



## GLOBAL BLUE CARBON RESEARCH: A BIBLIOMETRIC ANALYSIS WITH A FOCUS ON SMALL ISLAND ECOSYSTEMS (CASE STUDY IN INDONESIA)

DELI WAKANO<sup>1\*</sup>, ISKANDAR Z. SIREGAR<sup>2</sup>, FREDINAN YULIANDA<sup>3</sup>, IRMAN FIRMANSYAH<sup>4</sup> AND BONO PRANOTO<sup>5</sup>

<sup>1</sup>Natural Resources and Environmental Management, Graduate Study Program, IPB University Baranangsiang Campus, Jl. Pajajaran, 16144 Bogor, West Java, Indonesia. <sup>2</sup>Department of Silviculture, Bogor Agricultural University, 16680 Bogor, West Java, Indonesia. <sup>3</sup>Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, 16680 Bogor, West Java, Indonesia. <sup>4</sup>System Dynamics Centre, 52254 Brebes, Central Java, Indonesia. <sup>5</sup>Research Centre for Limnology and Water Resources, National Research and Innovation Agency, KST Soekarno, 16911 Bogor, West Java, Indonesia.

\*Corresponding author: [delly\\_wakano@yahoo.co.id](mailto:delly_wakano@yahoo.co.id)

### ARTICLE INFO

#### Article History:

Received: 26 October 2024

Revised: -

Accepted: 7 July 2025

Published: 15 February 2026

#### Keywords:

Blue carbon, small island ecosystems, bibliometric analysis, climate change mitigation, carbon sequestration.

### ABSTRACT

This study presents a bibliometric analysis of global blue carbon research, with a specific focus on small island ecosystems in Indonesia. Recognising Indonesia's significant contribution of approximately 17% to global blue carbon reserves, the analysis explores publication trends, key contributors, and thematic developments in blue carbon science. Notably, a marked increase in research output since 2005, peaking in 2023, underscores the growing recognition of blue carbon's role in mitigating climate change. This is particularly true in vulnerable coastal ecosystems such as mangroves and seagrasses. Accordingly, the findings reveal an evolution from fundamental carbon storage studies to complex interactions involving anthropogenic impacts and biodiversity considerations. Moreover, this diversification highlights the need for integrated conservation strategies that combine ecological insights with community engagement and policy frameworks. In addition, recommendations for future research include enhancing monitoring methodologies, improving mangrove rehabilitation practices, and increasing community awareness of the benefits of blue carbon. Essentially, by fostering collaborative efforts among scientists, policymakers, and local communities, this analysis contributes to effective conservation policies that optimise the blue carbon potential of Indonesia's small island ecosystems. This ultimately contributes to global efforts to mitigate climate change.

© UMT Press

### Introduction

Blue carbon refers to the capacity of coastal ecosystems such as mangroves and seagrass meadows, to act as carbon sinks, absorbing and storing atmospheric carbon (Macreadie *et al.*, 2019). Small island ecosystems, particularly those dominated by seagrasses and mangroves, play a crucial role in the global carbon cycle by providing significant ecosystem services, including carbon storage and other regulatory functions. Correspondingly, research has

demonstrated that seagrass ecosystems have a significant capacity to absorb and store atmospheric carbon. This, in turn, can help mitigate greenhouse gas emissions that contribute to global warming (Maemunah *et al.*, 2022). In addition, mangroves play a crucial role in reducing national carbon emissions through rehabilitation and planting activities (Imran *et al.*, 2022). Related research has also been conducted to estimate carbon stocks in seagrass

and mangrove ecosystems in various locations. This includes the waters of Bintan Island (Hertyastuti *et al.*, 2020), Bunaken National Park (Verisandria *et al.*, 2018), and Karimunjawa National Park (Rhamadany *et al.*, 2021). The results indicate that mangrove ecosystems have significant potential as carbon stores, capable of sequestering substantial amounts of carbon (Rifandi, 2021). Additionally, research emphasises the significance of enhancing public awareness and participation in climate change mitigation and adaptation efforts, including through education and the rehabilitation of coastal areas (Zukmadini & Rohman, 2023). In the Indonesian context, these studies provide a deeper understanding of the importance of coastal ecosystems such as mangroves and seagrass beds, in the face of climate change. Furthermore, the conservation, rehabilitation, and management of coastal ecosystems are crucial for maintaining atmospheric carbon balance and reducing the impacts of climate change. Additionally, policies that support coastal ecosystem management and raise public awareness of the role of these ecosystems are also necessary to effectively achieve climate change mitigation goals.

Notably, Indonesia's small island ecosystems, particularly their mangrove and seagrass habitats, are critical components of the global blue carbon landscape. While bibliometric analyses of blue carbon research have been published in journals such as *Ecological Indicators*, *Wetlands*, *Water*, and *Environmental Science and Pollution Research*, this study offers a novel contribution by focusing explicitly on Indonesia's small islands. Despite often being overshadowed by the larger landmasses of Kalimantan and West Papua, these islands contribute significantly to carbon sequestration. This is based on the combined carbon storage capacity of Indonesia's mangroves and seagrasses, estimated at 3.4 Pg C, representing approximately 17% of the global blue carbon stock (Alongi *et al.*, 2016). Collectively, these statistics underscore the significance of small islands in climate mitigation strategies and

underscore the need for research specifically examining their blue carbon dynamics.

The unique ecological characteristics of Indonesia's small islands make them particularly vulnerable to climate change and sea-level rise. Studies indicate that rising sea levels could inundate approximately 34,000 km<sup>2</sup> of Indonesian territory, including many small islands, by 2100 (Rahmadi *et al.*, 2022). Consequently, this vulnerability poses a threat to the carbon storage potential of these ecosystems and to their ecological balance. For instance, degradation of seagrass meadows and mangrove forests could lead to significant losses in carbon stocks, as these ecosystems are essential for trapping and storing carbon in their sediments (Fauzi *et al.*, 2021). At the same time, impacts of climate change such as increased storm intensity and frequency, further exacerbate these risks, potentially leading to immediate and drastic losses in seagrass coverage (Dunic *et al.*, 2021). Such challenges emphasise the urgency for tailored blue carbon conservation and management strategies suited to the specific context of small islands.

This study distinguishes itself by focusing on small island ecosystems and highlighting their unique challenges and contributions to blue carbon research. Although the methodological approach aligns with established bibliometric analyses, our work provides an in-depth evaluation of trends specific to Indonesia's small islands and their blue carbon ecosystems, thereby filling a critical knowledge gap. Unlike studies that take a global or broad regional approach, our analysis considers the distinct environmental conditions and socio-economic contexts of Indonesia's small islands. For example, the protection of mangrove forests in the Karimunjawa-Kemujan Islands has been demonstrated to be vital for carbon sequestration and mitigating the impacts of climate change (Wirasatriya *et al.*, 2022). Additionally, integrating local community practices and knowledge into conservation strategies enhances the effectiveness of blue carbon initiatives (Aminah *et al.*, 2019; Suryani *et al.*, 2023).

Thus, by providing insights into research gaps, key contributors, and evolving themes, this study aims to inform the development of conservation policies tailored to these ecosystems.

Furthermore, the potential for blue carbon conservation in small islands is substantial, as these ecosystems store carbon at rates surpassing those of terrestrial forests (Muliawati & Choesin, 2024). Seagrass ecosystems, for instance, have been reported to have carbon storage capacities of up to 830 MgC/ha, which is notably higher than the carbon absorption potential of many terrestrial ecosystems (Muliawati & Choesin, 2024). This highlights a significant opportunity for blue carbon conservation and underscores the need for targeted research and policy development to enhance the resilience and carbon sequestration capabilities of these vital ecosystems.

Following this, bibliometric analysis serves as a powerful tool for systematically scanning and mapping knowledge within the field of blue carbon, particularly in small island ecosystems. This method allows for an in-depth exploration of research outputs by analysing patterns of citations, authorship, collaboration, and key themes. By providing a comprehensive overview of existing literature, bibliometric analysis helps identify research trends, influential studies, and the contributions of key authors. It also reveals knowledge gaps and areas requiring further exploration such as the estimation of carbon stocks in critical ecosystems, including mangroves and seagrasses (Rustam *et al.*, 2021; Aprilia & Nandiyanto, 2022). In other words, this method is instrumental in guiding future research directions and informing policy development for the conservation and management of blue carbon ecosystems.

While bibliometric analyses of blue carbon research exist in several global and regional contexts (e.g., in journals such as *Ecological Indicators*, *Wetlands*, *Water*, and *Environmental Science and Pollution Research*), this study uniquely focuses on the dynamics of blue carbon within Indonesia's small island ecosystems. Note that these ecosystems play a crucial yet

underexplored role in carbon sequestration and climate change mitigation. Unlike previous bibliometric studies that encompass broad geographic areas, our analysis provides a nuanced examination of the research trends, key contributors, and knowledge gaps specific to Indonesia's small islands, which face unique environmental pressures, socio-economic challenges, and management needs.

Additionally, this study identifies these knowledge gaps, emphasising the critical need to integrate blue carbon research into national conservation policies, with an eye toward practical applications and strategies to enhance blue carbon potential in small island habitats. Accordingly, by adopting a detailed trend analysis spanning 1980 to 2024, we aim to uncover the evolution and development of blue carbon research in these small islands. This offers targeted insights that support both the scientific community and policymakers in addressing the unique challenges and opportunities presented by these ecosystems. Additionally, this approach allows for a deeper understanding of the interplay between global research trends and localised conservation needs. It also provides a foundation for developing tailored strategies to optimise the blue carbon potential in Indonesia's small islands.

This study aims to analyse the trends and evolution of research on blue carbon in small island ecosystems in Indonesia using a bibliometric analysis based on Scopus data. Scopus was selected as the primary database for this analysis due to its comprehensive coverage of peer-reviewed literature across a wide range of disciplines. This includes environmental science, and it has a reputation as one of the largest and most reliable sources of scientific publications globally. By utilising Scopus, this study ensures that the analysis is based on high-quality and widely recognised research outputs. Additionally, Scopus provides advanced tools for citation tracking and author collaboration networks, making it particularly suitable for bibliometric studies. Concurrently, this study utilises analytical tools such as VOSviewer

and Bibliometrix to identify critical scientific collaborations, contributions from influential authors, and dominant themes that have evolved from 1980 to 2024. Specifically, it examines the significant increase in publications since 2005 and investigates the factors contributing to the 2023 peak in research activity.

Furthermore, it highlights the significance of Indonesia's small island ecosystems within the global and national contexts of blue carbon research and explores the implications for developing effective conservation strategies. Ultimately, the study aims to identify future research opportunities to strengthen climate change mitigation efforts in Indonesia, particularly by integrating blue carbon principles into national conservation policies. Through these objectives, the study aims to make a meaningful contribution to the effectiveness of conservation policy and practice, and to support broader climate change initiatives.

## Materials and Methods

The bibliometric method is a component of the research evaluation methodology that enables the use of a separate method for bibliometric analysis (Ajinegara & Soebagyo, 2022). Bibliometric analysis involves using analytical tools such as Biblioshiny, R-based applications, and the Bibliometrix R-package as the main tool (Hidayatulloh, 2024). In bibliometric analysis, a quantitative and statistical approach to scientific publications enables the mapping of research trends, popular topics, and scientific collaborations (Madjido, 2021; Perdana *et al.*, 2023). Meanwhile, software such as VOSviewer, RStudio, and SEforRA are common in bibliometric analysis for data processing and visualisation (Wulan Aulia Azizah & Nur Indah Wahyuni, 2024). In addition, bibliometric analysis can involve using the "bibliometrix" package in R and the Publish or Perish application (Widyatami & Sari, 2023). Remarkably, bibliometric analysis has been applied in various fields, including learning media, supply chain management, mathematical reasoning, and health information

systems (Pratiwi & Soebagyo, 2022). Using bibliometric methods enables a better understanding of the development of a field of science, the identification of research trends, and the facilitation of scientific collaboration.

This study employed bibliometric methods based on blue carbon publications in small island ecosystems, using data from Scopus. Data collection was conducted on May 14, 2024, following keyword criteria that encompassed various aspects of blue carbon and small island ecosystems. In addition, the Scopus database was selected for its comprehensive global coverage of peer-reviewed journals and advanced citation analysis tools, ensuring high-quality data for bibliometric research.

In the context of the PICO framework, the Population refers to scientific publications focusing on blue carbon ecosystems, particularly in small island environments. Meanwhile, the Intervention involves applying bibliometric analysis, which systematically scans and maps research outputs, trends, and collaborations. Moreover, Comparison is facilitated by examining publications across different time periods and regions, enabling an understanding of how blue carbon research in small island ecosystems has evolved relative to larger island studies and global trends. Finally, the Outcome is the identification of research gaps, key contributors, and trends, intending to guide future studies and inform conservation policies for more effective climate change mitigation strategies in small island ecosystems (Roever, 2018).

Using analytical tools such as VOSviewer and Bibliometrix, this study evaluates key scientific collaborations, influential authors, and dominant themes from 1980 to 2024. The research highlights the marked increase in publications since 2005, culminating in a peak in 2023, and analyses the factors behind these trends. By focusing on Scopus data, this study ensures access to a comprehensive and reliable source of global scientific publications, which is critical for the depth and accuracy of the bibliometric analysis.

Furthermore, the study emphasises the importance of blue carbon in small island ecosystems in both global and national contexts, highlighting the need to integrate these findings into conservation strategies. Through this approach, the study contributes to strengthening climate change mitigation efforts, especially by integrating blue carbon principles into national policies, and provides insights for the future direction of research in this critical area. Building on this, the analysis of productive researchers in the field of blue carbon aims to identify key contributors, research networks, and collaborations that have shaped the field's direction and development. Accordingly, understanding these networks can help uncover patterns of knowledge production and dissemination, revealing how blue carbon research has evolved and highlighting influential research groups or collaborations that may guide future research agendas.

The (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) PRISMA diagram outlines a systematic process for identifying and including articles in a study on blue carbon. The search was conducted in the Scopus database, focusing on titles, abstracts, and keywords related to various terms such as "Blue carbon", "Coastal carbon", "Marine carbon", "Seagrass carbon", "Mangrove carbon", and others linked to marine and coastal ecosystems. The search spanned from 1890 to 2024, with the search date being May 14, 2024. It excluded terms such as "bibliometric", "scoping review", and "systematic review". The initial search yielded 447 documents, which were then screened, resulting in 365 articles. Of these, 360 were in the final publication stage, and 349 were in English. A total of 346 journal articles were selected for bibliometric analysis. For case study purposes, 25 articles from Indonesia were included. This process demonstrates the thorough approach to identifying, screening, and selecting relevant articles for the study, with a special focus on publications from Indonesia.

This study utilises the R application and RStudio for bibliometric analysis. For the first

use, install the bibliometric package by entering "install.packages("bibliometrix")" in the console tab. Following this, to run Biblioshiny, type "library(bibliometrix)" and press Enter or run. Subsequently, continue by writing "biblioshiny()" in the console tab and run it again.

Combining journal data analysis with bibliometric analysis is a powerful approach for exploring research trends and collaboration patterns across disciplines. In particular, this method utilises bibliographic data from journals to indicate author collaboration and research productivity (Rodríguez & Sandoval-Escobar, 2022). As such, data collection involves gathering books, articles, and journals to support the analysis (Fahrezi *et al.*, 2020). Data sources for bibliometric analysis can come from meta-analyses of national and international journals (Santosa *et al.*, 2021). Meanwhile, bibliometric analysis utilises tools such as Bibliometrix, which enables text mining and data analysis from various databases, including Scopus, Web of Science, and others (Rodríguez & Sandoval-Escobar, 2022). In addition, the meta-analysis research method enables researchers to assess the impact of Science, Technology, Engineering and Mathematics (STEM) based teaching materials on ecology learning (Santosa *et al.*, 2021).

Moreover, data analysis techniques in certain research contexts include organising, synthesising, and identifying. Data on collaboration and author productivity in specific journals can be collected and analysed to understand research trends. At the same time, bibliometric analysis can provide insights into research trends, the conceptual structure of the field of study, and the identification of researcher collaboration patterns (Rodríguez-García, 2022). Using tools such as Bibliometrix enables co-word analysis to understand the conceptual structure of a particular field of research (Salazar-Ceciliano & Aguilar, 2020). Additionally, bibliometric analysis can also be performed to understand the evolution and trends within a field of study (Libri *et al.*,

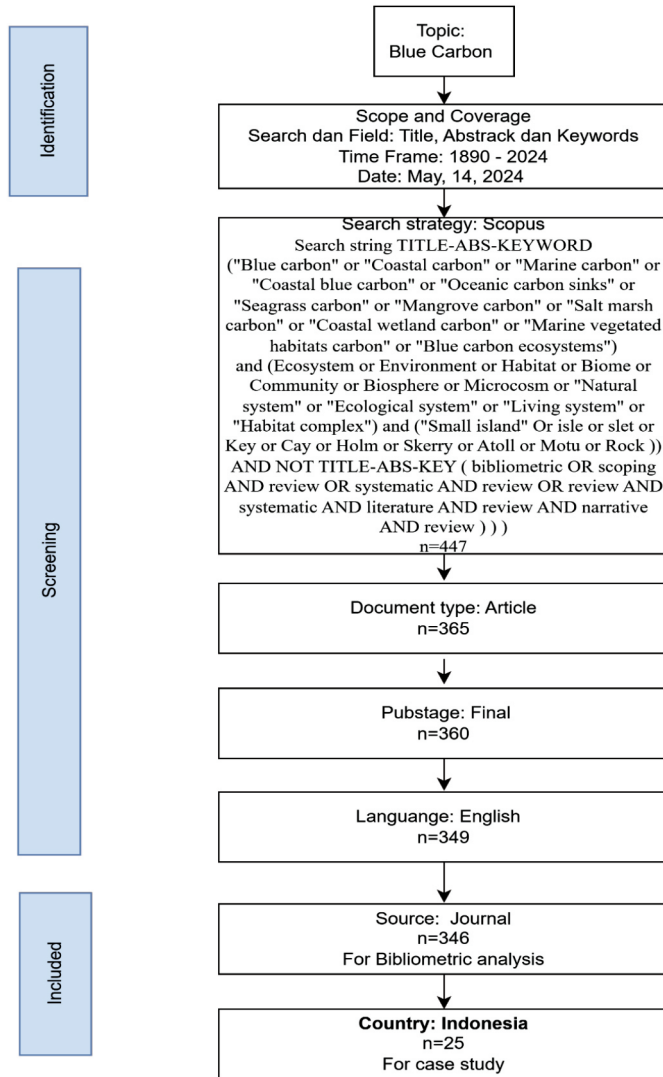


Figure 1: The PRISMA approach used in this bibliometric

2023). Bibliometric analysis, which employs quantitative techniques, can comprehensively comprehend research patterns and investigator contributions within a particular field of study (Husna & Sayekti, 2023). Using tools such as VOSviewer and Bibliometrix enables descriptive statistical analysis, citation analysis, and network analysis, which are helpful in bibliometric studies (Rubio & Salazar, 2022). Bibliometric analysis can also map concepts and research trends within a field (Trejos-Salazar et al., 2021).

In a given research context, bibliometric analysis can provide insights into the structure of knowledge, research trends, and the contributions of researchers in a field of study (Duque & Cervantes, 2019). Tools such as RStudio and Bibliometrix enable comprehensive, in-depth bibliometric analysis (Moyano Londoño & Marín Cardona, 2024). With this approach, researchers can gain insight into the evolution of knowledge, research trends, and the contributions of researchers in a specific field of study.

## Results and Discussion

### *Trend in Publication*

Based on general information about blue carbon publications in small island ecosystems (Figure 2). It indicates that blue carbon research on small island ecosystems has started since 2005.

From Figure 2, the number of articles published from 1980 to approximately 2023 reveals several notable trends. The first trend indicates that from 1980 to 2005, the number of articles published increased slowly yet consistently. This trend indicates an increasing interest in or development within the article's field. Following this, the second trend illustrates that from 2005 to 2015, there was an acceleration in the number of articles published. Our analysis highlights that the rise in blue carbon research publications, particularly since 2005, has presented a sharper incline than many broader environmental or climate science fields. This trend may reflect a growing recognition of the critical role these ecosystems play in global carbon sequestration and climate change mitigation. Additionally, it corresponds to the growing international emphasis on conservation efforts, the launch of various climate agreements, and the prioritisation of blue carbon ecosystems in national and global environmental policies.

Furthermore, the peak in 2023 demonstrates that small island ecosystems are gaining traction as a focal area for blue carbon research. This

trend underscores a shift towards more localised and specific studies, indicating a maturing research landscape in which smaller ecosystems are being explored. While they were previously underrepresented in scientific discourse, they are now receiving the attention they deserve due to their unique contributions to carbon storage and ecosystem services.

To contextualise this within broader research trends, we compared the rate of increase in blue carbon publications with that of general environmental science. We observed that blue carbon research, particularly in small island ecosystems, has increased at a rate above average. This suggests that the subfield is expanding rapidly due to increased global focus on climate change solutions, particularly in underexplored regions such as small islands.

From this data, it can be inferred that various factors influence research productivity and the publication of articles related to these studies, including changes in research priorities, access to research resources, and the impact of global events. Nonetheless, for a more in-depth analysis, additional specific information on the types of articles and research areas in question, as well as external factors that may be influencing these trends, is required.

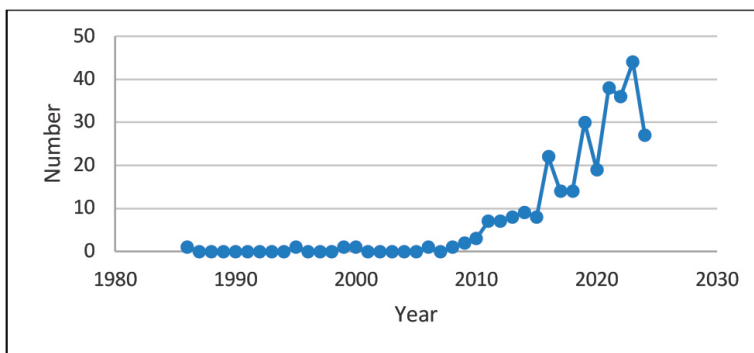


Figure 2: Publication of blue carbon in small island ecosystems

**The Most Relevant Author in Blue Carbon at the Ecosystem Small Island**

Figure 3 displays the most relevant authors based on the number of documents they have. The horizontal axis (X) represents the number of documents, while the vertical axis (Y) represents the authors. This graph highlights Macreadie Pi as the author with the highest number of documents, specifically 11, indicating a significant contribution to the field or topic being discussed.

Authors Li J and Liu J have seven documents each, making them relevant after Macreadie Pi based on the number of documents. Meanwhile, authors Barnes Dka, Serrano O, Wang C, and Zhang Y each have six documents, indicating that they also make significant contributions, although they are slightly below Li J and Liu J. Moreover, authors Kusumaningtyas Ma and Zhang Z have each published five documents, demonstrating their activity and relevance in their respective fields. However, Author Chen B has the lowest number of papers listed in this graph, with four documents. While this is still relevant in certain contexts, it is lower than the other authors mentioned.

From this graph, it can be inferred that authors with more documents may have a greater

influence or make more contributions in the field under study. In particular, Macreadie Pi is the most dominant author in this data, followed by Li J and Liu J. Some authors have almost equal contributions (six documents), indicating high competition or collaboration in the field. This graph helps identify key authors and their contributions based on the number of documents they produce. It can also be useful for further research, collaboration, or understanding trends in a particular field.

**Top Ten Authors' Production Over Time in the Blue Carbon Ecosystem of Small Islands**

Figure 4 illustrates the authors' productivity in publishing articles from 2014 to 2024. Each circle in this figure indicates the number of articles published by an author in a given year, with circle sizes varying from small (1 article), medium (2 articles), to large (3 or more articles). The colour of the circles also indicates the number of citations received by those articles, with darker circles indicating higher citations (more than 20 citations per year) and lighter circles indicating lower citations (around ten citations per year or less).

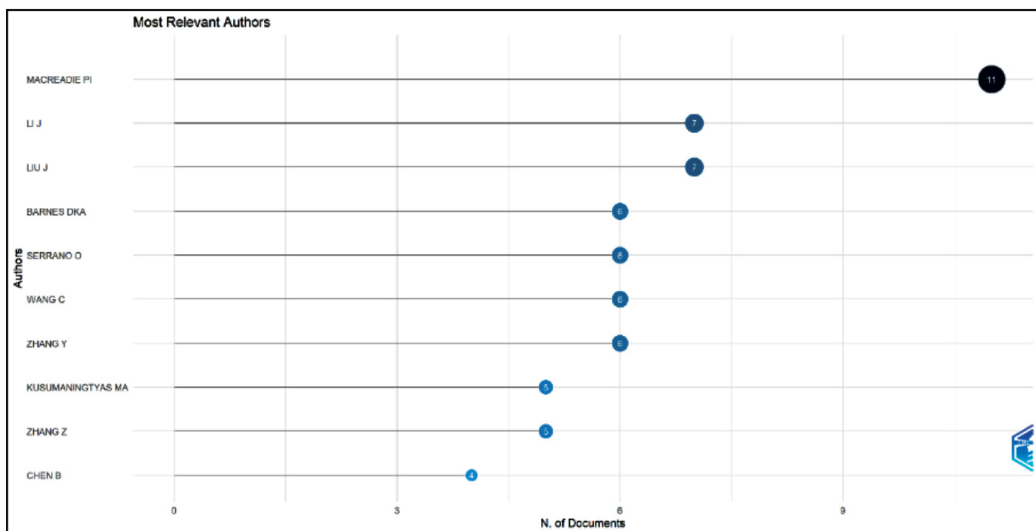


Figure 3: Most relevant author

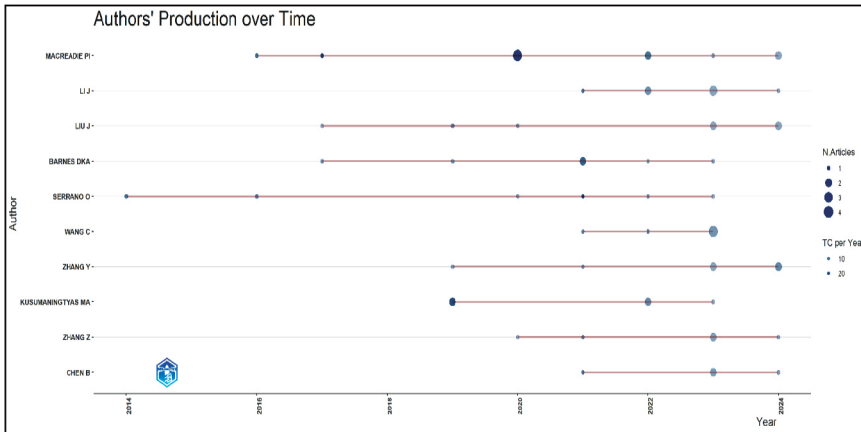


Figure 4: Top author production over time

Some consistent authors, such as Macreadie Pi, demonstrate continuous publication activity from 2014 to 2024, with fluctuations in the number of citations. Authors such as Zhang Y and Zhang Z stand out with larger and darker circles, indicating many frequently cited articles. Conversely, new authors such as Kusumaningtyas Ma, began actively publishing articles around 2021 and appear to exhibit a significant increase in research activity with fairly high citations. Figure 4 also provides information on trends in author productivity and research impact over time. Authors who are consistent in their publications and have frequently cited articles such as Macreadie Pi, demonstrate long-term contributions to their field of research. On the other hand, newly active authors such as Kusumaningtyas Ma, indicate potential growth and research relevance in current topics. Overall, this figure also helps identify influential authors and emerging research trends in the period shown.

While individual productivity is informative, a key focus of this study is to understand the collaborative networks that drive blue carbon research. Thus, by examining co-authorship patterns and influential research clusters, we aim to reveal how interdisciplinary and international collaborations contribute to advancements in blue carbon science. This is particularly true for those that intersect with the ecosystems of

Indonesian small islands. Collectively, these networks play a critical role in shaping research priorities, disseminating methodologies, and fostering partnerships necessary for advancing both scientific knowledge and practical conservation efforts.

**Top Five Most Cited Countries**

Table 1 presents data on scientific production related to the theme of blue carbon in small island ecosystems from various countries. This data reflects the frequency or number of scientific publications from each country. This table also highlights each country’s contribution to blue carbon research, a crucial topic in small island ecosystems. Accordingly, the table indicates that China has the highest scientific production with 392 publications, followed by the United Kingdom (UK) with 288 publications, and the United States (US) with 278 publications. Moreover, this table indicates that these

Table 1: Country scientific production

Region	Cited
China	392
UK	288
USA	278
Australia	168
Germany	128

countries devote considerable attention and allocate sufficient resources to research and publish scientific works related to this theme.

With 646 citations, China secured fourth place, demonstrating the country's significant contribution to research on blue carbon in small island ecosystems. Specifically, the author with the highest number of citations is Guo *et al.* (2013). The research paper focuses on the organic and inorganic carbon isotope composition of the Mesoproterozoic Jixian Group in North China, particularly during the Calymnian period (1600 Ma -1400 Ma). Notably, the study presents high-resolution isotope profiles of carbonate and organic carbon from three sections in the Yanshan Basin, revealing muted isotope variations in marine carbonate rocks that increase through succession, suggesting a long-term decrease in  $p\text{CO}_2$ . The isotopic composition of marine organic matter revealed differences in carbon cycling between lithological units, with variations in carbon fixation and decomposition attributed to depositional environments. This reflects distinct carbon cycling patterns in benthic microbial mats under low-oxygen conditions. Additionally, the findings indicated a predominance of autotrophic carbon fixation and aerobic decomposition in shallow water environments, contrasting with enhanced remineralisation by anaerobic heterotrophs in deeper water environments within the Jixian Group.

The UK has 526 citations, placing it in fifth place, indicating the significance of research from the UK on this topic. The author with the highest number of citations is Tokoro *et al.* (2014). The research paper focuses on blue carbon and its role in mitigating climate change by capturing carbon through marine living organisms. Furthermore, studies conducted in Japanese seagrass meadows from 2010 to 2013 revealed that coastal vegetation systems can act as direct sinks of atmospheric  $\text{CO}_2$ . This is contrary to the common belief that they are sources of  $\text{CO}_2$ . Additionally, different methods were employed to measure air-sea  $\text{CO}_2$  fluxes, including the bulk formula, the floating chamber

method, and the eddy covariance method, each with its own advantages and limitations.

Moreover, the findings suggested that net ecosystem production is important in determining whether coastal ecosystems lower atmospheric  $\text{CO}_2$  concentrations, highlighting the novel ecosystem function of coastal vegetation systems. Note that limitations of the study include differences in spatial scale and measurement position between the methods used, emphasising the need for further quantitative analysis to understand differences in flux values. However, this paper does not extensively discuss the potential effects of diagenesis on preserving the marine carbon isotope record, which could be a limitation in fully understanding the isotopic variations observed in the study.

Furthermore, the US has the highest number of citations, with 2,354, suggesting that research on blue carbon in small island ecosystems conducted by US researchers or covering the US region is highly referenced by other researchers. The highest cited journal is Spivak *et al.* (2019). The research paper was published in the prestigious scientific journal *Nature Geoscience*, known for its high-impact research in Earth science. In particular, the study focused on blue carbon ecosystems, which are crucial in the global carbon cycle and play a significant role in carbon sequestration and storage. Findings from the study highlighted the importance of understanding soil microbiome interactions with organic matter sources, reactivity, and diagenetic state to improve Soil Organic Carbon (SOC) and ecosystem change models. In line with this, the paper emphasised the need for advances in computational and methodological approaches to integrate better knowledge of the soil microbiome with organic matter characteristics, soil properties, and ecological interactions for more accurate modelling. However, one limitation discussed is the current knowledge gaps that hinder the development of realistic SOC and ecosystem change models. These gaps require the adoption of standardised field and laboratory methodologies, the collection

of time-series data, and the development of open-access databases to improve the predictive understanding of preservation mechanisms in blue carbon ecosystems.

In Australia, the author with the highest number of citations is Dyksma *et al.* (2016). The research paper, which focuses on microbial ecology and aims to understand the role of microorganisms in various environments, was published in the ISME Journal. The study investigated dark carbon fixation in coastal sediments, revealing that uncultivated Gammaproteobacteria, especially sulphur-oxidising bacteria, dominate this process, accounting for 70% to 86% of dark carbon fixation in coastal sediments. Through a combination of 16S Ribosomal Ribonucleic Acid (rRNA), single-cell genomics, metagenomics, and transcriptomics analyses, the researchers identified three distinct gammaproteobacterial clades responsible for most dark carbon fixation in tidal sediments.

Additionally, the findings suggested that chemoautotrophic Gammaproteobacteria play a crucial role in fixing carbon in coastal sediments, potentially sequestering carbon in a manner similar to that of marine vegetation habitats worldwide. Nonetheless, this study acknowledges limitations such as uncertainties regarding the burial of dark-fixed carbon in subsurface sediments and the need to understand whether buried populations actively cycle carbon or survive in subsurface sediments. Following this, this research underscored the need for further investigation to elucidate the long-term fate of carbon fixed by Gammaproteobacteria in marine sediments and its role in mitigating carbon and sulphide emissions in the marine environment.

Germany came in third with 829 citations, indicating that research from or about Germany also significantly influences this field, with Pedersen *et al.* (2020) being the highest cited journal. The research paper focused on detrital carbon production and export in high-latitude kelp forests, specifically *Laminaria hyperborea* sites in northern Norway. In particular, the

study measured kelp biomass, net production, detritus formation, and release processes at ten different sites with varying wave exposure in northern Norway. Findings revealed that seaweed detritus production was substantial, with detritus primarily consisting of whole plants or blades. Moreover, a large detritus pulse was delivered in spring, potentially supporting secondary production or contributing to blue carbon through burial in marine sediments. The study also compared detrital carbon donation by *L. hyperborea* with other terrestrial and coastal habitats, highlighting the significance of understanding detritus production for resource subsidies and carbon sequestration. Limitations of the study include a focus on a specific seaweed species in a specific geographic region, which may limit the generalizability of findings to other seaweed species or locations. Additionally, this study did not thoroughly investigate the long-term fate of exported detritus, warranting further research into the ultimate destination and impacts of detrital carbon.

### **Research Topic and Trend Analysis**

Figure 5 displays the trend of “blue carbon” topics in small island ecosystems from 2006 to 2024. The x-axis represents the year, while the y-axis represents the different topics in the literature or scientific discussions during the period. In addition, the size and number of dots along the topic line reflect the frequency with which the topic appears in the literature, with larger sizes indicating higher frequency.

Some of the main topics that appear frequently include “carbon storage”, “climate change”, “carbon sequestration”, “ecosystem”, “biomass”, and “carbon cycle”. These topics are represented by long lines and large dots, indicating that they have been the main focus of research and discussion in the period under review.

From Figure 5, it is evident that attention to these topics increased significantly after 2010. For example, the terms “carbon storage” and “climate change” began to be discussed more frequently in 2010 and continued to increase

until 2024. Similar trends can be observed for topics such as “blue carbon”, “ecosystem”, and “carbon sequestration”.

In addition, some specific topics such as “mangroves”, “wetlands”, and “marine environment” have also displayed an increase in frequency in recent years, signalling that these ecosystems are becoming increasingly important in the context of blue carbon research. This term signifies an increased awareness of the importance of these ecosystems in mitigating climate change and storing carbon.

Figure 5 indicates that research and discussion on blue carbon and related ecosystems have grown rapidly in recent years. This figure reflects increasing awareness and attention to the critical role of natural ecosystems in storing carbon and mitigating climate change, as well as

the importance of understanding and protecting these ecosystems in the context of global environmental change.

**Thematic Evolution**

Figure 6 presents a thematic evaluation of research on blue carbon in small island ecosystems from 1986 to 2024. The graph is divided into three time periods: 1986 to 2018, 2019 to 2022, and 2023 to 2024, with each period representing the main themes associated with blue carbon research. From 1986 to 2018, research largely focused on carbon, carbon storage, and the marine environment. The carbon theme dominated early research on small island ecosystems and the role of carbon in them. In contrast, carbon storage has become a significantly important topic, highlighting

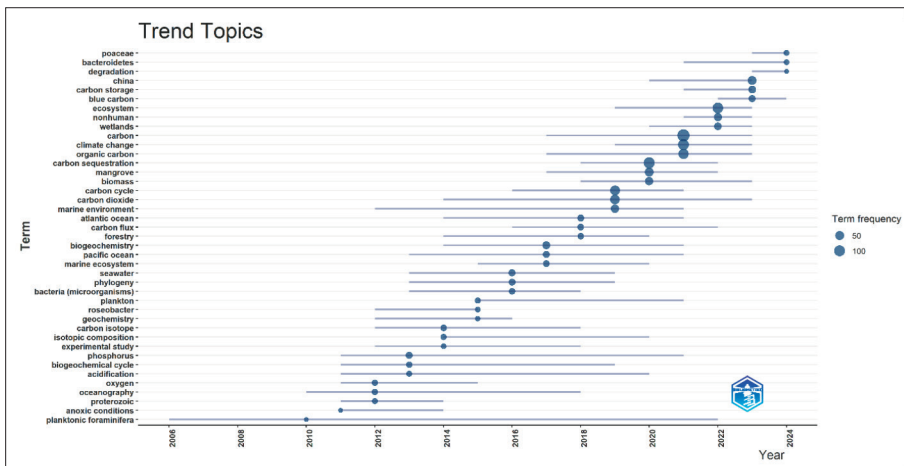


Figure 5: Topic trends

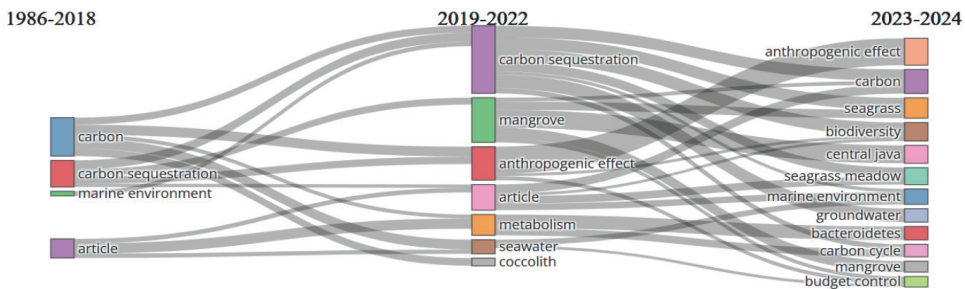


Figure 6: Thematic evolution

the ability of these ecosystems to store carbon. On the other hand, the marine environment, in general, was also a major concern, with numerous articles and publications addressing this topic. Subsequently, from 2019 to 2022, research began to shift toward new themes, including carbon storage, which remains a key topic. For instance, a new focus on the role of mangroves in blue carbon ecosystems emerged, along with the recognition of the impact of human activities on these ecosystems, known as anthropogenic effects.

The metabolism theme examines biochemical processes in these ecosystems, while seawater and coccoliths are important emerging sub-themes. From 2023 to 2024, research broadened its focus to more specific themes. Anthropogenic effects remain a key theme, implying increasing attention to human impacts. In addition, basic research on carbon and the role of seagrasses continued while biodiversity became a new focus in these ecosystems. Region-specific research such as Central Java, also emerged. Moreover, themes such as seagrass meadows, marine environment, groundwater, Bacteroidetes, carbon cycling, mangroves, and budget control denote the diversification of research into other aspects of blue carbon ecosystems.

Figure 6 illustrates the evolution and shifting focus of research on blue carbon in small island ecosystems over time. Initially, research focused on the fundamentals of carbon and its storage. Over time, it began to emphasise human impacts, biodiversity, and interactions with other ecosystem components. This increasing diversification of themes indicates a deeper and more comprehensive understanding of the role of small island ecosystems in carbon storage and the impacts of various external factors. In line with this, these developments are crucial for effective conservation and environmental management policies, as they offer greater insight into how various components of ecosystems interact and how human activities impact them.

### **Most Frequent Words**

As such, it provides an overview of the most frequently discussed topics in the relevant literature, which can help researchers understand the main focus and direction of research in blue carbon in small island ecosystems.

Figure 7 is a tree map illustrating the frequency of words appearing in journals with the theme of blue carbon in small island ecosystems. The most frequent word is “carbon,” with a frequency of 141 times, which represents 9% of the total words analysed. This number suggests that carbon is a central theme in these journals. Meanwhile, “climate change” appeared 97 times (6%), indicating that climate change is highly relevant in the context of blue carbon and small island ecosystems. Following this, the word “carbon sequestration” appears 103 times (6%), indicating the significance of carbon sequestration in this ecosystem. Subsequently, the word “ecosystem” appeared 92 times (6%), indicating that ecosystem studies are important in blue carbon studies. At the same time, “Wetlands” appeared 26 times (2%), illustrating the importance of wetlands in the context of small island ecosystems. Additionally, “carbon cycle” appears 68 times (4%), indicating that carbon cycling is a key process studied in these ecosystems. Moreover, the word “nitrogen” appears 34 times (2%), indicating that nitrogen is an important element being studied in addition to carbon.

Regarding geography, the term “China” appears 43 times (3%), indicating that a significant portion of the research is conducted in or relevant to China. Coastal zones are also a focus, with 20 occurrences (1%). The word “biomass” appeared 38 times (2%), highlighting the significance of biomass in blue carbon ecosystems, while “organic carbon” appeared 78 times (5%), emphasising the importance of organic carbon in this study. Specific themes, such as “mangrove” appearing 49 times (3%) and “seagrass” appearing 37 times (2%), indicate that these two ecosystems are also a focus of the study. From this analysis,



it can be concluded that the study of blue carbon in small island ecosystems is highly multidimensional, involving aspects ranging from carbon cycling and climate change to biogeochemistry and specific ecosystems such as mangroves and seagrass beds. The research is also highly geographically focused, with many studies conducted in coastal regions and specific countries such as China. As a result, this information is invaluable for understanding how small island ecosystems contribute to carbon sequestration and how they are affected by environmental change.

**Collaboration Network Between Authors**

Figure 8 presents the collaboration network between authors involved in research on blue carbon in small island ecosystems. Each point or node in the figure represents an author, with the node’s size indicating the number of publications or level of collaboration by that author. In particular, larger nodes indicate authors with more collaborations or publications. The lines connecting the nodes represent collaborative relationships between authors.

An author has more collaborations with more lines connected to a node. The figure also displays several clusters or groups of authors who collaborate closely with each other. These clusters represent groups of researchers who frequently collaborate on blue carbon research

in small island ecosystems. Authors with large nodes such as “Macreadie Pi”, “Liu J”, and “Serrano O”, appear to be lead authors or researchers with extensive collaborations in this field. They may serve as research leaders or coordinators in collaborative projects. In addition, some sub-clusters illustrate more specialised collaboration within the larger group. For example, “Liu J” and “Macreadie Pi” have a close relationship, suggesting they often collaborate. Some authors serve as bridges between different groups such as “Serrano O”, who is connected to several clusters. They may play a role in connecting different research groups and facilitating collaboration across disciplines or institutions. Note that the colour of the nodes and lines likely indicates institutional or geographic affiliation, although this needs to be confirmed with additional information. In essence, different colours indicate different groups within the collaboration network. Overall, this figure illustrates a complex and broad network of collaborations among authors focused on blue carbon research in small island ecosystems. Furthermore, lead authors who have multiple collaborations are likely to have played an important role in driving this research forward. Nonetheless, further analysis could involve identifying the authors’ home institutions or countries to understand how these collaborations are geographically and institutionally distributed.

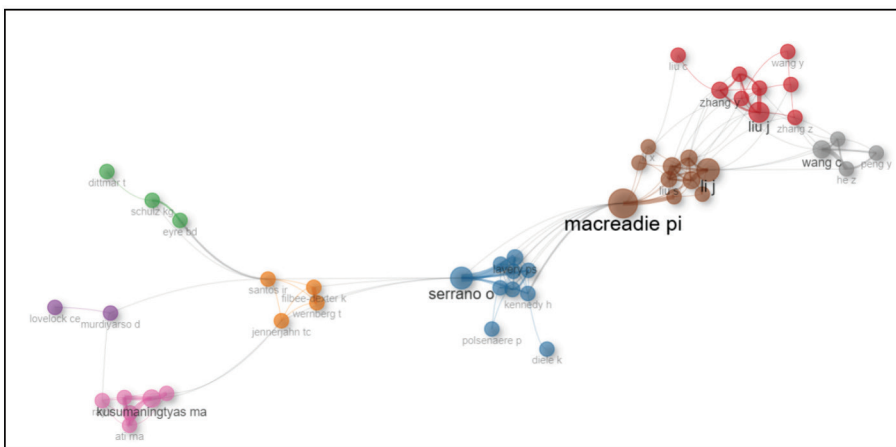


Figure 8: Collaboration network between authors

### **Case Study: Blue Carbon Research on Small Islands in Indonesia**

The collective contributions of various papers on blue carbon ecosystems in Indonesia's small island ecosystems underscore the critical role that these habitats play in carbon sequestration and climate change mitigation. For instance, Vanderklift *et al.* (2022) emissions and advocate for their inclusion in national greenhouse gas inventories to enhance protection and restoration efforts. Meanwhile, Fauzi *et al.* (2021) highlighted Indonesia's significant contribution to global blue carbon reserves, noting that the country accounts for approximately 17% of the world's total blue carbon. Together, they stressed the need for improved monitoring and socio-economic integration in conservation strategies to mitigate pressures from climate change, urbanisation, and fishing activities.

Research by Hafizt *et al.* (2024) further supported the notion that these ecosystems face considerable threats and require enhanced data collection and monitoring methodologies. This aligns with the findings of Malik and Sideng (2022), who assessed mangrove biomass carbon stocks and highlighted the need to prevent further habitat conversion to maintain carbon sequestration functions. Similarly, Kusumaningtyas *et al.* (2022) and Cameron *et al.* (2019) advocated for improved rehabilitation practices and emphasised the significance of appropriate ecological assessments to maximise carbon storage potential.

Studies by Jaya *et al.* (2017) and Nurdin *et al.* (2022) provided insights into advanced remote sensing techniques for estimating carbon stocks in mangroves and seagrasses, promoting the adoption of these methods for better accuracy in carbon accounting. Additionally, the research by Rifai *et al.* (2023) focused on community awareness regarding seagrass ecosystems, suggesting that education and local engagement are vital for effective conservation efforts.

Finally, papers Rahayu *et al.* (2023) and Pradisty *et al.* (2022) emphasised the need for integrated coastal management strategies and

continuous monitoring of blue carbon stocks. They recommended enhancing community involvement and promoting sustainable practices to safeguard these ecosystems.

Overall, the body of research presents a comprehensive roadmap for improving blue carbon conservation in Indonesia's small island ecosystems, emphasising collaborative efforts between scientists, policymakers, and local communities to ensure the long-term sustainability of these vital carbon sinks.

### **Future Research Prospects in Indonesia**

Future research recommendations regarding blue carbon ecosystems in Indonesia's small island ecosystems, according to the references:

- **Incorporation into National Inventories:** Vanderklift *et al.* (2022) suggested that coastal ecosystems such as mangroves and seagrasses should be incorporated into national greenhouse gas inventories to generate incentives for their protection and restoration. This inclusion could enhance financial support through carbon markets and promote comprehensive data collection on carbon storage capabilities.
- **Improved Monitoring and Spatial Analysis:** Fauzi *et al.* (2021) emphasised the need for improved monitoring of blue carbon ecosystems, advocating the use of remote sensing technologies and spatial analysis to assess ecosystem services and threats. They recommended integrating socio-economic factors into research to involve stakeholders in conservation efforts.
- **Enhanced Data Collection Methodologies:** Hafizt *et al.* (2024) called for enhanced monitoring and data collection methodologies to address gaps caused by environmental factors such as cloud cover. They advocated for a multidisciplinary approach that includes various stakeholders and suggested developing ideal fishing zones that coexist with conservation areas.

- **Preventing Habitat Conversion:** Malik and Sideng (2022) highlighted the importance of preventing the conversion of mangrove areas to aquaculture and settlements, recommending policies that align land-use management with low-carbon development agendas. Still, ongoing research is necessary to monitor carbon stocks and assess the impacts of climate change.
  - **Improved Rehabilitation Practices:** Kusumaningtyas *et al.* (2022) determined the necessity for improved mangrove rehabilitation practices, suggesting that future efforts should consider appropriate species selection and site conditions. Continuous monitoring and evaluation of these projects are crucial for ensuring effective carbon storage.
  - **Refinement of Carbon Stock Estimations:** Jaya *et al.* (2017) recommended enhancing the accuracy of carbon stock estimations by integrating advanced remote sensing methods and advocating for ongoing monitoring to better understand the dynamics of mangrove carbon stocks.
  - **Community Awareness and Involvement:** Rifai *et al.* (2023) stressed the urgent need to enhance community awareness of seagrass ecosystem services, suggesting public campaigns and local engagement in management efforts. They also highlighted the potential for Payment for Ecosystem Services (PES) schemes to incentivise conservation.
  - **Conservation and Sustainable Practices:** Nurdin *et al.* (2022) recommended enhanced conservation strategies for seagrass ecosystems and emphasised the importance of integrating remote sensing for ongoing monitoring. Increasing community engagement and awareness is vital for sustainable management.
  - **Integrated Coastal Management:** Rahayu *et al.* (2023) advocated for comprehensive coastal management strategies that address the factors influencing organic carbon storage in seagrass meadows and suggested establishing effective Marine Protected Areas (MPAs).
  - **Holistic Conservation Approaches:** Pradisty *et al.* (2022) recommended adopting diverse planting strategies in restored mangrove areas and emphasised community involvement to enhance the ecological benefits of restoration efforts.
  - **Predictive Modelling Integration:** Bukoski *et al.* (2020) suggested integrating predictive modelling with field data to improve the accuracy of carbon stock estimates and involve local communities in blue carbon programs for sustainable management.
  - **Continued Research on Carbon Dynamics:** Friess *et al.* (2015) highlighted the need for ongoing research into the factors influencing carbon dynamics in oceanic mangrove ecosystems, emphasising the integration of soil carbon assessments with above-ground measurements.
  - **Long-Term Monitoring Programs:** Sillanpää *et al.* (2024) recommended establishing long-term monitoring systems and conducting Environmental Impact Assessments (EIAs) to better understand local pressures.
  - **Further Studies on Mangrove Ecosystems:** Lukman *et al.* (2022) called for integrated management approaches that incorporate both conservation and non-conservation areas to enhance the functionality of mangroves as carbon sinks.
- These recommendations collectively emphasise the importance of community engagement, improved monitoring, integrated management strategies, and continued research to effectively protect and enhance blue carbon ecosystems in Indonesia's small islands.

## Conclusions

This bibliometric analysis elucidates the significant contributions and evolving trends in blue carbon research, particularly within the context of Indonesia's small island ecosystems. The findings highlight the crucial role that these coastal ecosystems, particularly mangroves and seagrass beds, play in carbon sequestration and climate change mitigation. With Indonesia accounting for approximately 17% of the global blue carbon reserves, the research underscores the urgent need to incorporate coastal ecosystems into national greenhouse gas inventories.

The study identifies a marked increase in publication output since 2005, with a notable peak in 2023, reflecting a growing recognition of the importance of localised research in small island ecosystems. Furthermore, this trend suggests that blue carbon research is becoming increasingly relevant, addressing unique environmental pressures and socio-economic challenges faced by these regions. The analysis further reveals key contributors and collaborative networks that have advanced blue carbon science, indicating the potential for interdisciplinary and international partnerships to enhance conservation efforts.

Moreover, the thematic evolution of blue carbon research has expanded from basic carbon storage concepts to encompass complex interactions involving anthropogenic effects, biodiversity, and regional specificity, as evidenced in recent publications. Accordingly, this diversification illustrates the necessity for holistic conservation approaches that integrate ecological understanding with community engagement and policy development.

Future research prospects emphasise the importance of enhanced monitoring methodologies, improved rehabilitation practices, and community awareness initiatives. The collective insights derived from this analysis provide a robust foundation for informing conservation policies and strategies tailored to optimise the blue carbon potential of Indonesia's small islands. Ultimately, by

fostering collaborative efforts among scientists, policymakers, and local communities, there is a greater opportunity to effectively mitigate the impacts of climate change and preserve these vital ecosystems for future generations.

## Acknowledgements

We extend our deepest gratitude to LPDP for their financial support. The funding provided by the Agency has been instrumental in facilitating the essential research presented in this manuscript, contributing significantly to advancements in our field. This support has assisted in the execution of this project and has also enhanced our academic and professional capabilities. On behalf of the research team, we extend our sincere gratitude for the trust and investment placed in us.

## Conflict of Interest Statement

The authors declare that they have no conflict of interest.

## References

- Ajinegara, M. W., & Soebagyo, J. (2022). Analisis bibliometrik tren penelitian media pembelajaran Google Classroom menggunakan aplikasi VOSViewer. *JNPM (Jurnal Nasional Pendidikan Matematika)*, 6(1), 193. <https://doi.org/10.33603/jnpm.v6i1.5451>
- Alongi, D. M., Murdiyarto, D., Fourqurean, J. W., Kauffman, J. B., Hutahaean, A., Crooks, S., Lovelock, C. E., Howard, J., Herr, D., Fortes, M., Pidgeon, E., & Wagey, T. (2016). Indonesia's Blue Carbon: A globally significant and vulnerable sink for seagrass and mangrove carbon. *Wetlands Ecology and Management*, 24(1), 3-13. <https://doi.org/10.1007/s11273-015-9446-y>
- Ariyana, A. H. M., Subejo, Suadi, Ihsannudin, & Hidayati, D. R. (2019). Fishermen's behavior of multi ethnic community in

- adapting climate change in small island. *International Journal of Agricultural Sciences*, 1(2), 2017, 48-55. <https://doi.org/10.25077/ijasc.1.2.1-7.2017>
- Bukoski, J. J., Elwin, A., Mackenzie, R. A., Sharma, S., Purbopuspito, J., Kopania, B., Apwong, M., Poolsiri, R., & Potts, M. D. (2020). The role of predictive model data in designing mangrove forest carbon programs. *Environmental Research Letters*, 15(8). <https://doi.org/10.1088/1748-9326/ab7e4e>
- Cameron, C., Hutley, L. B., Friess, D. A., & Brown, B. (2019). Community structure dynamics and carbon stock change of rehabilitated mangrove forests in Sulawesi, Indonesia. *Ecological Applications*, 29(1). <https://doi.org/10.1002/eap.1810>
- Dunic, J. C., Brown, C. J., Connolly, R. M., Turschwell, M. P., & Côté, I. M. (2021). Long-term declines and recovery of meadow area across the world's seagrass bioregions. *Global Change Biology*, 27(17), 4096-4109. <https://doi.org/https://doi.org/10.1111/gcb.15684>
- Duque, P., & Cervantes, L. S. C. (2019). Responsabilidad Social Universitaria: Una revisión sistemática Y análisis bibliométrico. *Estudios Gerenciales*, 451-464. <https://doi.org/10.18046/j.estger.2019.153.3389>
- Fahrezi, I., Taufiq, M., Akhwani, A., & Nafia'ah, N. (2020). Meta-analisis pengaruh model pembelajaran Project Based Learning terhadap hasil belajar siswa pada mata pelajaran IPA Sekolah Dasar. *Jurnal Ilmiah Pendidikan Profesi Guru*, 3(3), 408. <https://doi.org/10.23887/jippg.v3i3.28081>
- Fauzi, A. I., Sakti, A. D., Robbani, B. F., Ristiyani, M., Agustin, R. T., Yati, E., Nuha, M. U., Anika, N., Putra, R., Siregar, D. I., Prasetyo, B. A., Julzarika, A., & Wikantika, K. (2021). Assessing potential climatic and human pressures in Indonesian coastal ecosystems using a spatial data-driven approach. *ISPRS International Journal of Geo-Information*, 10(11). <https://doi.org/10.3390/ijgi10110778>
- Friess, D. A., Phelps, J., Garmendia, E., & Gómez-Baggethun, E. (2015). Payments for Ecosystem Services (PES) in the face of external biophysical stressors. *Global Environmental Change*, 30, 31-42. <https://doi.org/10.1016/j.gloenvcha.2014.10.013>
- Guo, H., Du, Y., Kah, L. C., Huang, J., Hu, C., Huang, H., & Yu, W. (2013). Isotopic composition of organic and inorganic carbon from the Mesoproterozoic Jixian Group, North China: Implications for biological and oceanic evolution. *Precambrian Research*, 224, 169-183. <https://doi.org/10.1016/j.precamres.2012.09.023>
- Hafizt, M., Yuwono, D. M., Janwar, Z., & Wouthuyzen, S. (2024). Benthic habitat mapping for estimating seagrass carbon stock across Takabonerate Islands, Indonesia. *Regional Studies in Marine Science*, 77. <https://doi.org/10.1016/j.rsma.2024.103703>
- Hertyastuti, P. R., Putra, R. D., Apriadi, T., Suhana, M. P., Idris, F., & Nugraha, A. H. (2020). Estimasi kandungan stok karbon pada ekosistem padang lamun di perairan Dompok dan Berakit, Kepulauan Riau. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, 12(3), 849-862. <https://doi.org/10.29244/jitkt.v12i3.32199>
- Hidayatulloh, T. (2024). Digitalisasi supply chain management dan kinerja perusahaan: Analisis bibliometrik. *Jurnal Ilmiah Manajemen Ekonomi & Akuntansi (MEA)*, 8(2), 170-186. <https://doi.org/10.31955/mea.v8i2.4019>
- Husna, R., & Sayekti, R. (2023). Analisis bibliometrik tren penelitian literasi informasi pada Jurnal Ilmu Perpustakaan Terakreditasi Science Technology Index (SINTA). *Tibannbaru Jurnal Ilmu Perpustakaan Dan Informasi*, 7(1), 83. <https://doi.org/10.30742/tb.v7i1.2837>

- Imran, Z., Easteria, G., & Yulianto, G. (2022). Estimasi stok karbon mangrove rehabilitasi di Pulau Harapan dan Kelapa, Taman Nasional Kepulauan Seribu, Jakarta. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, 14(2), 191-204. <https://doi.org/10.29244/jitkt.v14i2.39861>
- Jaya, L. O. M. G., Wikantika, K., Sambodo, K. A., & Susandi, A. (2017). Comparison of PolSAR and PolinSAR method to estimate mangrove carbon stocks in Southeast Sulawesi Indonesia, using ALOS PALSAR dual-polarisations in the perspective of climate change mitigation. *International Journal of Tomography and Simulation*, 30(3), 21-34.
- Kusumaningtyas, M. A., Kepel, T. L., Solihuddin, T., Lubis, A. A., Putra, A. D. P., Sugiharto, U., Ati, R. N. A., Salim, H. L., Mustikasari, E., Heriati, A., Daulat, A., Sudirman, N., Suryono, D. D., & Rustam, A. (2022). Carbon sequestration potential in the rehabilitated mangroves in Indonesia. *Ecological Research*, 37(1), 80-91. <https://doi.org/10.1111/1440-1703.12279>
- Libri, M., Tregua, M., Viruel, M. J. M., & Gálvez, J. C. P. (2023). Hacia una revisión sistemática del concepto de turismo patrimonial. *Revista Venezolana De Gerencia*, 28(101), 369-383. <https://doi.org/10.52080/rvgluz.28.101.23>
- Lukman, A. H., Hidayat, M. F., Sugara, A., & Arief, M. C. W. (2022). Mangroves composition, biomass, carbon stock and their role in the climate change mitigation in Bengkulu City, Indonesia. *AAFL Bioflux*, 15(4), 1975-1988.
- Macreadie, P. I., Anton, A., & Raven, J. A., et al. (2019). The future of Blue Carbon science. *Nature Communications*, 10(1), 3998. <https://doi.org/10.1038/s41467-019-11693-w>
- Madjido, M. (2021). Pemetaan topik publikasi Sistem Informasi Kesehatan (SIK) di Indonesia: Analisis Bibliometrik. *Journal of Information Systems for Public Health*, 6(1), 29. <https://doi.org/10.22146/jisph.44122>
- Maemunah, L., Rachmad, B., Zulkifli, D., Dewi, I. J. P., Mulyoto, M., F, M. N. R., & Rahman, A. (2022). Cadangan Blue Carbon pada ekosistem lamun di Pulau Bintan Propinsi Kepulauan Riau. *Prosiding Seminar Nasional Perikanan Indonesia*, 239. <https://doi.org/10.15578/psnp.11945>
- Malik, A., & Sideng, U. (2022). Biomass carbon stock assessment of mangrove ecosystem in Pannikiang Island South Sulawesi Indonesia. *Indonesian Journal of Geography*, 54(1), 11-19. <https://doi.org/10.22146/ijg.46989>
- Moyano Londoño, G. A., & Marín Cardona, P. F. (2024). La perdurabilidad empresarial de los emprendimientos sociales: Revisión sistemática Y perspectivas de investigación. *Tendencias*, 25(1), 269-295. <https://doi.org/10.22267/rtend.242501.249>
- Muliawati, A. H., & Choesin, D. N. (2024). Seagrass community structure and ecosystem carbon stocks along the shoreline of Semujur Island, Bangka Belitung Province, Indonesia. *Environment and Natural Resources Journal*, 22(3 SE-Original Research Articles), 210-221. <https://ph02.tci-thaijo.org/index.php/ennrj/article/view/251734>
- Nurdin, N., Amri, K., Mashoreng, S., & Komatsu, T. (2022). Estimation of seagrass biomass by in situ measurement and remote sensing technology on small islands, Indonesia. *Ocean Science Journal*, 57(1), 118-129. <https://doi.org/10.1007/s12601-022-00054-2>
- Pedersen, M. F., Filbee-Dexter, K., Norderhaug, K. M., Fredriksen, S., Frisk, N. L., Fagerli, C. W., & Wernberg, T. (2020). Detrital carbon production and export in high latitude kelp forests. *Oecologia*, 192(1), 227-239. <https://doi.org/10.1007/s00442-019-04573-z>

- Perdana, Y., Suryana, S., Mulyadi, H., Miftahuddin, A., & Sandjaya, T. (2023). Studi jaringan dan kolaborasi ilmiah dalam entrepreneurship menggunakan analisis bibliometrik dan VOSviewer. *Responsive*, 5(4), 247. <https://doi.org/10.24198/responsive.v5i4.44557>
- Pradisty, N. A., Sidik, F., Bimantara, Y., Susetya, I. E., & Basyuni, M. (2022). Litterfall and associated macrozoobenthic of restored mangrove forests in abandoned aquaculture ponds. *Sustainability (Switzerland)*, 14(13). <https://doi.org/10.3390/su14138082>
- Pratiwi, V. E., & Soebagyo, J. (2022). Analisis bibliometrik terhadap kemampuan penalaran matematis. *Jurnal Riset Pembelajaran Matematika Sekolah*, 6(2), 11-18. <https://doi.org/10.21009/jrjpm.062.02>
- Rahayu, Y. P., Kusumaningtyas, M. A., Daulat, A., Rustam, A., Suryono, D. D., Salim, H. L., Ati, R. N. A., Sudirman, N., Kepel, T. L., Hutahaean, A. A., & Adi, N. S. (2023). Sedimentary seagrass carbon stock and sources of organic carbon across contrasting seagrass meadows in Indonesia. *Environmental Science and Pollution Research*, 30(43), 97754-97764. <https://doi.org/10.1007/s11356-023-29257-3>
- Rahmadi, M. M., Liviawaty, E., Faizal, I., Purba, N. P., Ramadhan, R. A., Amrullah, R., & Dianti, I. E. (2022). The vulnerability of small islands from coastlines change in Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1095(1), 12026. <https://doi.org/10.1088/1755-1315/1095/1/012026>
- Rhamadany, A., Suryono, C. A., & Pringgenies, D. (2021). Biomasa dan simpanan karbon pada ekosistem lamun di perairan Batulawang dan Pulau Sintok Taman Nasional Karimunjawa, Jepara. *Journal of Marine Research*, 10(3), 413-420. <https://doi.org/10.14710/jmr.v10i3.31692>
- Rifai, H., Quevedo, J. M. D., Lukman, K. M., Hernawan, U. E., Alifatri, L.-O., Risandi, J., Uchiyama, Y., & Kohsaka, R. (2023). Understanding community awareness of seagrass ecosystem services for their blue carbon conservation in marine protected areas: A case study of Karimunjawa National Park. *Ecological Research*, 38(4), 541-556. <https://doi.org/10.1111/1440-1703.12391>
- Rifandi, R. A. (2021). Pendugaan stok karbon dan serapan karbon pada tegakan mangrove di kawasan ekowisata mangrove Desa Mojo Kabupaten Pemalang. *Jurnal Litbang Provinsi Jawa Tengah*, 19(1), 93-103. <https://doi.org/10.36762/jurnaljateng.v19i1.871>
- Rodríguez-García, J. S. (2022). *Implicaciones de la investigación sobre el emprendimiento social en tiempos de la COVID-19: Un enfoque desde la gestión negocios*. Scientia et PRAXIS, 2(4), 38-58. <https://doi.org/10.55965/setp.2.04.a3>
- Rodríguez, C. E. L., & Sandoval-Escobar, M. (2022). Tendencias de investigación en branding enfocadas al adulto mayor: Análisis bibliométrico Y revisión sistemática de la literatura. *Revista De Métodos Cuantitativos Para La Economía Y La Empresa*, 34, 305-327. <https://doi.org/10.46661/revmetodo.scuanteconempresa.6100>
- Roever, L. (2018). PICO: Model for clinical questions. *Evidence Based Medicine and Practice*, 3(2).
- Rubio, A. E., & Salazar, J. A. V. (2022). Tendencias en la investigación del turismo sostenible en latinoamérica Y el caribe: Un análisis bibliométrico. *Revista Universidad Y Empresa*, 24(42), 1-30.
- Salazar-Ceciliano, E., & Aguilar, R. E. M. (2020). La conservación programada Y su aplicación en la arquitectura: Un análisis bibliométrico. *Revista Tecnología En Marcha*. <https://doi.org/10.18845/tm.v33i8.5511>
- Santosa, T. A., Sepriyani, E. M., Lufri, L., & Zulyusri, Z. (2021). Meta-analysis: Penggunaan modul berbasis HOTS pada

- pelajaran ekologi dan lingkungan di SMA. *Jurnal Eduscience*, 8(1), 53-56. <https://doi.org/10.36987/jes.v8i1.2122>
- Sillanpää, M., Friess, D. A., Heatubun, C. D., Cragg, S. M., Alei, F., Bhargava, R., Kalor, J. D., Marlessy, C., Yudha, R. P., Sidik, F., Murdiyarsa, D., & Lupascu, M. (2024). Mangrove management practices, policies, and impacts in New Guinea. *Biological Conservation*, 296. <https://doi.org/10.1016/j.biocon.2024.110697>
- Spivak, A. C., Sanderman, J., Bowen, J. L., Canuel, E. A., & Hopkinson, C. S. (2019). Global-change controls on soil-carbon accumulation and loss in coastal vegetated ecosystems. *Nature Geoscience*, 12(9), 685-692. <https://doi.org/10.1038/s41561-019-0435-2>
- Suryani, R., Budi Susilo, N., Desta, O. A., Silfiana, A., Wulansari, R., & Sila Puspita, A. (2023). A mapping outcome method using Social Return on Investment (SROI) to assess the impacts of program: A case study in Setunak Island. *Jurnal Presipitasi: Media Komunikasi Dan Pengembangan Teknik Lingkungan*, 20(2), 2023. <https://doi.org/10.14710/Presipitasi.V20i2.378-389>
- Tokoro, T., Hosokawa, S., Miyoshi, E., Tada, K., Watanabe, K., Montani, S., Kayanne, H., & Kuwae, T. (2014). Net uptake of atmospheric CO<sub>2</sub> by coastal submerged aquatic vegetation. *Global Change Biology*, 20(6), 1873-1884. <https://doi.org/10.1111/gcb.12543>
- Trejos-Salazar, D. F., Duque, P., Restrepo, L. A. M., & Montoya-Restrepo, I. A. (2021). Neuroeconomía: Una revisión basada en técnicas de mapeo científico. *Revista De Investigación Desarrollo E Innovación*, 11(2), 243-260. <https://doi.org/10.19053/20278306.v11.n2.2021.12754>
- Vanderklift, M. A., Herr, D., Lovelock, C. E., Murdiyarsa, D., Raw, J. L., & Steven, A. D. L. (2022). A guide to international climate mitigation policy and finance frameworks relevant to the protection and restoration of Blue Carbon ecosystems. *Frontiers in Marine Science*, 9. <https://doi.org/10.3389/fmars.2022.872064>
- Verisandria, R., Schadu, J. N., Sondak, C. F. A., Ompi, M., Rumengan, A. P., & Rangan, J. K. (2018). Estimasi potensi karbon pada sedimen ekosistem mangrove di pesisir Taman Nasional Bunaken Bagian Utara. *Jurnal Pesisir Dan Laut Tropis*, 6(1), 81. <https://doi.org/10.35800/jplt.6.1.2018.20567>
- Widyatami, K., & Sari, M. (2023). Pemetaan lanskap teori sinyal dalam kewirswastaan: Perspektif bibliometrik. *Journal of Economic Bussines and Accounting (Costing)*, 7(1), 2725-2732. <https://doi.org/10.31539/costing.v7i1.8511>
- Wirasatriya, A., Pribadi, R., Iryanthony, S. B., Maslukah, L., Sugianto, D. N., Helmi, M., Ananta, R. R., Adi, N. S., Kepel, T. L., Ati, R. N. A., Kusumaningtyas, M. A., Suwa, R., Ray, R., Nakamura, T., & Nadaoka, K. (2022). Mangrove above-ground biomass and carbon stock in the Karimunjawa-Kemujan Islands estimated from unmanned aerial vehicle-imagery. *Sustainability (Switzerland)*, 14(2). <https://doi.org/10.3390/su14020706>
- Wulan Aulia Azizah, N., & Nur Indah Wahyuni, N. (2024). Tren riset pendekatan STEAM (2018-2022): Analisis bibliometrik. *Scholaria Jurnal Pendidikan Dan Kebudayaan*, 14(01), 68-78. <https://doi.org/10.24246/j.js.2024.v14.i01>
- Zukmadini, A. Y., & Rohman, F. (2023). Edukasi mitigasi dan adaptasi perubahan iklim menggunakan film dokumenter. *Kumawula Jurnal Pengabdian Kepada Masyarakat*, 6(1), 191. <https://doi.org/10.24198/kumawula.v6i1.39503>