

RESEARCH MAPPING OF BLUE CARBON AND MANGROVE PLANTS IN INDONESIA : BIBLIOMETRIC ANALYSIS WITH SCOPUS DATABASE 2014-2024

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ABSTRACT

Indonesia is one of the countries with the largest blue carbon ecosystems in the world. This is due to its long coastline and vast marine areas. Indonesia has the largest mangrove forests in the world, covering approximately 3.3 million hectares, spread across the coasts of Sumatra, Kalimantan, Sulawesi, Papua, and Java. The method used in this research is bibliometric analysis, a quantitative approach to analyzing scientific literature with the aim of identifying publication patterns, research trends, scientific impact, author collaborations, and relationships between scholarly works. Based on the results, it was found that among the 10 most productive authors, Murdiyanto is the most productive, with 13 publications. In terms of institutional affiliation, authors come from institutions such as Bogor Agricultural University, the National Research Agency, and the Center for International Forestry Research. Bibliometric mapping using Vos-viewer, through co-occurrence analysis for network, overlay, and density visualization, shows that topics related to blue carbon and mangroves, such as organic carbon, carbon storage, carbon emissions, and mangroves, were trending between 2021 and 2024. However, these topics as a whole have not been widely researched.

Keywords: *Blue carbon, mangroves, global warming.*

INTRODUCTION

Global warming is one of the most exciting topics today and has become a theme of research and discussion at various scientific meetings. In this respect, there are some major needs why global warming has become object of attention that is really excessive because several phenomena occur like flood, draught, storm as well as forest burning. Other effects from global warming comprise of increasing sea level, natural disasters, wildfires, and endangerment of lifestyle (Lanae, 2019). However, in terms of its effect, climate change influences the environment, health, economy and food security of many nations simply it is mainly influenced on the climate vulnerable region.

When speaking about global warming, it is the rise in earth average temperature from the increased emission of greenhouse gases like carbon dioxide, methane and nitrous oxide. These gases are released into the atmosphere from human activities like burning fossil fuels, clearing forests and intensive agriculture. A significant measure to reduce climate warming, we

can undertake in this planet is the management of blue carbon (Carbon that sequestered and stored in coastal ecosystem such as mangroves, seagrass beds and salt marsh). Such ecosystems can take up significant amounts of carbon from the atmosphere and sequester them in biomass and sediment, thereby lessening greenhouse gases that drive global warming. Among the most effective blue carbon sinks, mangroves develop in tropical and subtropical coastal environment regions. In mangroves, carbon can be stored above ground (stems, leaves, and branches) or below ground (roots and sediments). Concrete says mangroves photosynthesize carbon dioxide, storing it in their intricate root systems and adjacent sediments for millennia. As such, mangrove forests serve as a natural "carbon sink" that are essential in removing carbon from the atmosphere.

Recognised as blue carbon, mangroves play a vital role in climate change reduction by storing carbon. As the climate change phenomenon is accompanied by rising greenhouse gas levels in the atmosphere, which are the main trigger of this global warming problem (Jang & Awiati, 2023). Mangroves help mitigate it due to their ability for long-term carbon absorption and storage. Failure to preserve these ecosystems, whether through deforestation, land conversion, or industrial logging can lead to the release of thousands of years' worth of sequestered carbon into the atmosphere creating feedback that make climate change effects even worse. To keep the carbon that mangroves can sequester and store, it is crucial to safeguard and rehabilitate them.

Blue carbon ecosystem is one of the largest blue carbons ecosystems owned by Indonesia and even the world. The rationale is that the archipelago comprises a large expanse of sea as well as land. Covering an area of approximately 3.3 million hectares, Indonesia has the largest mangrove forests in the world, dotted throughout its coasts from Sumatra to Kalimantan, Sulawesi to Papua and Java. Indonesia is also home to vast seagrass and coastal swamp ecosystems with rich biodiversity. Indonesia becomes one of the largest carbons store yards in the world owing to these blue carbon ecosystems as well as a natural fortification of climate change impacts, that is rising sea levels and storms (Widagti et al., 2021).

Indonesia's main blue carbon ecosystem is mangrove forest. Carbon in mangroves has potential storing capacity over four times more than carbon found inland in tropical forests per hectare. These mangroves solubilize and fix atmospheric Co₂ in their roots, stems and soils on the anticipated settlement of mangroves. They also act as a protective barrier to the shoreline wind- and wave-abrasion, protecting them from storms or tsunamis. In addition, Mangrove forests are home to many types of fish, birds, and other marine creatures making them play a dual function in sustaining the local economies via fisheries and tourism (Putri et al., 2022).

Over the last decade, there has been an immense growth of research on mangrove ecosystems and blue carbon based on Indonesian studies. It relates to the rising consciousness of mangrove ecosystem functions in reducing global climate change level, as well as preserving and rehabilitating coastal ecosystems (Rustam et al., 2023; Syafrudin et al., 2018). Hence, in light of the above, researchers are interested in tracing the trend of blue carbon and mangrove studies conducted in Indonesia. Scopus with research 2014–2024: this search used bibliometric studies.

METHOD

This research used the bibliometric method, a quantitative method based on the analysis of scientific literature to identify publication patterns/research trends. This identification is important because it provides information about the impact of science, collaboration between authors, and relationships between scientific works. Bibliometric analysis normally consists of

the collection and processing of publications, such as journal articles, book chapters, or books throughout a field of science to describe its evolution (Nafisah & Winoto, 2022b; Anjani & Winoto, 2022).

Then, regarding the database used in the research, it comes from Scopus and ranges from 2014 to 2024. Meanwhile, to present the data, researchers used the Vos viewer application. As for this research, there are three stages carried out in mapping the trend of blue carbon and mangrove research in Indonesia, namely:

1. **Data Harvesting.** This stage is carried out to collect documents derived from articles and seminar proceedings that the Scopus indexing institution has published. The articles are collected using the keywords "blue carbon" and "mangrove." As for the time range of documentation collected, namely articles and seminar proceedings published between 2014-2024.
2. **Data Screening.** Data obtained and collected from the data collection process cannot be directly analyzed. Therefore, data filtering needs to be done. Data filtering is carried out at this stage, where publications are collected only in articles and seminar proceedings. Meanwhile, other publications, such as book chapters and books, were not collected. From the results of data screening for research on blue carbon and mangroves in Indonesia, 103 publications were obtained in the form of articles and seminar proceedings during the 2014-2024 period with the following details: 81 articles and 22 seminar proceedings.
3. **Data Analysis and Visualization.** The selected documents were cleaned and saved in .csv format. Trend analysis was done using the VOSViewer tool. We filtered the terms included in the VOSviewer network mapping visualization at this stage. In this data analysis and visualization, researchers mapped the distribution of articles in the 2014-2024 range and the citation ranking of article authors. In addition, we also mapped clusters of study themes related to blue carbon and mangrove research in Indonesia, examined study references, and saw the novelty of the topic of blue carbon and mangrove fields.

The three stages, namely the data harvesting, data filtering, and data analysis and visualization stages, can be described as follows:

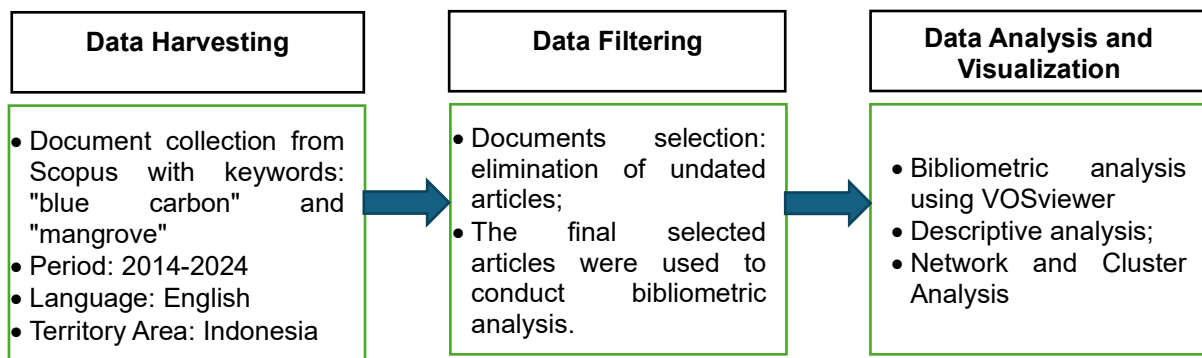


Figure 1: Methodological Design of Bibliometric Analysis on Blue Carbon and Mangroves in Indonesia

RESULTS and DISCUSSIONS

This study aims to map research on blue carbon and mangroves in Indonesia. Based on the data collection and selection results, the number of publications was 103 documents, with details of 81 articles (78.6%) and 22 seminar proceedings (21.4%).

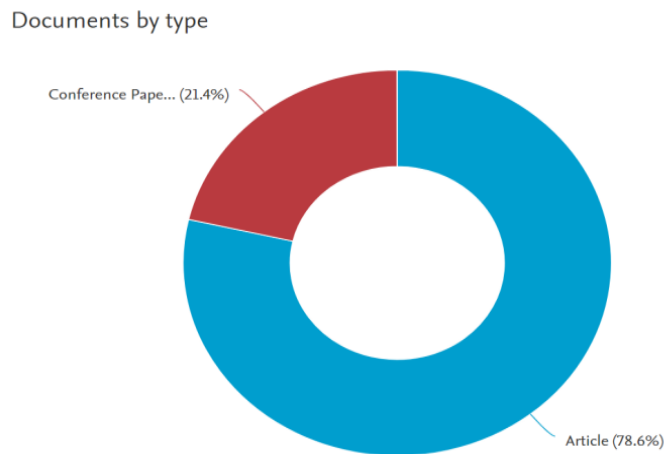


Figure 2. Document types for the topics "blue carbon" and "mangroves"
Source: Processed by researchers from the Scopus database, 2024.

Based on Figure 2 above, there are 103 documents comprising 81 articles and 22 proceeding seminar papers. Meanwhile, when viewed from the development of publications every year during the 2014-2024 range, it consists of 2014 as many as one publication, 2015 as many as one publication, 2016 as many as five publications, 2017 4 publications, 2018 as many as seven publications, 2019 as many as seven publications, 2020 as many as 13 publications, 2021 as many as 13 publications, 2022 as many as 13 publications, 2023 as many as 22 and 2024 as many as 17 publications.

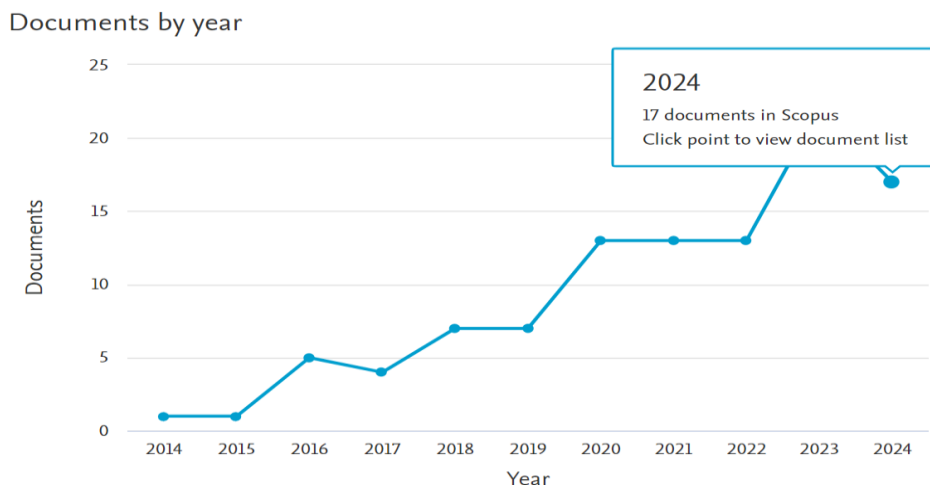


Figure 3: Development of publications between 2014-2024
Source: Data processed by researchers from the Scopus database, 2024.

Author's Analysis

In this author analysis, we present a list of 10 authors who researched blue carbon and mangroves in Indonesia during 2014-2024.

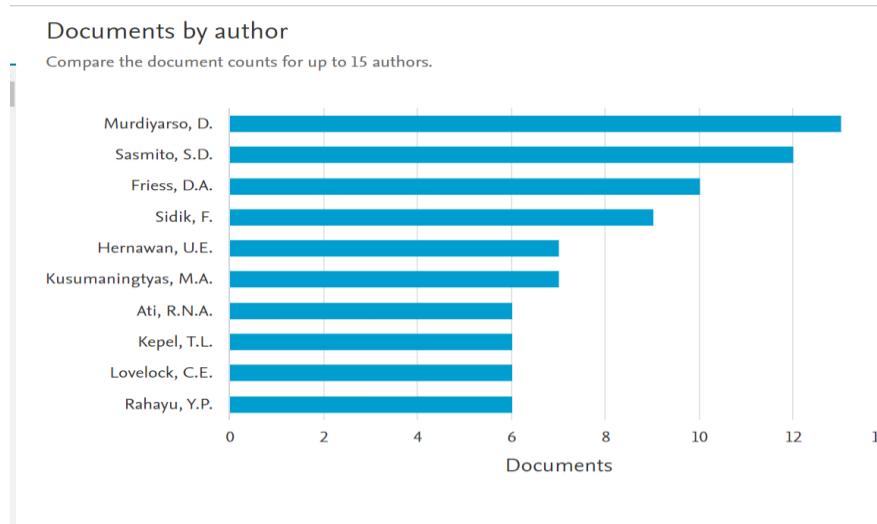


Figure 3. List of 10 productive authors during 2014-2024
 Source: Processed by the author from Scopus database, 2024.

Based on Figure 3, it is known that from 2014 to 2024, ten authors had a productive level of publications produced, as follows: Murdiyarso with 13 publications, Sasmita with 12 publications, Fries with ten publications, Sidik with nine publications, Hernawan UE with seven publications, Kusumayati with seven publications, ATI RNA with six publications, Kepel with six publications, Lovelock with six publications and Rahayu Yp with six publications. Meanwhile, when viewed from the institution or institutional affiliation, it was revealed that 21 people came from Bogor Agricultural University (IPB), 20 people came from the National Research Agency (BRIN), 19 people came from CIFOR (Center For International Forestry Research) West Java, 17 people came from the National University of Singapore, as many as ten people each came from Charles Darwin University; Diponegoro University (UNDIP); University Malaysia, nine people from Sam Ratulangi University, eight people from the Ministry of Marine Affairs and Fisheries and seven people from The University of Queensland.

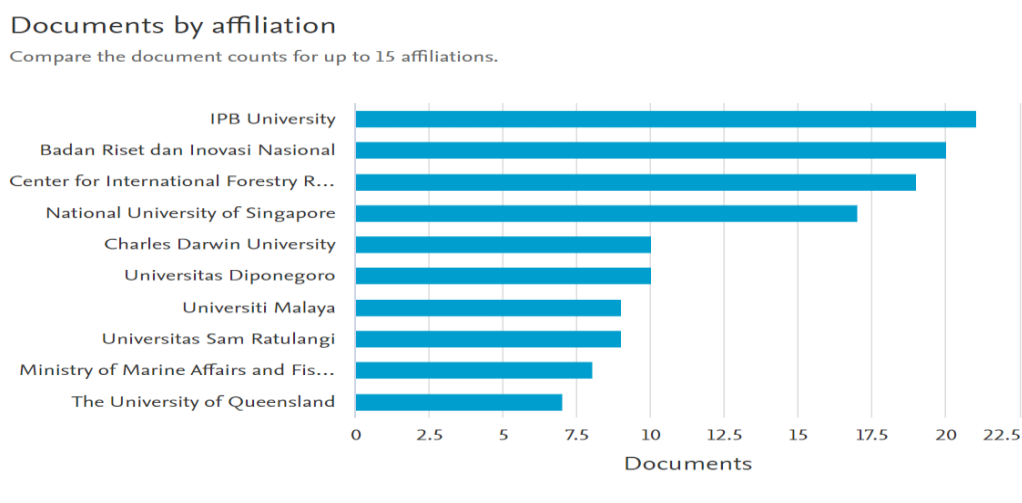


Figure 4. List of authors' institutions/affiliations
 Source: Data processed by the author from the Scopus database, 2023

When paying attention to the institution or affiliation of the author, it can be seen that there are several authors whose institutions come from abroad, such as the National University of

Singapore with 17 authors, Charles Darwin University with ten authors, the University of Malaya with ten authors and The University of Queensland with seven authors. The presence of several institutions from outside Indonesia is due to several things, such as the author continuing his education at the institution and collaborative research activities involving researchers from the institution.

Most cited publications

Suppose the author's analysis presents the author's productivity and the author's existence seen from the institution or affiliation. In that case, this section will present the publications in the form of research results on blue carbon and mangroves in Indonesia that are widely cited. The ten publications can be presented in the following table:

Table 1. List of the ten most cited publications

Number of Citations	Author Name	Article Title	Journal Name
184	Sasmito, S.D., Taillardat, P., Clendenning, J.N., ... Murdiyarso, D., Hutley, L.B.	Effect of land-use and land-cover change on mangrove blue carbon: A systematic review	Global Change Biology, 25(12), pp. 4291-4302, 2019.
167	Kauffman, J.B., Adame, M.F., Arifanti, V.B., ... Simpson, L., Hernández Trejo, H.	Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients	Ecological Monographs, 90(2), e01405, 2020.
160	Serrano, O., Lovelock, C.E., B. Atwood, T., ... Trevathan-Tackett, S.M., Duarte, C.M.	Australian vegetated coastal ecosystems as global hotspots for climate change mitigation	Nature Communications, 10(1), 4313, 2019.
153	Alongi, D.M., Murdiyarso, D., Fourqurean, J.W., ... Pidgeon, E., Wagey, T.	Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients	Wetlands Ecology and Management, 24(1), pp. 3-13. 2016
135	Friess, D.A., Thompson, B.S., Brown, B., ... Sasmito, S.D., Sidik, F.	Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia	Conservation Biology: The Journal of the Society for Conservation Biology, 30(5), pp. 933-949. 2016
134	Kusumaningtyas, M.A., Hutahaean, A.A., Fischer, H.W., ... Ransby, D., Jennerjahn, T.C.	Variability in the organic carbon stocks, sources, and accumulation rates of Indonesian mangrove ecosystems	Estuarine, Coastal and Shelf Science, 218, pp. 310-323. 2019
105	Nam, V.N., Sasmito, S.D., Murdiyarso, D., Purbopuspito, J., MacKenzie, R.A.	Carbon stocks in artificially and naturally regenerated mangrove ecosystems in the Mekong Delta	Wetlands Ecology and Management, 24(2), pp. 231-244. 2016.

102	Sasmito, S.D., Sillanpää, M., Hayes, M.A., ... Hutley, L.B., Murdiyarso, D.	Hydrogeomorphic settings and land-use change control mangrove blue carbon stocks and dynamics.	Global Change Biology, 26(5), pp. 3028-3039. 2020
100	Sondak, CFA, et al	Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs)	Journal of Applied Phycology, 2017, 29(5), pp. 2363-2373.
59	Bhomia, R.K., Mackenzie, R.A., Murdiyarso, D., Sasmito, S.D., Purbopuspito, J.	Impacts of land use on Indian mangrove forest carbon stocks: Implications for conservation and management	<i>Ecological Applications</i> , 2016, 26(5), pp. 1396-1408.

Source: Processed by researchers from the Scopus database, 2024.

Based on Table 1 above, it is known that of the ten lists of publications mentioned above, the publication that received the highest citation (first place) was an article entitled, "Effect of land-use and land-cover change on mangrove blue carbon: A systematic review," written by Sasmito, S.D, et al. published in the journal *Global Change Biology* with 184 citations. The publication at the bottom (10th place) is an article entitled, "Impacts of land use on Indian mangrove forest carbon stocks: Implications for conservation and management," written by Bhomia, R.K., et al. and published in the journal *Ecological Applications*.

Co-Occurrence Analysis

In this section, researchers will explain the development map of blue carbon and mangrove research publications in Indonesia based on keywords (co-occurrence). The definition of co-occurrence can be interpreted as a concept that describes the frequency of two or more keywords, terms, or entities (for example, authors, institutions, or research fields) that appear simultaneously in one document or collection of documents. In other words, co-occurrence highlights the relationship or linkage between two or more entities frequently appearing together in scientific literature (Rohanda & Winoto, 2019). Co-occurrence analysis is usually applied to scientific article keywords, titles, or abstracts to identify conceptual relationships or topics often studied together. There are several main benefits of co-occurrence analysis in bibliometrics, including mapping research trends or fields of study based on the co-occurrence of terms or concepts and identifying clusters of emerging concepts or research topics (Fahira & Winoto, 2022).

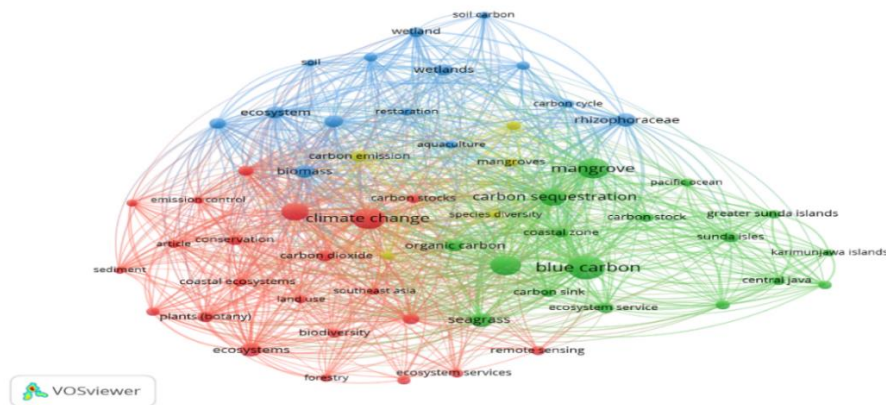


Figure 5. Network visualization on co-occurrence
Source: Data processed by researchers from Vosiewer, 2024.

Figure 5 above shows a network visualization on co-occurrence that explains the network or relationship of one term with another in research in the blue carbon and mangroves in Indonesia in 2014-2024. The 103 documents selected from the Scopus database can be grouped into 4 clusters that can be identified through the color of each keyword node. Cluster 1, symbolized in red, includes terms related to the field of blue carbon and mangroves studied: climate change, carbon dioxide, coastal ecosystem, carbon storage, conservation, sediment, and emission control. Cluster 2, symbolized in green, includes terms related to the topic under study, namely research on blue carbon and mangroves in Indonesia. The terms in cluster 2 are mangrove, blue carbon, karimun java islands, organic carbon, carbon sequestration, seagrass, coastal zone, central java, and greater sunda islands. Cluster 3 is symbolized in blue, which presents keywords such as restoration ecology, carbon cycle, soil carbon, aquaculture, climate change mitigation, and land use change. Cluster 4 is symbolized in yellow, which displays keywords such as carbon imitation, restoration ecology, special diversity, and mitigation.

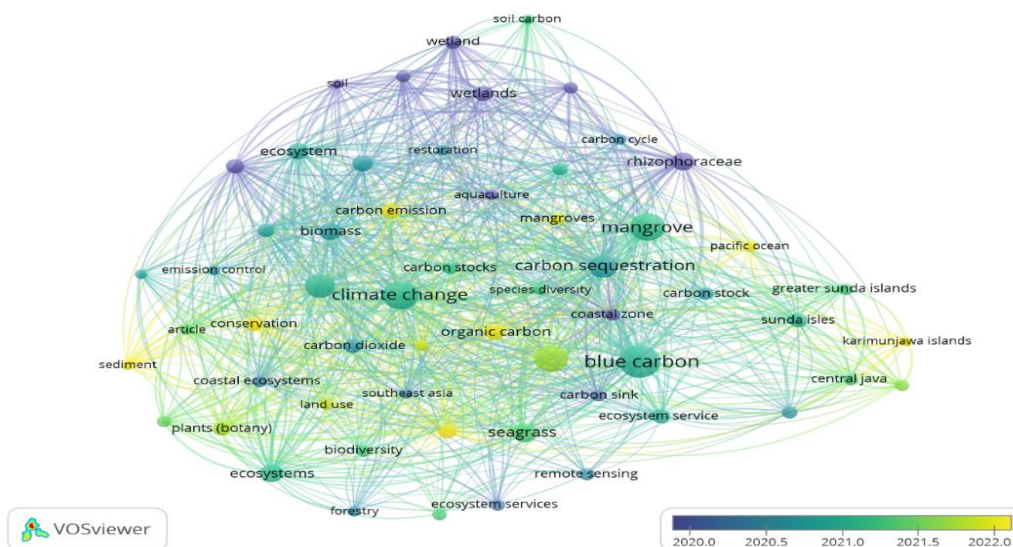


Figure 6. Visualization of overlay on co-occurrence
Source: Data processed by researchers from Vosiewer, 2024.

If Figure 5 describes network visualization, which is a technique for mapping and visualizing relationships between elements such as keywords, authors, journals, or institutions in academic literature based on their co-occurrence in the same document, then another mapping in co-occurrence analysis is clustering trends in bureau carbon and mangrove research in Indonesia based on historical traces or years of research publications. The information obtained from the overlay visualization results, as shown in Figure 6, can be used as a reference to identify and detect state-of-the-art research in the bureau carbon and mangroves conducted within a certain period.

The results of bibliometric analysis through the Scopus database visualized through the Vosviewer application produce an overlay visualization. In this visualization, the node's color represents keywords that indicate the year of publication. For example, the keywords organic carbon, carbon storage, carbon emission, mangrove, sediment, Indonesia, and Karimun Java Islands have large and yellow nodes, which means that articles containing keywords in addition to being a topic that is widely studied also this keyword is the latest topic in the 2014-2024 range.

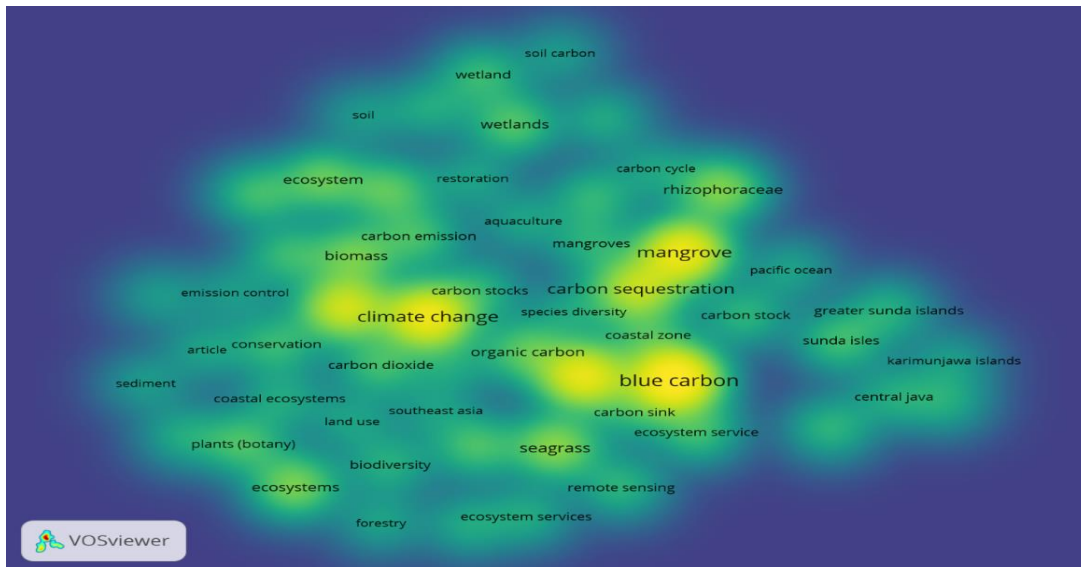


Figure 7. Visualization of density on co-occurrence
Source: Data processed by researchers from Vosiewer, 2024.

Then, the next analysis of co-occurrence is bibliometric analysis using density visualization. From the visualization results shown in Figure 7, it can be identified that some areas are dense or have a high density in one node with other nodes. The level of saturation identified in the number of keywords is marked yellow, which means that the region is a topic that has been widely researched and indexed by Scopus; for example, the keywords climate change, seagrass, and carbon sequestration are topics that have been widely researched. Meanwhile, nodes marked with dark colors indicate that these topics are still not widely researched, such as the keywords soil carbon, sediment, mangrove and coastal ecosystem, and central java. This can foster opportunities to conduct research on these topics, such as the keywords mangrove and blue carbon in mangrove tourism areas. With bibliometric analysis on density visualization that shows a strain and low intensity, it shows that research on blue carbon and

mangroves in the Indonesian region is still relatively low, which makes research on these topics still comprehensive to be researched.

CONCLUSIONS

The topic of blue carbon in mangroves is a topic that is still rarely researched in Indonesia. In the range of 2014-2024 publications in the Scopus database, from the results of data filtering, I obtained as many as 103 documents consisting of 81 articles and 22 papers proceeding seminars. As seen from the development of research publications on the topic of blue carbon and mangroves in Indonesia from year to year, has increased, and the highest number of publications is in 2023, which is 22 publications.

Regarding the list of the ten most productive authors, Murdiyanto is the most productive author, producing 13 publications, and Sasmito has 12 publications. As for the institution or institutional affiliation of the authors, among them are 21 people from Bogor Agricultural University, 20 from the National Research Agency, and 19 from the Center for International Forestry Research. Meanwhile, the most cited publication is the article, "Effect of land-use and land-cover change on mangrove blue carbon: A systematic review," written by Sasmito, S.D et al. published in the journal *Global Change Biology* with 184 citations. However, the ten articles with the most citations all discuss blue carbon and mangroves, and the research area is in Indonesia.

Then, based on the results of bibliometric mapping using Vosviewer from co-occurrence analysis for network visualization, overlay, and density, it can be concluded that in the period 2021-2024, topics related to blue carbon, and mangroves such as organic carbon, carbon storage, carbon emission, mangroves, sediments and topics related to Indonesia are the most researched topics.

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CONFLICT OF INTEREST

We hereby declare that all authors in this study have no conflict of interest.

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