and widely used by scholars worldwide.

In this study, data in mangrove research were collected from published articles in the Scopus database between 2013 and 2022. Years of data are limited to specific timeframes to ensure comparability and accuracy of the data [32]. Research data was retrieved through the online version of Scopus in December 2022, available for research institutions at Diponegoro University, Indonesia.

Keyword search uses boolean operators to enrich search data [33], by combining two or more keywords so that the search results find all or one of the keywords using "AND," "OR" in the keywords TITLE-ABS- KEY mangroves AND environmental AND conservation AND Indonesia AND PUBYEAR > 2012 AND PUBYEAR < 2023 AND ("mangrove conservation") AND ("mangrove forest") AND ("mangrove development") AND ("mangrove management") AND ("mangrove damage"), ("damage countermeasures") AND ("mangrove policy"). The resulting data is 24.179 documents, which men will filter in the data extraction section.

### 3.2 Data extraction

We do further data extraction to filter data based on unique search keywords that we have determined, namely the keywords TITLE-ABS-KEY mangroves AND environmental AND conservation AND Indonesia AND PUBYEAR > 2012 AND PUBYEAR < 2023 AND ( LIMIT-TO ( DOCTYPE, " article" )) AND ( LIMIT-TO ( LANGUAGE, "English" )) AND ( LIMIT-TO ( SRCTYPE, "journal" )) AND ( LIMIT-TO ( PUBSTAGE, "final" )) AND ( LIMIT-TO ( AFFILCOUNTRY, "Indonesia" )) which must contain articles related to mangroves in Indonesia, we searched based on title, abstract, author's keywords and year. We also limited our data search to Scopus' "pre-review" published articles, primarily focusing on mangroves in Indonesia to get a small part of the larger context [34]. We intentionally limit this advanced extraction to see trends and trends more accurately.

After carefully checking by title, abstract, author keywords, and year-related keywords ("mangrove" AND "Indonesia"), the data from the bibliometric search was extracted in an Excel file (CSV), which we sorted the bibliographic data as follows: (i) author, (ii) title of the article, (iii) year of publication, (iv) name of the journal, (v) number of citations, (vi) main details of author (name and affiliation), (vii) abstract, (viii) ) author keywords.

From the extraction data, we have determined as many as 1.286 Scopus "pre-review" articles that are appropriate for us to use as data for bibliometric analysis. This study makes it possible to see trends and trends in international research and publications on mangroves in Indonesia. The information obtained from this bibliometric analysis and visualization can help researchers understand various issues regarding mangroves in Indonesia. For example, this information can be used to understand various trends, such as shifts in the use of mangroves in Indonesia from time to time [27] or how various scientific journals contribute to research on mangroves in Indonesia.

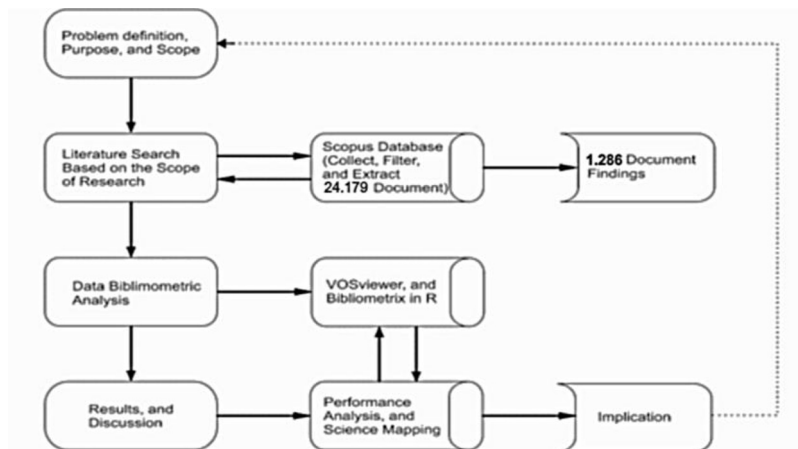
### 3.3 Data analysis

Bibliometric analysis methodology was originally a systematic methodology generally used in information science and libraries that apply statistics and mathematics [22]. Bibliometric analysis as a scientific communication tool can identify research trends, collaborate on projects, and exchange information with other academics. In this study, bibliometric analysis is used to evaluate trends and trends in international research and publications on the utilization of mangroves in Indonesia. This method allows researchers to

evaluate and visualize trends and trends in the number of publications, types of publications, topics, and journals [30], [31].

To analyze and visualize the data, we combined the VOSviewer software [25] and the Biblioshiny package in RStudio [26]. Both software provides diagrams and maps such as thematic maps, country collaboration maps, and network visualizations to provide an overview of the past, present, and future in one research area [30].

In this study, we used a framework based on an adaptation of the bibliometric analysis procedure developed by Donthu et al. [30]. Bibliometric analysis will identify the number of publications over a certain period and measure the accumulation of publications published in a particular journal. Furthermore, this bibliometric analysis framework will also enable us to examine the contribution of international research to developing mangroves in Indonesia. In addition, bibliometric analysis activities will also enable us to identify the most popular journals, as well as evaluate the contributions of authors and institutions to mangrove publications in Indonesia. The visualization resulting from this bibliometric analysis also allows us to simplify and visualize the results of this study so that it is easier to understand.



**Figure 1.** Study framework developed and adapted from the bibliometric analysis procedure of Donthu.

In the description of **fig 1.** above, the methodology used in this research allows us to monitor, assess, and find patterns in global research on Indonesian mangroves.

## 4 Result

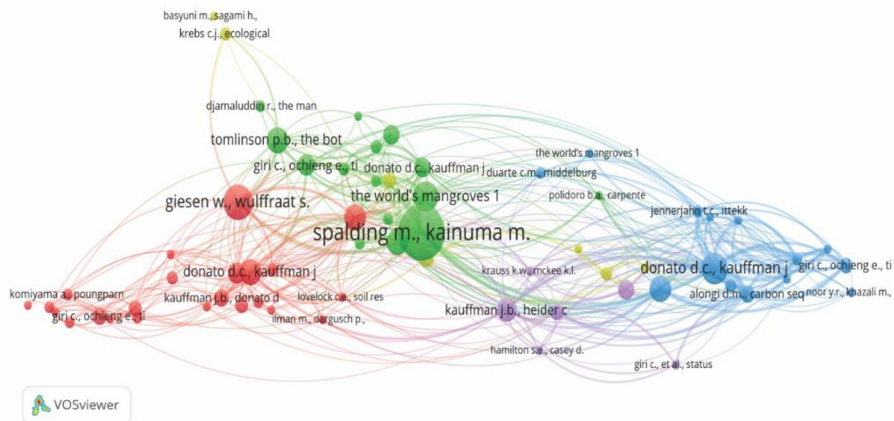
### 4.1 Science Mapping

Science mapping is a visualization technique used to map and analyze scientific literature in a research field [35]. Science mapping is based on bibliometric analysis, a popular and rigorous method for exploring and analyzing large amounts of scientific data [30]. We use various tools and methods to conduct scientific mapping studies, such as co-citation analysis, bibliographic coupling analysis, and keyword co-occurrence analysis. This

method can help us identify important research topics, influential authors, and productive institutions in the field of mangroves in Indonesia.

#### 4.1.1 Co-citation analysis

Co-citation analysis identifies relationships between papers co-cited by other papers [36]. We present the findings and discussion of the co-citation analysis of this study in Figure 7 below.



**Figure 2.** Visualization of most Co-cited references. Source scopus/VOSviewer.

Based on **Fig 2.** above, co-citation of references, and bibliometric analysis of the data above, the total citations were 33081. After a minimum limit of 10 references quoted, 68 references cited met the predetermined threshold.

The results and findings show that the book “World Atlas of Mangroves” by [37] has the highest number of citations, namely 28, and a total link strength of 33. They are followed by the “Mangrove Guidebook for Southeast Asia” by [38], with 18 citations and a total link strength of 19. An article [39] entitled “Mangroves Among the Most Carbon-Rich Forests in the Tropics” has 16 citations and a total link strength of 28. This analysis shows that these three references are closely related to other references. Thus, it can conclude that the references mentioned above have a strong and moderate relationship with other references. This analysis shows that the topic of mangroves has many related references.

From these findings, the mangrove literature most often mentions references that discuss carbon stored in mangroves and the environmental impact of mangrove loss. This analysis shows that mangrove research focuses on carbon issues and environmental impacts.

#### 4.1.2 Cited Sources

Cited Sources in bibliometrics analysis refer to examining frequency, patterns, and graphs of citations in articles and books [40]. Analysis is one of the most widely used bibliometrics methods in scientific work to make links to other works or other researchers.

**Table 1.** Most popular Cited sources Journal

Journal	Scope	Total of Publications	Strength	H-Index	Rank-Scimago
Biodiversitas	biodiversity, biodiversity conservation, evolutionary biology, ecology, research and environmental management.	152		12	Q2
AACL Bioflux	evolutionary biology, ecology, animal health, conservation, genetics, biotechnology, biochemistry, and molecular biology.	79		8	Q2
Ecology, Environment And Conservation	ecology and conservation, environmental management and stewardship, evolutionary biology, ecology, and wildlife research.	21		3	Q1
Estuarine, Coastal And Shelf Science	biodiversity, marine biology, coastal ecology, marine ecosystem biology, oceanography, and marine management.	14		9	Q2
Ocean And Coastal Management	marine conservation, coastal and marine management, marine ecology, marine biology, and marine and coastal	13		10	Q1
Journal Of Ecological Engineering	ecological engineering, environmental management, and natural design.	12		4	Q2

Journal Of Environmental Management And Tourism	natural resource and environmental management, environmental management, and tourism.	10	4	Q2
International Journal On Advanced Science, Engineering And Information Technology	information technology, mechanical engineering, industrial engineering, information systems engineering,	9	1	Q1
Jurnal Manajemen Hutan Tropika	tropical forest management, forest conservation, and natural resource conservation.	9		Q1
Remote Sensing	remote imaging, remote sensors, and image modeling.	8	6	Q1

The bibliometric analysis from table 1 above states that the cited sources with the highest linkage strength found that the total number of journal sources was 721. After applying the minimum limit of 10 sources cited, the resulting 20 sources of joint citations met the threshold we had set.

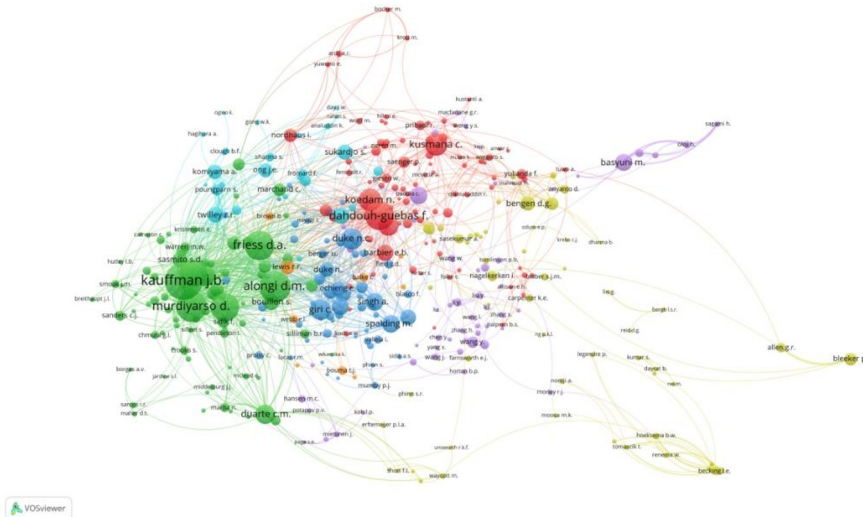
The results of our analysis show that Biodiversity is the journal with the highest number of publications, namely 152 publications, 707 strength links, the highest h-Index is 12, and the highest ranking is Q2. The AACL Bioflux journal has the second highest number of publications, namely 79 publications, 285 strength links, and the second highest h-Index 8. Journal of Ocean and Coastal Management has the highest h-Index (10). Journal of Estuarine, Coastal, and Shelf Science has the lowest number of publications (14) and the highest ranking (Q2). International Journal of Scientific and Technology Research has the lowest h-Index (2). The Raffles Bulletin of Zoology journal has the lowest number of publications (5 publications) and the second lowest h-Index (2). Biotropia journal has the lowest ranking (Q3). From the data above, the central theme of the source is environmental management and conservation. Recommendations for research trends in these journals emphasize practical aspects of managing mangrove ecosystems, such as human behavior and new technologies. This source can also measure human impact on the environment, including predicting the impact of climate change and effective mangrove ecosystem conservation strategies.

Base on the data above indicates that there is a positive change that is taking place in research publications. This analysis can be from the fact that publications have increased steadily over the last few years. This analysis shows that more people are interested in researching mangroves and publishing the results.



### 4.1.3 Co-Citation Author

Co-citation author is an analytical technique used to examine the relationship between articles or authors who use the same references or citations [39].



**Figure 3.** Visualization of the most co-citation authors. Source scopus/VOSviewer.

The bibliometric analysis in **Fig 3.** above states that the author's co-citation has been recognized and is used to determine the relationship between authors whose articles are cited in the same publication. In this study, we have set a minimum of 20 citations from an author. Found 47702 authors, and 4384 authors have met the threshold we set. Based on the bibliometric data above, it can see that three influential writers on mangroves are Kauffman J.B., with a total of 321 citations and a total link strength of 308.24. Furthermore, Alongi D.M., with a total of 257 citations and a total link strength of 250.28. then Murdiyarso D. The number of citations is 250, and the total link strength is 243.78.

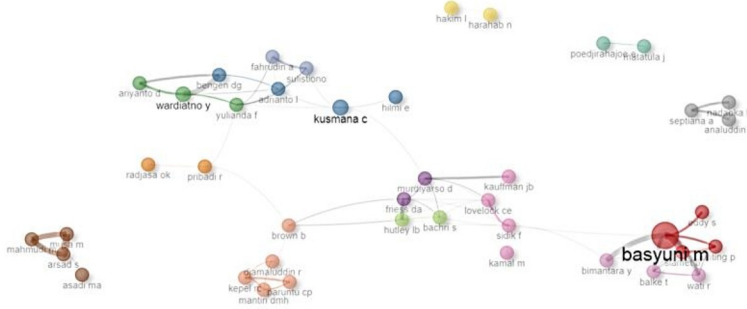
Based on the bibliometric data above, it can be predicted that the following research trend on mangroves will explore the relationship between mangroves and the environment by emphasizing the importance of mangroves in maintaining the balance of the ecosystem and how mangroves can use to prevent soil erosion and water pollution. Mangroves are essential in reducing the impact of global climate change.

### 4.1.4 Keyword Co-occurrence Analysis

Keyword co-occurrence analysis identifies relationships between papers that use similar keywords [30].



of the author's collaboration, findings, and discussion of this study in Figure 5 and Table 2 below.



**Figure 5.** Visualization of Indonesian author collaboration, Source scopus/biblioshiny.

**Table 2.** Indonesian author collaboration. Source scopus/biblioshiny

Node	Cluster	Betweenness	Closeness	PageRank
Basyuni M	1	117.1183384	0.010752688	0.051154162
Bunting P	1	0	0.008403361	0.02190254
Eddy S	1	0	0.008196721	0.008841857
Kusmana C	2	131.6277778	0.012195122	0.018977631
Wardiatno Y	2	29.00589411	0.008928571	0.036950171
Adrianto L	2	39.83056388	0.010638298	0.025213406
Hilmi E	2	0	0.009009009	0.006797626
Sulistiono	2	9.46031746	0.010309278	0.026833025
Friess D.A	3	49.73333333	0.013157895	0.033525623
Murdiyars D	3	145.5055556	0.01369863	0.036815614

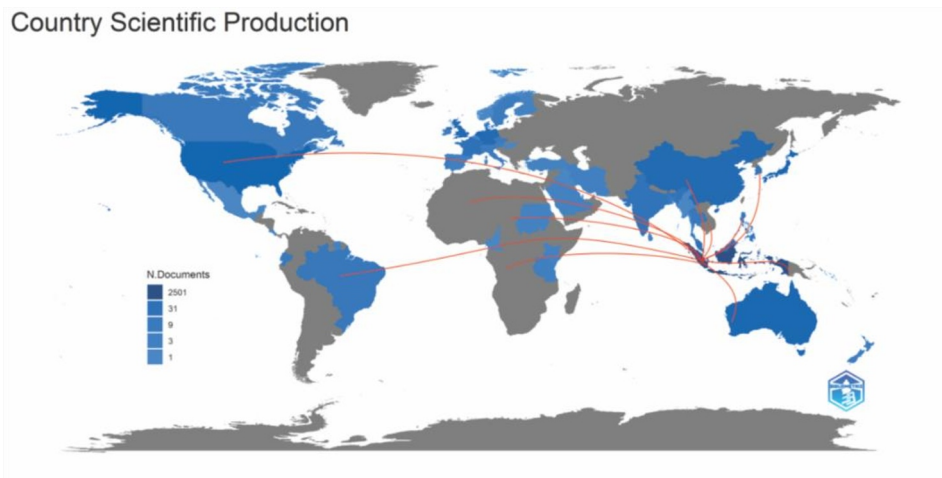
According to **Fig.5** and **Table 2** above, the author’s examination of collaboration employs several variables, including nodes, betweenness, closeness, and PageRank. The author, who is a part of the partnership, goes by Node. Clusters are associations between writers or articles. The least number of paths any author or article must take to link two other nodes is known as the betweenness. A “closeness” score gauges how likely a writer or article is to work closely with other writers or articles. *PageRank* is a rating that expresses how strong a writer or article is compared to others.

From the data above, it can see that Basyuni M has the highest Betweenness score, namely 117.1183384. This analysis means that Basyuni M connects the other two nodes with the most minimal number of routes. Furthermore, Kusmana C. has the highest Closeness score, namely 0.012195122. This analysis shows that Kusmana C. tends to collaborate with other authors or articles. Friess D.A. has the highest PageRank score, which is 0.033525623.

This analysis shows that Friess D.A. has the greatest strength concerning other authors or articles.

### 4.3 Indonesian Geographical Collaboration Analysis

In the context of the Geographical Collaboration Analysis of mangrove ecosystems in Indonesia, Indonesia's research network with other countries has also increased over the last few years. In particular, Indonesia has collaborated with other countries in researching mangroves.



**Figure 6.** Indonesian visualization of author collaboration, Source scopus/biblioshiny.

In **fig. 6** above, it is clear that Indonesia is a country that has been the object of research by countries such as the United States, Japan, Australia, the Netherlands, the United Kingdom, China, Germany, Singapore, and Malaysia. This analysis shows Indonesia has become one of the world's leading mangrove research centers. This analysis follows the findings of the Global Mangrove Association (GMA) and the Indonesian Ministry of Maritime Affairs and Fisheries, which state that the conservation and restoration of mangrove forests in Indonesia is a significant effort to preserve the world's essential mangrove ecosystems. Support from the government with its policies is expected to maintain and increase the growth of mangroves in Indonesia.

## 5 Discussion

The findings on our questions how do previous researchers in Scopus-indexed journals carry out the publications and research? are discussed as the development of mangroves in Indonesia in the future will continue to increase. Indonesian mangrove researchers have made a significant contribution to developing world mangrove knowledge. From 2013 to 2022, the number of publications on mangrove ecosystems in the Scopus database increased by 475%. This study indicates that mangroves will become an

increasingly popular research topic. This study shows that researchers have paid great attention to the sustainability of the world's mangrove ecosystems, especially in Indonesia. Research continues to develop and dig deeper into mangrove ecosystems over time.

The findings on our how is the development of research trends in mangrove research in Indonesia? are discussed this study has produced various findings that have helped mangrove experts better understand mangroves and develop solutions to address existing mangrove problems. From the data above, we predict that future mangrove research themes in Indonesia will concentrate on developing mangrove technology and management, as well as conducting more in-depth research on mangroves' biological and environmental conditions.

The findings on our explore the latest findings that can develop to maintain and enhance the development of Indonesian mangroves are discussed this study will assist mangrove researchers and experts in developing solutions to existing mangrove problems. Thus, mangrove research in Indonesia will continue to grow and significantly contribute to knowledge about mangroves in the future.

## **6 Conclusion**

This study has several findings that we consider essential for mangrove research in Indonesia. There are 747 research documents in 2013-2022 that have been published by many researchers and indexed in the Scopus database. It has been noted that there has been a scientific collaboration between world scientists and Indonesian scientists, for example, the collaboration of Kauffman J.B. with Alongi D.M., Murdiyarso D, and Basuni. Many books and scientific articles have been published and have become references for many researchers. For example, in 2010, M. Spalding et al. wrote a book entitled World Atlas of Mangroves, and Giesen et al., 2007, reported the Mangrove Guidebook for Southeast Asia, which has received a high number of citations.

Many scientific journals with the h-Index and the highest Quartile ranking have published publications on mangrove ecosystems in Indonesia, for example, the international journal Biodiversitas, AACL Bioflux Journal, and Ocean and Coastal Management Journal. Many keywords related to mangrove ecosystems were found, including conservation, biodiversity, blue carbon, ecotourism, climate change, and remote monitoring. Based on the keyword co-occurrence analysis also shows that some of the most popular mangrove species are *Avicennia marina*, *Rhizophora*, and seagrass.

The State of Indonesia will feel this positive influence because the contribution of these researchers will encourage researchers from the State of Indonesia to continue to conduct further research on mangroves. In addition, the results of the study by scientists will increase the awareness of the Indonesian people about the importance of mangroves and encourage the development of mangroves in the future.

In the future, there is expected to be more research covering the use of remote technology, the use of GIS, and environmental monitoring to analyze mangrove areas.

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