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AGRO PRODUCTIVIDAD

Update on the terrestrial orchid flora of the Tacana volcano and close area, Chiapas, Mexico

pág. 171

Año 17 • Volumen 17 • Número 6 • junio, 2024

CO_2 emissions from solid biofuel consumption in rural communities in Durango, Mexico 3

Effects of the combining ability of piquin pepper (*Capsicum annuum* var. *Glabriusculum*) from different geographical sites 13

Availability, accessibility, and intake of vegetables native to Mexico 23

Glyphosate contamination: implications for honeybee *Apis mellifera* and consumers in Southeastern Mexico 33

Infestation of Cattle with the Tick *Amblyomma mixtum* in the States with the Highest Cattle Inventory in Mexico 47

Productive and Ruminal Microbiological Behavior of Sheep Fed with Two Levels of Dehydrated Orange Residue 59

y más artículos de interés...

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Global Trends in Blue Carbon Research in Mangroves

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ABSTRACT

Objective: To identify the central themes and research trends on blue carbon in mangroves through a bibliometric analysis of the existing global scientific literature.

Design/Methodology/Approach: A total of 1,128 scientific documents from the period 1986-2023 were analyzed, obtained from the Scopus database. The Bibliometrix package in R Studio and VOSviewer were used for processing.

Results: The results, encompassing 4,602 authors, 94 countries, 64 research areas, and 346 journals, indicated an exponential growth (R^2=0.99) in mangrove carbon research. The most productive author, country, research area, and journal were Lovelock, L. C., the United States of America, environmental sciences, and Science of The Total Environment, respectively. The studies focused on four thematic clusters: carbon storage, sedimentation, carbon dynamics, and climate change and anthropogenic impact. Topics related to blue carbon, carbon stores, climate change, restoration, and remote sensing are currently of significant interest to the scientific community.

Study Limitations/Implications: While Scopus covers a vast number of peer-reviewed journals, it may omit some relevant research on the topic. Although the main research themes were identified, more in-depth information on each of them is still needed.

Findings/Conclusions: Four globally relevant themes in blue carbon research in mangroves were identified, providing a roadmap for researchers to strategically direct efforts and funding in future scientific investigations.

Keywords: Carbon stores, sediments, carbon dynamics, climate change, anthropogenic impact.

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INTRODUCTION

Since the second half of the last century, Lugo & Snedaker (1974) pointed out that mangroves are wetlands composed of halophytic plants that develop along the tropical and subtropical intertidal zones of the planet. These ecosystems have a significant capacity to capture and store carbon dioxide (CO_2) from the atmosphere (Duarte de Paula Costa & Macreadie, 2022), thus playing a crucial role in climate change mitigation and adaptation (Macreadie *et al.*, 2021).

The organic carbon (C) captured and stored by mangroves is termed "blue carbon," a concept introduced to underscore the significant contribution of ocean and coastal ecosystems with vegetation to carbon capture (Nellemann *et al.*, 2009). Global interest from various stakeholders in blue carbon has spurred the scientific community to address a breadth of uncertainties surrounding carbon science in mangroves (Macreadie *et al.*, 2019). While some important topics have been well-documented in abundant scientific literature (Duarte de Paula Costa & Macreadie, 2022; Yin *et al.*, 2023), there are still areas that require greater attention.

Bibliometrics is considered one of the most effective tools for the quantitative and qualitative analysis of academic literature. Through statistical methods based on computer science, bibliometrics allows exploration of the current state of scientific research (De Moya-Anegón *et al.*, 2007). This analysis also helps identify gaps and trends to strategically guide efforts and budgets for scientific research (Chen, 2017). Therefore, the objective of this study was to identify the central themes and research trends on blue carbon in mangroves through bibliometric analysis of the existing global scientific literature.

MATERIALS AND METHODS

The document search was conducted on September 6, 2023, using Scopus, which is widely recognized for its authority and importance in the international scientific community. An advanced search strategy with Boolean operators was employed, using the following equation: TITLE-ABS-KEY ("mangrove" OR "mangroves" AND "carbon sink" OR "carbon storage" OR "carbon sequest" OR "blue carbon" OR "carbon burial" OR "carbon pool" OR "carbon stock" OR "carbon accumulation" OR "carbon drawdown" OR "carbon cycl"). Additionally, a filter was applied for document type, selecting only research and review articles.

For the processing and analysis of the documents, eight indicators were utilized: number of documents, language, historical scientific production, research area, geographical distribution, most productive authors, most cited articles, and most productive journals. To perform a quantitative and statistical analysis of these indicators, the Bibliometrix package in RStudio was employed (Aria & Cuccurullo, 2017).

Cluster analysis was conducted to identify thematic groups in the current state of research using the keyword co-occurrence technique in VOSviewer (van Eck & Waltman, 2010). Additionally, to identify current topics of interest among researchers, an overlaid visualization of the co-occurrence network was utilized. Keyword co-occurrence included all terms from titles, abstracts, and keywords of the documents, with a minimum occurrence threshold set at 14 to facilitate network visualization.

RESULTS AND DISCUSSION

A total of 1,281 documents related to blue carbon in mangroves were recorded (1,172 research articles and 109 reviews) over a period of 37 years (1986-2023), with the majority published in English (1,241). Historical scientific production shows exponential growth (R^2=0.99, Figure 1) in the number of publications. Publication trends can be categorized into three distinct periods.

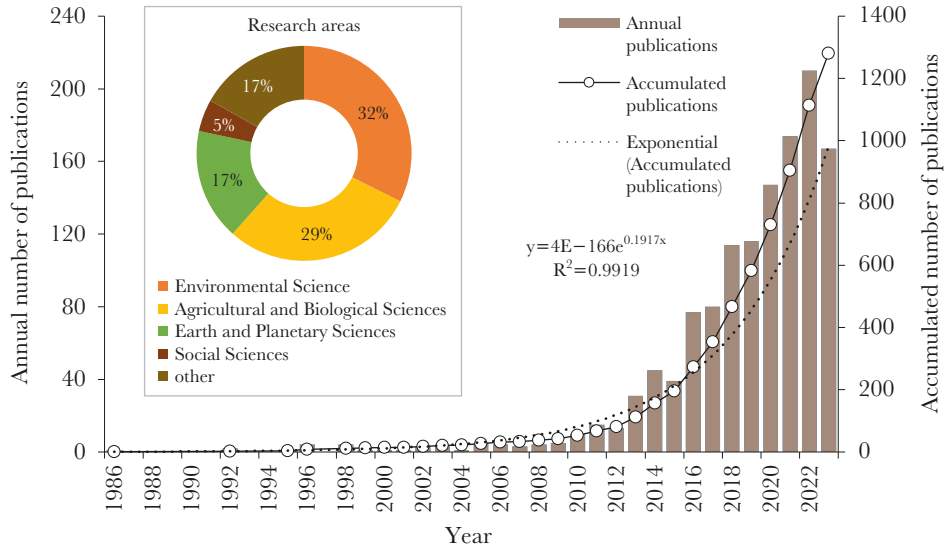

Figure 1. Historical global scientific production and research areas on carbon in mangroves during the period 1986-2023.

Firstly, the exploratory phase (1986-2008) saw a maximum of five documents published per year. Secondly, the phase of steady growth (2009-2014) began after Nellemann *et al.* (2009) first introduced the term "blue carbon" to the literature. Lastly, the period of rapid development (2015-2023) which started following the 21st United Nations Climate Change Conference and the Paris Agreement, events that led to the official recognition of the role of blue carbon ecosystems in climate change mitigation and adaptation (Zhong *et al.*, 2023).

Studies were classified into 64 research areas related to the topic of interest, demonstrating that blue carbon science in mangroves is a multidisciplinary field, similar to findings reported by Jiang *et al.* (2022). The most popular research areas were environmental sciences and agricultural and biological sciences, accounting for over 60% of the scientific production (Figure 1). Social sciences showed significant growth, ranking fourth, highlighting the importance of including mangroves in national greenhouse gas inventories (Friess, 2023) and their connection with rural communities (Herrera-Silveira *et al.*, 2020). Moreover, there is a need to enhance research in the field of economics to reduce uncertainty in carbon valuation (Macreadie *et al.*, 2019).

Regarding geographical distribution, a total of 94 countries were identified as involved in research on this topic (Figure 2). More than 50% of the total publications were jointly produced by the three most productive nations: United States of America (348), Australia (284), and China (242). Indonesia, United Kingdom, and Brazil followed in the ranking. Mexico ranked 11th with 61 documents.

This distribution responds to two main reasons: the level of economic development of the country and the extent of mangrove coverage they have. Thus, developed countries like the United States of America, China, and the United Kingdom, which have little to no mangrove coverage, benefited from their strong economic base facilitating high scientific output (Yin *et al.*, 2023). Conversely, the extensive mangrove ecosystems in Indonesia,

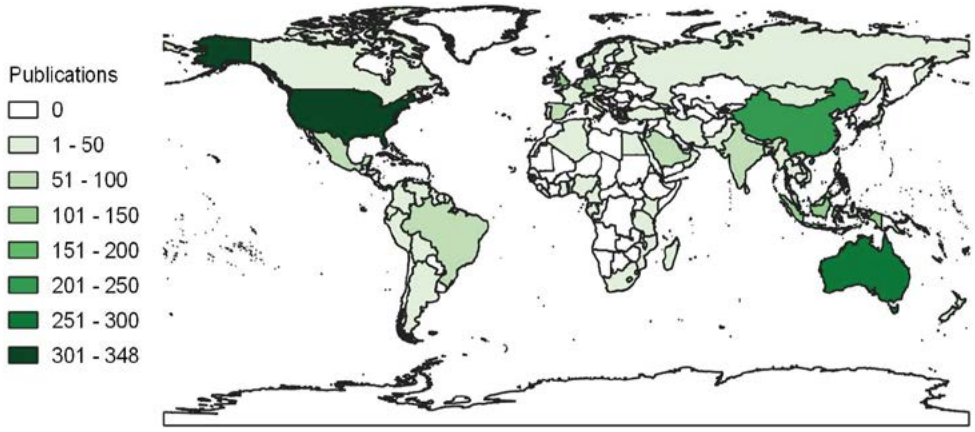

Figure 2. Countries that published on carbon in mangroves during the period 1986-2023.

Australia, and Brazil —ranked first, second, and third globally in terms of area— explain their high number of publications (Bunting *et al.*, 2018). In contrast, Mexico ranks fourth in mangrove area but studies on this topic are considered scarce, indicating a need for more assessments to promote climate change adaptation, in Mexico and other developing countries rich in blue carbon (Herrera-Silveira *et al.*, 2020).

Out of the 4,602 authors involved in the research, the top ten most productive in terms of number of publications come from five different countries (Table 1). Six of these authors are affiliated with institutions in Australia, the second most productive country globally. The strong performance of Australian researchers in blue carbon science was also noted by Jiang *et al.* (2022).

Within the top ten most cited articles, the primary one addresses methodology for estimating tree carbon in tropical forests (Table 2). Only two of these articles exclusively studied mangroves, while the others evaluated them alongside other coastal ecosystems. Moreover, four out of the ten were published before the term "blue carbon" was first introduced in the literature (2009), including the most cited and influential article in blue carbon science (Duarte de Paula Costa & Macreadie, 2022).

Table 1. Authors who produced the highest number of publications on carbon in mangroves during the 1986-2023 period.

Number	Authors	Affiliation	Publications	Citations
1	Lovelock, C. E.	The University of Queensland, Australia	51	2117
2	Sanders, C. J.	Southern Cross University, Australia	48	1020
3	Duarte, C. M.	King Abdullah University, Arabia Saudí	39	2307
4	Macreadie, P. I.	Deakin University, Australia	35	909
5	Friess, D. A.	Tulane University, United States of America	33	1169
6	Santos, I. R.	Southern Cross University, Australia	32	770
7	Serrano, O.	Spanish National Research Council, Spain	25	704
8	Maher, D. T.	Southern Cross University, Australia	24	686
9	Rogers, K.	University of Wollongong, Australia	23	712
10	Murdiyarso, D.	IPB University, Indonesia	21	1214

Table 2. Most cited articles in research on blue carbon in mangroves during the 1986-2023 period.

Number	Article	Authors	Citations
1	Tree allometry and improved estimation of carbon stocks and balance in tropical forests	Chave *et al.* (2005)	2139
2	A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2	Mcleod *et al.* (2011)	2051
3	Mangroves among the most carbon-rich forests in the tropics	Donato *et al.* (2011)	1765
4	Global carbon sequestration in tidal, saline wetland soils	Chmura *et al.* (2003)	1178
5	Seagrass ecosystems as a globally significant carbon stock	Fourqurean *et al.* (2012)	1159
6	The role of coastal plant communities for climate change mitigation and adaptation	Duarte *et al.* (2013)	1151
7	Major role of marine vegetation on the oceanic carbon cycle	Duarte *et al.* (2005)	962
8	Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems	Pendleton *et al.* (2012)	958
9	Carbon cycling and storage in mangrove forests	Alongi (2014)	862
10	Carbon and carbonate metabolism in coastal aquatic ecosystem	Gattuso *et al.* (1998)	804

The ten journals (out of a total of 346) with the highest scientific impact related to blue carbon in mangroves represented 25.9% of the total production (Table 3). The research landscape was dominated by Elsevier (four journals) and Springer (two journals), while other publishers had only one journal each in the top 10 list. Science of The Total Environment and Estuarine, Coastal and Shelf Science were the most productive, similar to findings highlighted by Jiang *et al.* (2022).

Regarding the current state of blue carbon science in mangroves, from a total of 6,520 keywords and 275 terms retained through co-occurrence, four clusters of research were identified (Figure 3):

Table 3. Most productive journals in blue carbon research in mangroves during the period 1986-2023.

Number	Journal	Impact factor	Quartile	Publications
1	Science of The Total Environment (Elsevier)	9.8	Q1	67
2	Estuarine, Coastal and Shelf Science (Elsevier)	2.8	Q1	53
3	Forests (MDPI)	2.9	Q1	35
4	Global Change Biology (Wiley Online Library)	11.6	Q1	31
5	Frontiers in Marine Science (Frontiers)	3.7	Q1	29
6	Wetlands (Springer)	2.0	Q2	25
7	Regional Studies in Marine Science (Elsevier)	2.1	Q2	24
8	Wetlands Ecology and Management (Springer)	1.8	Q2	24
9	Forest Ecology and Management (Elsevier)	3.7	Q1	23
10	Biodiversitas (Society for Indonesian Biodiversity)	1.5	Q3	21

I) Carbon storage (red cluster). This thematic group comprises the largest number of studies, primarily related to the estimation of carbon stocks in tree biomass and soil components across different regions worldwide (Akhand *et al.*, 2023). Long-term accumulation rates are reported to a lesser extent due to their difficulty in obtaining, yet Adame *et al.* (2015) emphasize their critical role in carbon payment programs. Globally, approximate values between 856 and 1,023 Mg ha^{-1} of total ecosystem carbon reservoirs are noted (Alongi, 2014; Kauffman *et al.*, 2020). Remote sensing is also addressed in this cluster as an emerging technological opportunity to enhance the accuracy of carbon measurement and monitoring in mangroves (Araya-Lopez *et al.*, 2023).

II) Sedimentation (green cluster). Sediment in mangroves accounts for between 70 and 85% of the total ecosystem carbon stocks (Beloto *et al.*, 2023), making it the focus of the majority of publications analyzed in this group. Recent studies in this cluster have implemented stable isotopes to effectively distinguish the origin of organic matter in sediments (Tang *et al.*, 2023). As noted by Huang *et al.* (2023), mangrove sediments derive from a variety of terrestrial, limnetic, and marine sources, including leaf litter and mangrove roots, algae, microalgae, and phytoplankton. On the other hand, some studies assess the impact of sea level rise on sediment accretion and its potential effect on carbon reservoirs (Saintilan *et al.*, 2023).

III) Carbon dynamics (blue cluster). An important theme in this cluster is the study of vertical and horizontal carbon fluxes in mangroves to understand their complex cycle. Studies highlight the significance of lateral exchange of dissolved and particulate organic carbon between mangroves and other coastal ecosystems (Lu *et al.*, 2023; Ray *et al.*, 2021). Regarding greenhouse gas flux measurements, in addition to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have been addressed, though they remain limited in many regions (Sugiana *et al.*, 2023). Multiple factors control carbon flux in these ecosystems, prominently biotic factors (Zhao *et al.*, 2023), as well as spatial-temporal and physical factors (Nie *et al.*, 2023).

IV) Climate change and anthropogenic impact (yellow cluster). This group addresses the study of carbon in mangroves as a nature-based solution to mitigate climate change (Zeng *et al.*, 2021), a topic of significant interest in achieving the global goal of limiting the increase in global temperature to no more than 1.5 °C by 2035. Relevant studies include those evaluating the impact of mangrove loss and land use change on CO_2 emissions to the atmosphere (Adame *et al.*, 2021; Das *et al.*, 2023), as well as those focusing on the conservation and restoration of these wetlands as a measure for carbon sequestration (Ray *et al.*, 2023; Sharma *et al.*, 2023). Additionally, the effects of climate change on future carbon stocks are analyzed through modeling approaches (Chatting *et al.*, 2022).

Regarding current research interests, the overlay map of the co-occurrence network depicts them in yellow circles (Figure 4). Notably among these are blue carbon and carbon stocks, which, despite being extensively studied, still have regions of the world where such research is scarce (Herrera-Silveira *et al.*, 2020). Other recent topics of interest include

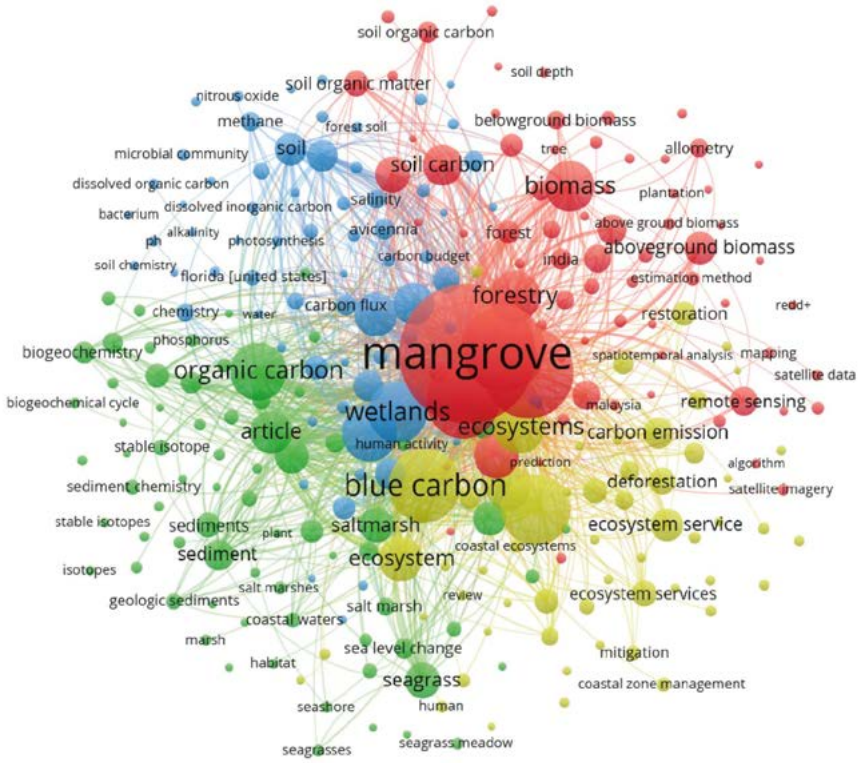

Figure 3. Co-occurrence network map based on articles related to carbon in mangroves during the period 1986-2023.

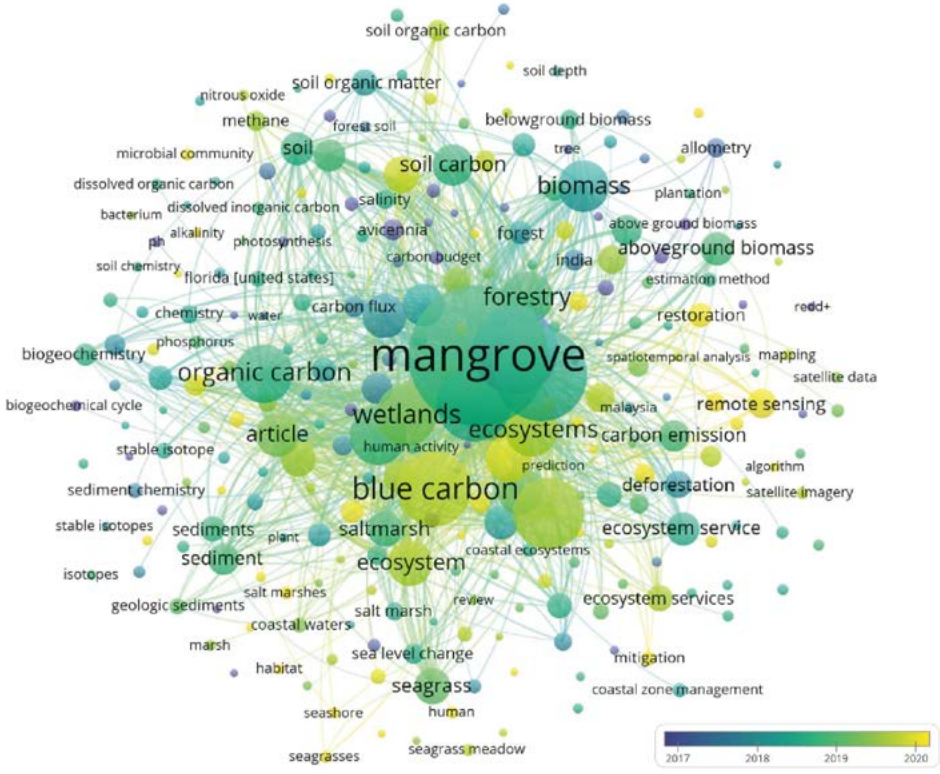

Figure 4. Overlay map of the co-occurrence network based on articles related to carbon in mangroves during the period 1986-2023.

climate change, greenhouse gas emissions, sea level rise, eutrophication, nutrients, restoration, conservation, biodiversity, microbial community, and remote sensing. Future research is expected to focus on addressing these topics.

CONCLUSIONS

The study successfully identified four key thematic trends in global research on blue carbon in mangroves, which can serve as a roadmap for researchers to strategically allocate efforts and funding in the future. Significant research has focused on carbon stock estimations, yet there is a need to increase studies providing insights into capture rates. Future research should target regions with scarce data to promote conservation and restoration efforts for these ecosystems. This study also highlights the importance of addressing research gaps related to the sociopolitical aspects of blue carbon science in these wetlands.

REFERENCES

Adame, M. F., Connolly, R. M., Turschwell, M. P., Lovelock, C. E., Fatoyinbo, T., Lagomasino, D., Goldberg, L. A., Holdorf, J., Friess, D. A., Sasmito, S. D., Sanderman, J., Sievers, M., Buelow, C., Kauffman, J. B., Bryan-Brown, D., & Brown, C. J. (2021). Future carbon emissions from global mangrove forest loss. *Global Change Biology, 27*(12), 2856-2866. https://doi.org/10.1111/gcb.15571

Adame, M. F., Santini, N. S., Tovilla, C., Vázquez-Lule, A., Castro, L., & Guevara, M. (2015). Carbon stocks and soil sequestration rates of tropical riverine wetlands. *Biogeosciences, 12*(12), 3805-3818. https://doi.org/10.5194/bg-12-3805-2015

Akhand, A., Chanda, A., Jameel, Y., & Dasgupta, R. (2023). The present state-of-the-art of blue carbon repository in India: a meta-analysis. *Sustainability Science, 18*(2), 1031-1042. https://doi.org/10.1007/s11625-022-01181-4

Alongi, D. M. (2014). Carbon cycling and storage in mangrove forests. *Annual Review of Marine Science*, 6, 195-219. https://doi.org/10.1146/annurev-marine-010213-135020

Araya-Lopez, R., de Paula Costa, M. D., Wartman, M., & Macreadie, P. I. (2023). Trends in the application of remote sensing in blue carbon science. *Ecology and Evolution, 13*(9), 1-13. https://doi.org/10.1002/ece3.10559

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Beloto, N., Cotovicz, L. C., Rodrigues, J. V. M., Gmach, M. R., Zimmer, M., Helfer, V., Soares, M. O., & Bezerra, L. E. A. (2023). Blue carbon stock heterogeneity in Brazilian mangrove forests: A systematic review. *Marine Pollution Bulletin*, 197, 115694. https://doi.org/10.1016/j.marpolbul.2023.115694

Bunting, P., Rosenqvist, A., Lucas, R. M., Rebelo, L. M., Hilarides, L., Thomas, N., Hardy, A., Itoh, T., Shimada, M., & Finlayson, C. M. (2018). The global mangrove watch - A new 2010 global baseline of mangrove extent. *Remote Sensing, 10*(10), 1669. https://doi.org/10.3390/rs10101669

Chatting, M., Al-Maslamani, I., Walton, M., Skov, M. W., Kennedy, H., Husrevoglu, Y. S., & Le Vay, L. (2022). Future Mangrove Carbon Storage Under Climate Change and Deforestation. *Frontiers in Marine Science*, 9, 781876. https://doi.org/10.3389/fmars.2022.781876

Chen, C. (2017). Science Mapping: A Systematic Review of the Literature. *Journal of Data and Information Science, 2*(2), 1-40. https://doi.org/10.1515/jdis-2017-0006

Das, N., Mondal, A., Saha, N. C., Ghosh, S., & Mandal, S. (2023). Decadal loss of above-ground biomass and subsequent potential CO_2 emission from the Sundarbans mangrove ecosystem, India. *Acta Ecologica Sinica, 43*(3), 452-458. https://doi.org/10.1016/j.chnaes.2021.11.002

De Moya-Anegón, F., Chinchilla-Rodríguez, Z., Vargas-Quesada, B., Corera-Álvarez, E., Muñoz-Fernández, F. J., González-Molina, A., & Herrero-Solana, V. (2007). Coverage analysis of Scopus: A journal metric approach. *Scientometrics, 73*(1), 53-78. https://doi.org/10.1007/s11192-007-1681-4

Duarte de Paula Costa, M., & Macreadie, P. I. (2022). The Evolution of Blue Carbon Science. *Wetlands*, 42, 109. https://doi.org/10.1007/s13157-022-01628-5

Friess, D. A. (2023). The potential for mangrove and seagrass blue carbon in Small Island States. *Current Opinion in Environmental Sustainability*, 64, 101324. https://doi.org/10.1016/j.cosust.2023.101324

Herrera-Silveira, J. A., Pech-Cardenas, M. A., Morales-Ojeda, S. M., Cinco-Castro, S., Camacho-Rico, A., Sosa, J. P. C., Mendoza-Martinez, J. E., Pech-Poot, E. Y., Montero, J., & Teutli-Hernandez, C. (2020). Blue carbon of Mexico, carbon stocks and fluxes: A systematic review. *PeerJ*, 8, e8790. https://doi.org/10.7717/peerj.8790

Huang, R., He, J., Wang, N., Christakos, G., Gu, J., Song, L., Luo, J., Agusti, S., Duarte, C. M., & Wu, J. (2023). Carbon sequestration potential of transplanted mangroves and exotic saltmarsh plants in the sediments of subtropical wetlands. *Science of the Total Environment, 904*(1), 166185. https://doi.org/10.1016/j.scitotenv.2023.166185

Jiang, L., Yang, T., & Yu, J. (2022). Global trends and prospects of blue carbon sinks: a bibliometric analysis. *Environmental Science and Pollution Research, 29*(44), 65924-65939. https://doi.org/10.1007/s11356-022-22216-4

Kauffman, J. B., Adame, M. F., Arifanti, V. B., Schile-Beers, L. M., Bernardino, A. F., Bhomia, R. K., Donato, D. C., Feller, I. C., Ferreira, T. O., Jesus Garcia, M. del C., MacKenzie, R. A., Megonigal, J. P., Murdiyarso, D., Simpson, L., & Hernández Trejo, H. (2020). Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients. *Ecological Monographs, 90*(2), 1–18. https://doi.org/10.1002/ecm.1405

Lu, Z., Xiao, K., Wang, F., Wang, Y., Yu, Q., & Chen, N. (2023). Salt marsh invasion reduces recalcitrant organic carbon pool while increases lateral export of dissolved inorganic carbon in a subtropical mangrove wetland. *Geoderma*, 437, 116573. https://doi.org/10.1016/j.geoderma.2023.116573

Lugo, A. E., & Snedaker, S. C. (1974). The Ecology of Mangroves. *Annual Review of Ecology and Systematics*, 5, 39-64. https://doi.org/10.1146/annurev.es.05.110174.000351

Macreadie, P. I., Anton, A., Raven, J. A., Beaumont, N., Connolly, R. M., Friess, D. A., Kelleway, J. J., Kennedy, H., Kuwae, T., Lavery, P. S., Lovelock, C. E., Smale, D. A., Apostolaki, E. T., Atwood, T. B., Baldock, J., Bianchi, T. S., Chmura, G. L., Eyre, B. D., Fourqurean, J. W., … Duarte, C. M. (2019). The future of Blue Carbon science. *Nature Communications, 10*(1), 1-13. https://doi.org/10.1038/s41467-019-11693-w

Macreadie, P. I., Costa, M. D. P., Atwood, T. B., Friess, D. A., Kelleway, J. J., Kennedy, H., Lovelock, C. E., Serrano, O., & Duarte, C. M. (2021). Blue carbon as a natural climate solution. *Nature Reviews Earth and Environment, 2*(12), 826-839. https://doi.org/10.1038/s43017-021-00224-1

Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L., & Grimsditch, G. (2009). Blue carbon: A Rapid Response Assessment. In Environment. http://www.grida.no/files/publications/blue-carbon/BlueCarbon_screen.pdf

Nie, S., Ouyang, X., Wang, W., Zhu, Z., Guo, F., Yang, Z., & Lee, S. Y. (2023). Sediment CO2 Flux from a Mangrove in Southern China: Is It Controlled by Spatiotemporal, Biotic or Physical Factors? *Forests, 14*(4). https://doi.org/10.3390/f14040782

Ray, R., Miyajima, T., Watanabe, A., Yoshikai, M., Ferrera, C. M., Orizar, I., Nakamura, T., San Diego-McGlone, M. L., Herrera, E. C., & Nadaoka, K. (2021). Dissolved and particulate carbon export from a tropical mangrove-dominated riverine system. *Limnology and Oceanography, 66*(11), 3944-3962. https://doi.org/10.1002/lno.11934

Ray, R., Suwa, R., Miyajima, T., Munar, J., Yoshikai, M., San Diego-Mcglone, M. L., & Nadaoka, K. (2023). Sedimentary blue carbon dynamics based on chronosequential observations in a tropical restored mangrove forest. *Biogeosciences, 20*(4), 911-928. https://doi.org/10.5194/bg-20-911-2023

Saintilan, N., Horton, B., Törnqvist, T. E., Ashe, E. L., Khan, N. S., Schuerch, M., Perry, C., Kopp, R. E., Garner, G. G., Murray, N., Rogers, K., Albert, S., Kelleway, J., Shaw, T. A., Woodroffe, C. D., Lovelock, C. E., Goddard, M. M., Hutley, L. B., Kovalenko, K., … Guntenspergen, G. (2023). Widespread retreat of coastal habitat is likely at warming levels above 1.5 °C. *Nature, 621*(7977), 112-119. https://doi.org/10.1038/s41586-023-06448-z

Sharma, S., Ray, R., Martius, C., & Murdiyarso, D. (2023). Carbon stocks and fluxes in Asia-Pacific mangroves: current knowledge and gaps. *Environmental Research Letters, 18*(4), 044002. https://doi.org/10.1088/1748-9326/acbf6c

Sugiana, I. P., Faiqoh, E., Adame, M. F., Indrawan, G. S., Andiani, A. A. E., Dewi, I. G. A. I. P., & Dharmawan, I. W. E. (2023). Soil greenhouse gas fluxes to the atmosphere during the wet season across mangrove zones in Benoa Bay, Indonesia. *Asian Journal of Atmospheric Environment*, 17, 13. https://doi.org/10.1007/s44273-023-00014-9

Tang, D., Liu, X., Xia, Z., Hou, J., Yang, X., Li, P., & Yuan, X. (2023). Sources of organic matter and carbon stocks in two mangrove sediment cores and surface sediment samples from Qinglan Bay, China. *Science of the Total Environment*, 893, 164897. https://doi.org/10.1016/j.scitotenv.2023.164897

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Yin, S., Wang, J., & Zeng, H. (2023). A bibliometric study on carbon cycling in vegetated blue carbon ecosystems. *Environmental Science and Pollution Research, 30*(30), 74691-74708. https://doi.org/10.1007/s11356-023-27816-2

Zeng, Y., Friess, D. A., Sarira, T. V., Siman, K., & Koh, L. P. (2021). Global potential and limits of mangrove blue carbon for climate change mitigation. *Current Biology, 31*(8), 1737-1743.e3. https://doi.org/10.1016/j.cub.2021.01.070

Zhao, X., Chen, Z., Xu, Y., Zhai, X., Song, X., Xu, H., Lü, X., & Li, X. (2023). Linkages between organic carbon composition and microbial community structure in two contrasting subtropical mangrove sediments in southern China. *Regional Studies in Marine Science*, 66, 103159. https://doi.org/10.1016/j.rsma.2023.103159

Zhong, C., Li, T., Bi, R., Sanganyado, E., Huang, J., Jiang, S., Zhang, Z., & Du, H. (2023). A systematic overview, trends and global perspectives on blue carbon: A bibliometric study (2003-2021). *Ecological Indicators*, 148, 110063. https://doi.org/10.1016/j.ecolind.2023.110063