



Mapping three decades of mangrove resilience research: Global insights into degradation and regeneration

Sweta Chatterjee* ¹ and Dr. Gupinath Bhandari ²

¹School of Water Resources Engineering, Jadavpur University, Kolkata 700032, India

²Department of Civil Engineering, Jadavpur University, Kolkata 700032, India

Abstract

Since the last three decades, climate change issues and other environmental obstacles are threatening global mangrove ecosystem and is oriented towards the study on mangrove degradation along with conservational and regeneration policies and strategies. This study draws out the comprehensive insights on degradation and regeneration of tropical mangrove ecosystem, utilizing bibliometric analysis over 5197 published research documents from Scopus database for the last three decades. USA, Australia, China, India, Germany are the top five categorized countries on the basis of total citations achieved. Co-occurrence network of the most frequently used keywords focuses on “climate change”, “ecosystem services”, “mangrove forest”, “deforestation”, “biodiversity”, “sustainable development”, “land use change”, “coastal zone”, “satellite imagery,” and “remote sensing” etc., primarily highlighted in leading journals like “*Remote Sensing*”, “*Science of the Total Environment*”, “*Estuarine, Coastal and Shelf Science*”, “*Ocean and Coastal Management*”, “*Marine Pollution Bulletin*”. Future trend analysis shows the probabilistic analysis on “mangrove”, “mangroves”, “climate change”, “remote sensing”, “blue carbon”, “conservation”. Thematic evolution and mapping highlights “mangrove sediment” and “biodegradation” persisting in niche themes, while “climate change” and “carbon stock” have transitioned into central motor themes, reflecting a growing interdisciplinary focus in mangrove studies. This study paves the future research on drivers of mangrove degradation and pathways to regeneration, translating scientific insights into evidence-based policies. Emphasizing interdisciplinary collaboration, remote sensing applications, and stakeholder engagement is vital for sustainable mangrove management, restoration, and conservation at local to global scales.

Keywords: Bibliometric Analysis, Mangrove Degradation, Mangrove Regeneration, Recent Trends, Future Sustainability, Co-occurrence Network

Received: Oct 08, 2025

Revised: Oct 26, 2025

Accepted: Oct 31, 2025

Citation

Chatterjee S., and Bhandari G. (2025). Mapping three decades of mangrove resilience research: Global insights into degradation and regeneration. *Int. J. Disast. Studies Climate Resil.* 1(2):13–31.

<https://doi.org/10.64866/j.ijdsr.2025.10012>



1 Introduction

Tropical countries are the regions that lie along the Equator where, several countries such as North America, South America and Southeast Asia falls upon, experiencing dry and wet season annually (Mohd Razali et al., 2021). Applicable fields for the integration of both Remote Sensing and GIS applications are such as mangrove forest status monitoring, forest degradation analyses, irrigation studies, land use and land cover along with change detection analyses and other geographical and geological studies. Numerical studies (Oostdijk et al., 2018; Pham et al., 2019; Cissell et al., 2018; Jia et al., 2018; Pastor-Guzman et al., 2018) show that utilization of Remote Sensing and

GIS applications using high resolution based satellite imageries (Landsat) to portray the mangrove forest dynamics under different hydro-geomorphological regimes; mangrove forest growth in Can Gio, Vietnam; monitor the change detection of mangroves in Campeche, Mexico; provide the first ever datasets on mangroves for China of more than 40 years; vegetation indices and phenology analysis on 15 years based datasets on mangrove forest of Southeast Mexico. Magnificent role of Remote Sensing and GIS based monitoring caught the eye, provisioning the information on tropical mangrove studies and other earthy objects all over the world, incorporating new techniques. Mao et al. (2013) invented new technique on estimation of epsilon for the atmospheric correction of satellite imageries,

*Corresponding author. Email: swetac.swre.rs@jadavpuruniversity.in (SC), gupinath.bhandari@jadavpuruniversity.in (GB)

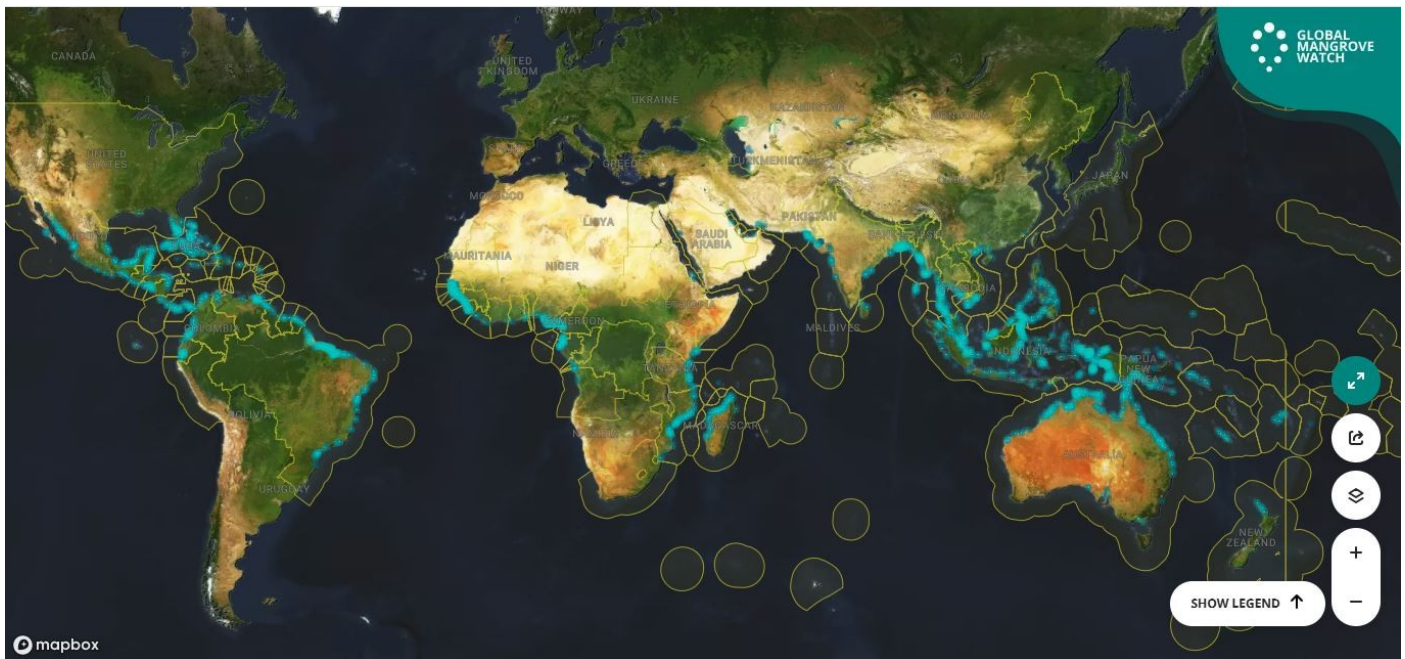


Fig. 1. Interface of Global Mangrove Watch (GMW) to visualize the continent wise dynamics in net change in mangrove areal coverage (1996–2020) (Source: <https://www.globalmangrovetwatch.org/>).

mainly can be utilized for the coastal and oceanic regions. Zabolotskikh et al. (2013) published a novel algorithm on sea surface wind speed utilizing microwave remote sensing. Cardoso-Fernandes et al. (2019) initiated new approach for the Li-bearing pegmatites detection using Remote Sensing database in Fregeneda-Almendrea region. Staben et al. (2018) developed a canopy height model, aided by machine learning algorithm and Landsat satellite imagery analyses for the Darwin area, Northern Australia. Recently, Yu et al. (2020) invented backdating methodology and object based land cover classification and change detection methods accurately that might be valuable insights for future researchers to integrate Geospatial techniques in mangrove changes.

Mangroves, being the coastal barrier at the salty estuarine based coastal belts of tropical and subtropical areas (Duke, 2011; Beddu et al., 2025; Sidik et al., 2023) (Fig. 1, 2), serve as the blue carbon ecosystem, mitigating climate change issues through carbon sequestration (Cameron et al., 2019; Jennerjahn, 2020) that enables the relevancy in regulating climate-scape of the earth (Tasneem and Ahsan, 2024). Furthermore, mangrove ecosystem also serves as the enriched primarily productive four times higher than other flora (Alongi, 2014) in terms of biomass level and carbon pool (Komiyaama et al., 2008; Donato et al., 2011; Kauffman et al., 2014), can store up to 4.19 Pg (Peta-grams) of carbon near about 87% in the soil layer globally (Fatoyinbo et al., 2023). UNEP (2014) justified the fact that mangroves have the ability to withstand substantially high wave energy, coastal erosion and protect the native coastal communities against the destructive coastal storms (Dasgupta et al., 2019). Mangrove ecosystem is also the wide range of service providers (Robertson and Duke, 1987) to the vulnerable and needy coastal communities in provisioning (fuel wood, charcoal, fodder, timber, crabs and fin-fish

production) (Chow, 2018; Djamaluddin, 2019), regulating (coastal protection being coastal barrier, fisheries functionality) (Huxham et al., 2017); habitats of several faunas and organisms (Nagelkerken et al., 2008). Sathirathai (1998) also mentioned that this vibrant ecosystem provides a valuable source to national income by attracting the tourists, hikers, fishermen, hunters, birdwatchers across the globe. Fourqurea et al. (2014) mentioned that soil and water systems of mangroves have the potentiality for greenhouse gas emissions. Carbon storage and pool amidst the mangrove ecosystem helps to counterbalance between natural reservoir of carbon storage and anthropogenic greenhouse gas emissions (Kusumaningtyas et al., 2019).

Significant threats such as habitat loss, deforestation issues, contamination related issues, coastal erosion, storm surges induced by cyclonic storms adversely impacted mangrove ecosystems (Dahdouh-Guebas, 2011; Chamberland-Fontaine et al., 2022). Anthropogenic factors such as urbanization, agricultural and aquaculture expansion, global and regional climate change (de Oliveira Gomes et al., 2021; Luo et al., 2022; Liang et al., 2023) also hinder the stability of mangrove ecosystem that is also environmental concern globally. Bunting et al. (2022) accounted the global loss, estimated as 5245 Square kilometers (3.4%) since 1996 to 2020 primarily focusing on the fact that deforestation due to agriculture and aquaculture practices accelerated the mangrove degradation that reduces the climate change capability, level of carbon sequestration, biodiversity and coastal barrier for protection. South east Asia, being the largest occupancy of mangrove coverage has experienced great loss of about 2456.5 km² as well as 4.8% since 1996 to 2020 that is about 47% of global net loss, followed by Western Asia (27.9 km²; 13.8%), Eastern Asia (29.5 km²; 11.5 %); Caribbean (513.8 km²; 7.9 %) have faced major losses within the tenure (1996–2020). Mangrove health also get deteriorated due to

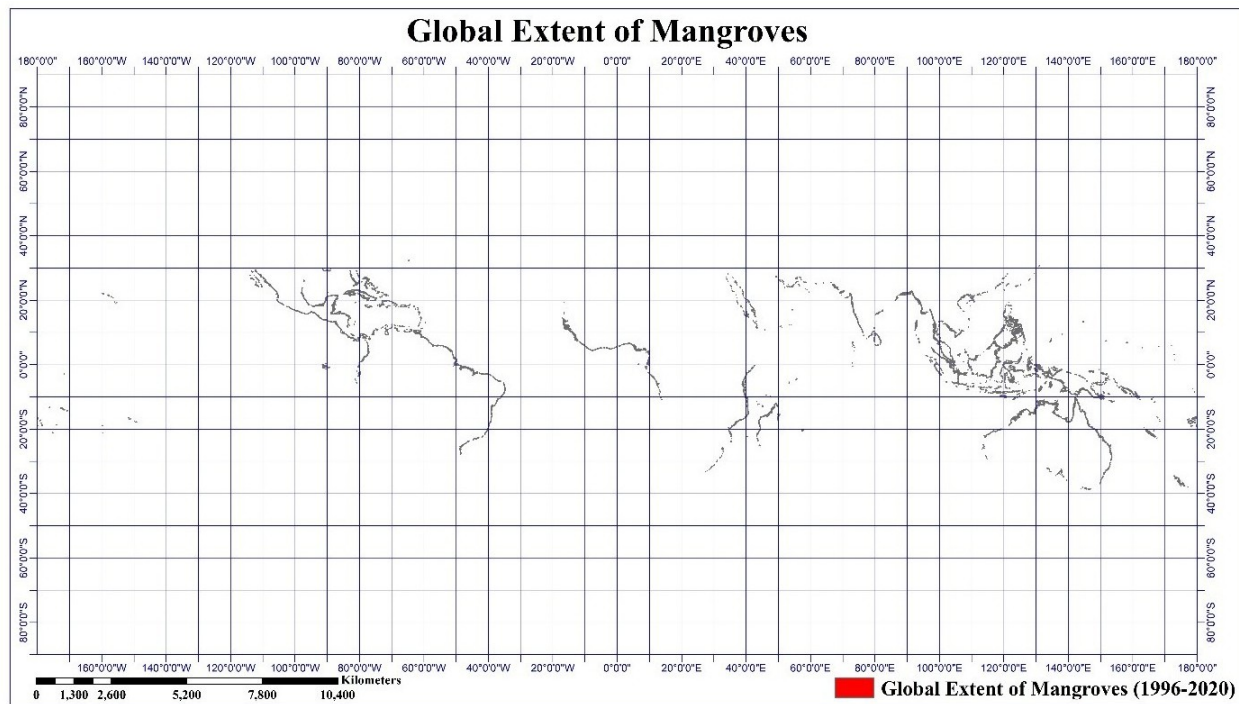


Fig. 2. Global Areal Coverage of Mangroves (1996–2020) to show the extent of mangrove forest, generated within the framework of Global Mangrove Watch (GMW) (Source: Modified after [Bunting et al., 2022](#)).

habitat fragmentation issues and coastal pollution ([Begum et al., 2021](#)). To improve the existing mangroves' health and potentiality, mangrove reforestation through natural and artificial (plantation) regeneration practices ([Paul and Criado, 2020](#)) might be implemented for the sustainable coastal protection and management. In terms of Sustainable Development Goals (SDGs) ([Mujtaba and Cavico, 2013](#)), mangrove ecosystem protection falls under several goals such as under SDG 13 (Climate Action), mangroves serve as carbon sinks; SDG 11 (Sustainable Cities and Communities), mangrove protects coastal belts by reducing potential disaster and risks; SDG 14 (Life Below Water) and SDG 15 (Life on Land), rich biodiversity of mangroves; SDG 1 (No Poverty) and SDG 2 (Zero Hunger), livelihood securities through fisheries and ecotourism; SDG 16 (Peace, Justice and String Institutions) and SDG 17 (Partnerships for the Goals), stakeholder participation in mangrove management and several attempts to protect the ecosystem for the sustainable development and management further.

Garfield introduced the bibliometric analysis in the mid-20th century, that is nothing but the quantitative approach to systematically enumerate, assess and organize the principal components aided by mathematical and statistical inferences ([Marrone and Linnenluecke, 2020](#); [Chen et al., 2022](#)) of a chosen research study ([Tasneem and Ahsan, 2024](#); [Aznar-Sánchez et al., 2018](#); [Huang et al., 2014](#)). It helps to figure out the quantitative approach and visualizations on behalf of the publication scenario on a certain research studies with respect to rates of publication, citation, keyword co-occurrences. For evaluating the various fields on scientific observations and investigations, bibliometric analysis is the most effective and optimum research tool to oblige and helps to detail entire insights of a particular research

area worldwide ([Mohd Razali et al., 2021](#)). [Gao and Ruan \(2018\)](#) deciphered that this quantitative measurement has become exclusively utilized in several science and engineering discourses for the further assessing the scientific observations, measurements on recent research trends. In other words, this advanced technique can draw out the spatial and non-spatial information on certain studies along with research gaps in a very technically advanced way. Numerous studies have implemented this analysis in various fields such as, [Duan et al. \(2020\)](#) monitored the protected areas, aided by remote sensing applications through bibliometric analysis. [Wang et al. \(2019a; 2019b\)](#) applied the same for crop growth monitoring for China and land use-land cover changes ([Kuenzer et al., 2011](#)) over the past 20 years. Furthermore, physical activity along with ageing studies have also been justified through Bibliometric analysis ([Müller et al., 2016](#)). Afterwards, [Huang and Lu \(2018\)](#) conducted urban heat island studies with the help of the same from 1991 to 2015. [Muhuri et al. \(2019\)](#) conducted this analysis in the engineering field to imply development of Industry 4.0. This analysis also got implemented in Support Vector Machine (SVM) based land cover classification technique in Remote Sensing arena ([Yu et al., 2020](#)). Drought monitoring, assessment and prediction was also possible through this analysis ([Adisa et al., 2020](#)). [Diniz et al. \(2019\)](#) monitored the recent status of Brazilian mangrove ecosystem and [Bindu et al. \(2020\)](#) estimated the carbon stock of mangrove ecosystem with the help of Remote Sensing based applications.

2 Objectives

This study is fully devoted to conduct a bibliometric analysis over the trends and inducing factors governing

Table 1. Primary keywords used.

Keywords used	Total Documents	Database Source
“Mangrove” and “Tropical Country”	301	https://www.scopus.com/
“Mangrove” and “Land use Change”	2285	
“Mangrove Degradation”	1765	
“Mangrove Regeneration”	455	
“Mangrove” and “Remote Sensing”	2294	
“Mangrove Degradation” and “Remote Sensing”	239	
“Mangrove Health” and “Remote Sensing”	181	
“Mangrove Dynamics” and “Remote Sensing”	386	
“Mangrove Regeneration” and “Sustainability”	27	
“Mangrove” and “SDGs”	74	
“Mangrove Reforestation” and “Rehabilitation” and “Restoration”	32	

degradation and regeneration aspects of worldwide mangrove ecosystem, exploring numerous published research documents of Scopus indexed database. Most specifically, this research study aims to investigate following key issues; a) most relevant authors, journals, articles, institutions and countries, b) most dominant research areas in field of degradation and regeneration aspects of mangrove ecosystem, c) interconnection among authors and countries with respect to the same, d) emergence and recent trend analysis to shape the future research agenda on mangrove ecosystem sustainability.

3 Materials and Methodology

3.1 Database

Scientific documents on several aspects related to mangrove degradation and regeneration were collected from Scopus as it is the most convenient and reliable core source for database for the bibliometric analysis, having over 100 million records (<https://www.scopus.com/>). In this database, primarily keywords were put using the Boolean operator mainly “and” related to this study (Table 1), limited to the temporal period for 30 years (1995–2025). For the higher accuracies and consistency, all the keywords were combined, attaching “or” to each and every keyword. Total 7937 records were collected from Scopus, afterwards, duplicities were removed using python code at R Studio (Version 2024.04.2) utilizing *bibliometrix* (Aria and Cuccurullo, 2017) and *dplyr* package and merging of the cleaned dataset in csv format was processed along with top authors, top countries and top journals files. As a result, 2740 numbers of duplicate rows were found and 4959 numbers of records were saved as the cleaned merged dataset to proceed for the bibliometric analysis. After refining the records, retrieved documents can be divided into several types (Table 2) such as published as conference papers, journals, book chapters, review papers.

Table 2. Consideration of types of document after cleaning duplicities and merging (1995–2025).

Document Types	Frequency
Article	4108
Book	22
Book Chapter	253
Conference Paper	576
Total	4959

3.2 Database Analysis Process (Methodology)

Fig. 3 presents a flow chart on exclusion criteria for the consideration of scientific records and how the size of the documents was determined in this study. In pursuing this research, multidisciplinary journals in accordance with all subject areas such as environmental science, agricultural and biological science, earth and planetary sciences, social sciences got privileged specifically. Boolean operator “and” was used between two primary keywords to identify the presence of both keywords being concepts simultaneously (Kroon et al., 2021; Tasneem and Ahsan, 2024). After merging all retrieved research documents, cleaning for erasing duplicities is the foremost work to proceed further. Afterwards, methodological framework is set to oblige the bibliometric analysis techniques, measurement and assessment of productivity, keywords, co-authorship interconnection among countries and thematic evolution and mapping.

3.3 Techniques on Bibliometric Analysis

Data collection from Scopus database was initiated in accordance with information related to scholarly publications for the bibliometric analysis, where patterns, trends, orientation of scientific literatures were included. Two kinds of techniques such as performance analysis and science mapping for the betterment of this study. As per Donthu et al. (2021), performance analysis comprises of deliberations of research elements, in other hand science mapping is the conceptual framework on correlation among research elements. Under the former one, top papers, cited authors, top most countries, topmost productive journals, organization, trending topics and others have been utilized and visualized.

3.4 Productivity Measurement

Measurement of productivity of any researchers’ is determined after the quantification of production and citation received after the publication. In this case, h-index and g-index are evaluated to monitor the productivity of researchers in particular domain of research among the fellows of researchers. Both indices are important to assess the comprehensive evaluation on global citation performance level of researchers whereas, g-index is served as more valid one than h-index recent days (Egghe, 2006; Ali, 2021-05). Subsequently, impact factor can be quantified to get notification on what rate of journal citation for a certain year, that is significant to rank a particular journal, quantify-

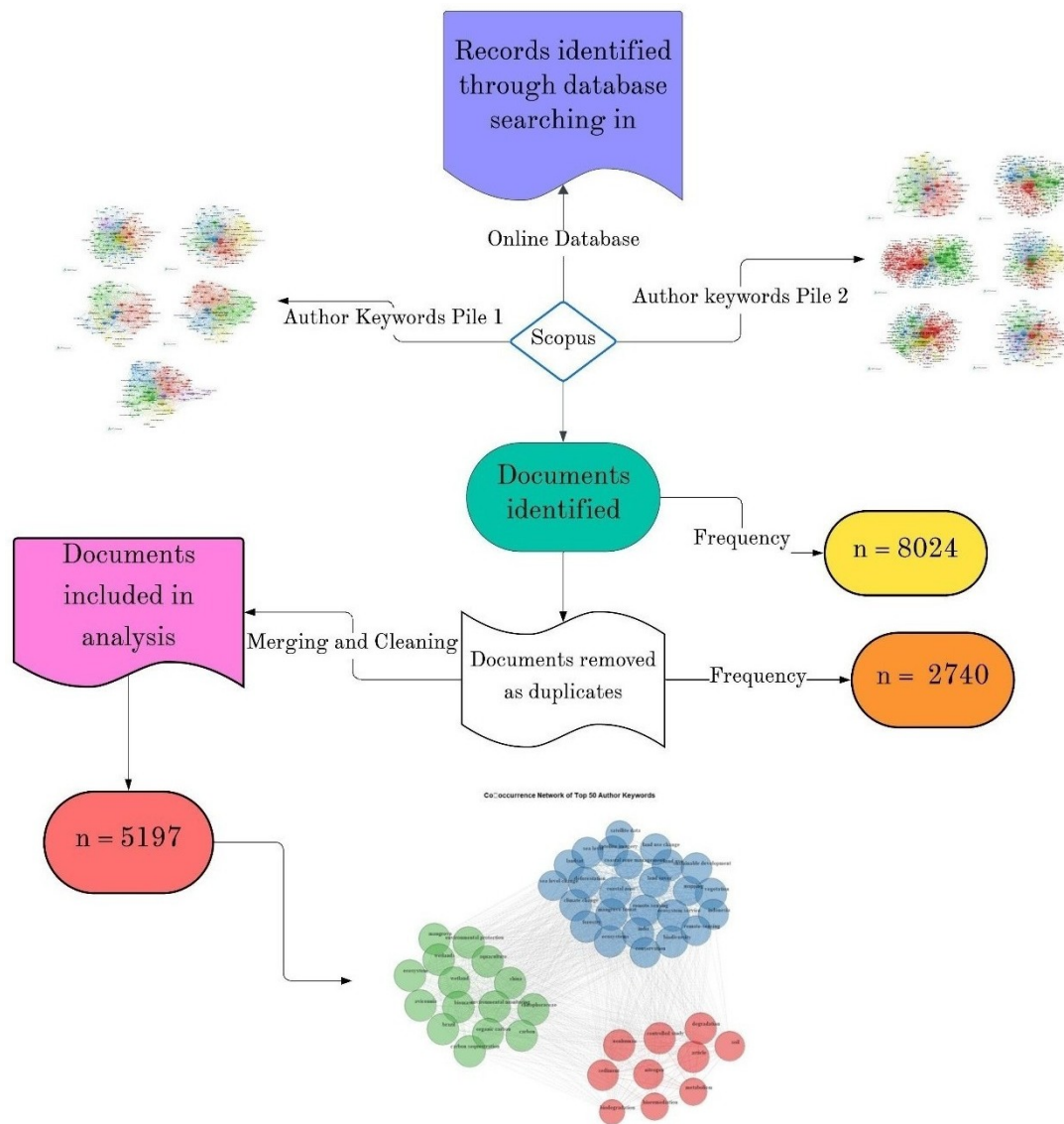


Fig. 3. Flowchart showing the bibliometric data processing steps. Records were retrieved and grouped by author keywords (Pile 1 and Pile 2), producing **8,024 documents** in total. After removing **2,740 duplicates**, **5,197 unique documents** were retained for analysis. The networks represent co-occurrence patterns among top author keywords during different stages of the workflow.

ing the citations received. In this study, after incorporating total frequency of publications (TP), topmost influential authors, journals, organizations, countries also got ranked. Afterwards, total citation (TC) was justified on the basis of country wise most influential journals. Average citations (TC/TP) was also quantified for the equal number of publications for normalizing the overall citation impact with respect to number of publications.

3.5 Keywords Assessment

Under science mapping methodology, co-occurrence of most frequently used keywords along with co-authorship of different countries was visualized utilizing bibliometric network analysis. According to Elsevier (2020), keywords being defined as the index terms of particular study utilized after professional indexers, are linked to published documents to increase the competence of search. Lu et al. (2020) discussed about the competencies of individual authors to add on keywords based on their background knowledge for the

research studies. As per the method of Yang et al. (2012), co-word analysis has been employed, aided after keywords and author keywords which is relevant measurement in information metrology, discovered after French bibliometric scientists in 1970s. For the co-occurrence analysis, enumeration of threshold level in keywords is the foremost step to proceed further (Chen and Xiao, 2016). Threshold level is chosen as per the requirements on individual aspects for this study. Clustered keywords connected with grouped nodes with each other is visualized for assessing the co-occurrence of keywords where, each clusters have similarity in terms of similar keywords, colored after significant distinct colors to delineate each and every clusters. Individual clusters with similarity represent similar domain of analyzed research study. Thickness of vertices connecting the nodes amidst keywords are determined after co-occurrences and correlation. Thicker the vertices, more close the correlation along with co-occurrences (Yang et al., 2012). This analysis can boost the existing insights on advancement of

Table 3. Statistics on publication output on raw datasets (SCOPUS, 2025).

Main Information about Database		Remarks
	Timespan	1995–2025
	Sources (Journals, Books etc.)	1611
	Documents	8024
	Annual Growth Rate (%)	6.93
	Document Average Age	7.6
	Average Citations per Document	26.66
	Average Citations per year per Document	3.057
	References	1
	Keywords Plus (ID)	18043
	Author's Keywords (DE)	11837
Document Contents	Authors	17262
	Author Appearances	37983
	Authors of Single-authored Documents	381
Authors	Single-authored Documents	550
	Documents per Author	0.465
	Co-authors per Documents	4.73
Authors' Collaboration	International Co-authorships (%)	32.49
	Article	6134
	Book Chapters	368
Document Types	Book	42
	Review	286
	Conference Paper	1108

scientific production and further development in academic sector.

3.6 Co-Authorship Analysis

Apart from keyword analysis, co-authorship monitoring was also visually represented throughout this study where, correlation among engaged countries along with contributing authors for the published articles is possible to make out technically. This visualization is made with reference to bibliometric network analysis where, authors of different countries are linked with respect to published articles (Zare-Farashbandi et al., 2014). Higher the value, higher the frequency of publications, co-authored by two researchers.

3.7 Thematic Mapping and Evolution

In this section, two things have been visualized where, thematic mapping is framed to show spatial distribution of specific theme such as population density, distribution, annual income level etc. using co-word analysis to justify the Spatio-temporal evolution of particular research arena. According to the definition of Callon et al. (1983); Cobo et al. (2011), this mapping comprises of clusters of “research themes” of four categories, proposed after He (1999) that are a) *Motor Themes*, placed in the upper right quadrant, are well developed and featured by vital, strong, central and highly densified themes; b) *Niche Themes*, placed in upper left quadrant, are too well developed but isolated in manner along with weak centrality and highly density; c) *Marginal Themes*, placed in lower left quadrant, are of wither emerging and declining in nature with low density and weak centrality; d) *Basic and Transversal Themes*, placed in lower right quadrant, are less developed along with string centrality but low density. Apart from this mapping, thematic evolution is defined as the temporal change detection of central ideas, studies and topics within a particular research arena, usually utilized after co-word analysis to

comprehend the repetitive appearance of frequently used keywords in research papers. Chen et al. (2019) visualized the co-occurring keywords for the similar thematic areas of research through graphical presentation.

This entire quantitative study is fully devoted to analyses at platforms such as open source programming language R (Version 2024.04.2), specifically utilizing packages like “*bibliometrix*” and “*dplyr*” for the merging, duplicities, descriptive analyses on frequency of authors, citations, types, years of publications, countries, journals. For the systematic visualization on this descriptive datasets, VOSviewer (Version 1.6.20) (Van Eck and Waltman, 2010) software and R Studio (2025 Version) are employed to represent bibliometric networks, patterns and trends of co-occurrence of keywords, co-authorship. Trending topics among selected author keywords are set to Bubble diagram and Alluvial plot to show the thematic evolution through selected temporal span (1995–2015; 2016–2025) through R Studio. Several packages are utilized for other visualization such as “*tidyr*”, “*ggplot2*”, “*ggalluvial*”, “*knitr*”, “*stringr*”, “*scales*”, “*RcolorBrewer*”, “*igraph*”, “*ggraph*”, “*purrr*”, “*readr*”.

4 Results and Discussion

4.1 Conceptual Framework on Publication Output

Summary of the input data from Scopus Database has been tabulated through Table 3 where, descriptive statistics is presented with key information. Total 8024 number of documents were downloaded along with author, bibliographic information and others, which consists of 76.45% of articles, 4.59% of book chapters, 0.52% of books, 3.56% of reviews and 13.81% of conference papers. As per citation statistics, average number of citations per document reaches at 26.66% that is quite significant related to published works. Annual growth rate is 6.93% that is also reflecting wider subject domains. Total 17262 numbers of authors are identified where, single authored documents are 550,

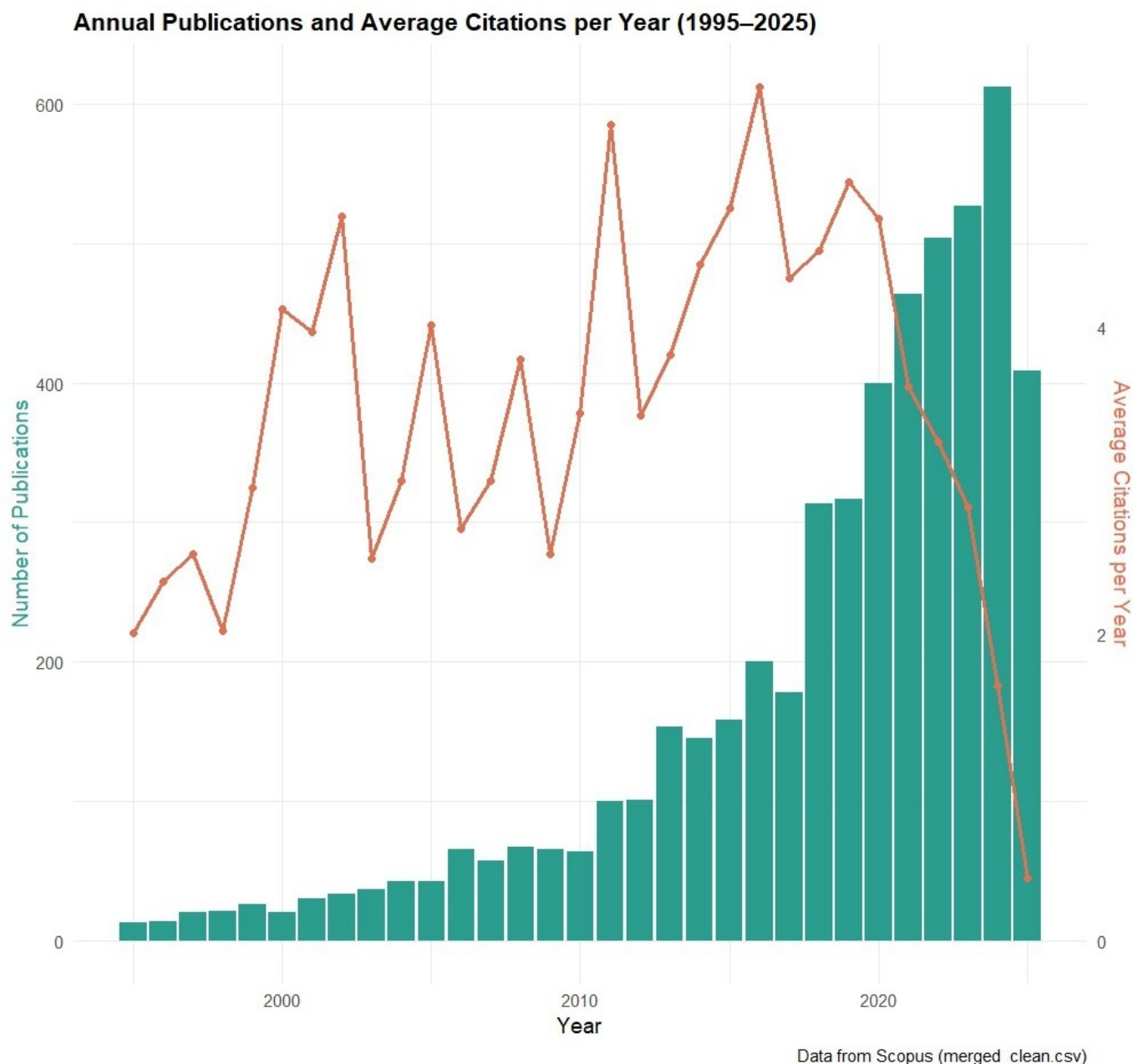


Fig. 4. Annual publications of scientific research along with average citations (TC/TP) per year (1995–2025) The bar chart represents the annual number of scientific publications, while the line graph depicts the trend of average citations per publication (Total Citations per Total Publications, TC/TP). A steady rise in research output is observed after 2010, accompanied by fluctuating citation averages, which decline in recent years likely due to the recency of publications. (Data Source: SCOPUS, 2025).

average value of co-authors per document is 4.73%, showing a significant trend in collaboration. Authors of single authored documents are specially 381. Author's keywords (DE) is 11837, exhibited wider range of multidisciplinary domains. Furthermore, international co-authorships reach to 32.49% that indicates a great scale of collaborative association on a global scale. Insights from Fig. 4 delivers from the early 2000s, gradual increase in the number of publications is observed, distinct surge in research productivity after 2015 due to perhaps technical advancements, research collaboration across the globe, increased funding. Publication output reaches its peak as per latest data from 2025 with over 600 documents, showcasing string hike in research activity. Average citations per year have dropped, showing

erratic patterns despite more publication frequencies particularly between 1995 and 2020, as there is negative correlation between the both, suggesting a citation lag. The highest average citation per year is observed around 2014 to 2016, exceeding four citations per paper that is the period of high impact research. However, a possible steep decline is observed after 2020, dropping by to less than one citation per paper by 2025.

4.2 Most Cited Journals, Authors, Countries, Institutions

In this section, most cited journals, authors, countries and institutions are taken into consideration as significant

Table 4. Top 10 published authors with metrics from cleaned and merged dataset (SCOPUS, 2025).

Authors	University & Country	h-index	g-index	PY Start	TC	NP
Dahdouh-Guebas F	Université Libre de Bruxelles (Belgium)	38	62	1997	3973	72
Zhang Y	Beibu Gulf University, China	23	44	2004	1995	70
Wang Y	Heilongjiang University, China	19	36	2003	1371	55
Koedam N	King Abdullah University Of Science And Technology (Kaust), Saudi Arabia	32	51	1997	3266	51
Friess DA	National University of Singapore, Singapore	34	48	2013	4753	48
Wang J	Jiangsu Center For Collaborative Innovation In Geographical Information Resource Development And Application, China	19	32	2001	1082	48
Li J	The Chinese University Of Hong Kong, Hong Kong, China	15	37	2005	1391	46
Wang Z	Jiangsu Province And Chinese Academy Of Sciences, Nanjing, China	17	36	2013	1331	42
Li Y	Chinese Academy Of Sciences (Cas), China	15	29	2012	876	41
Liu Y	Gulin University Of Technology, China	12	19	2006	402	37

Note(s): h-index: it indicates the highest number of individual author's papers to have similar and or higher citations; g-index: it helps to identify the more weightage to highly cited paper; TC: Total Citation; NP: Number of Publication; PY Start: Publication Year Start. (Source: SCOPUS, 2025).

Table 5. Top 10 published papers with metrics from cleaned and merged dataset (SCOPUS, 2025).

No.	Authors (Year)	Country	Title	Journal	Total Citations (TC)	TC per Year
1	Giri, Ochieng, Tiesen, Zhu, Stough, Loveland and Duke (2011)	USA	Status And Distribution Of Mangrove Forests Of The World Using Earth Observation Satellite Data	Global Ecology And Biogeography	2347	156.47
2	Alongi (2014)	Australia	Present State And Future Of The World's Mangrove Forests	Environmental Conservation	1533	63.88
3	Temmerman, Meire, Bouma, Herman, Ysebaert and Vriend (2013)	Belgium	Ecosystem-Based Coastal Defence In The Face Of Global Change	Nature	1345	103.46
4	Pendleton, Donato, Murray, Crooks, Jenkins, Silliman and Balderas (2012)	USA	Estimating Global "Blue Carbon" Emissions From Conversion And Degradation Of Vegetated Coastal Ecosystems	PLoS One	1195	85.36
5	Barber, Koeh, Silliman, Hacker, Wolanski, Primavera and Reed (2008)	USA	Coastal Ecosystem-Based Management With Nonlinear Ecological Functions And Values	Science	916	50.89
6	Richards and Friess (2016)	Singapore	Rates And Drivers Of Mangrove Deforestation In Southeast Asia, 2000-2012	PNAS (USA)	910	91.00
7	Hamilton and Casey (2016)	USA	Creation Of A High Spatio-Temporal Resolution Global Database Of Continuous Mangrove Forest Cover For The 21st Century (Cgmfc-21)	Global Ecology And Biogeography	851	85.10
8	Murray, Worthington, Bunting, Duce, Hagger, Lovelock and Lyons (2022)	Australia	The Global Distribution And Trajectory Of Tidal Flats	Nature	768	109.71
9	Shepard, Crain and Beck (2011)	UK	The Gulf: A Young Sea In Decline	Marine Pollution Bulletin	694	43.38

Table 6. Top 10 most productive journals with metrics from cleaned and merged dataset (SCOPUS, 2025).

Sources	Articles	%	MC	IF	Subject field
<i>IOP Conference Series: Earth And Environmental Science</i>	188	3.62	5.36	-	Environmental Science; Earth Systems
<i>Remote Sensing</i>	161	3.10	45.14	4.1	Remote Sensing; Earth Observation
<i>Science of The Total Environment</i>	108	2.08	33.49	8.0	Environmental Science; Pollution
<i>Estuarine, Coastal and Shelf Science</i>	104	2.00	57.08	2.6	Marine Science; Estuarine Studies
<i>Ocean and Coastal Management</i>	93	1.79	36.23	5.4	Coastal Management; Policy
<i>Marine Pollution Bulletin</i>	88	1.69	59.62	4.9	Marine Pollution; Coastal Ecology
<i>Forests</i>	70	1.35	22.71	2.5	Forestry; Ecosystems
<i>Regional Studies in Marine Science</i>	68	1.31	11.69	2.4	Marine Science
<i>Wetlands Ecology and Management</i>	57	1.10	32.84	1.6	Wetlands; Ecology
<i>International Geoscience and Remote Sensing Symposium (IGARSS)</i>	55	1.06	3.40	-	Remote Sensing; Geoscience

Note(s): % = Percentage share of total articles contributed by that source, MC = Mean Citations per article (MC) i.e., the average number of citations received per article in that particular source. It shows the impact and influence of publications from that journal., IF = Impact Factor of the journals.

parameters of the published documents on selected keywords over Scopus database. Table 4 showcases the top 10 published authors with metrics from merged datasets, where individual author published more than thirty documents along with the several metrics such as Total Citations (TC), h-index and g-index. This statistic ranks the authors as per the h-index level, where, Dahdouh-Guebas F was the first rank holder, having 38 h-index published 72 papers and received 3973 citations starting in this field since 1997. Zhang Y had the second rank, having 23 h-index, appearing in 70 research documents starting since 2004, followed by Wang Y (h-index: 19), appearing in 55 documents since 2003. Next comes Koedam N, who had 32 h-index, showcasing 55 research outputs since 1997. 5th rank holder was Friess DA, having 34 h-index with 48 total documents since 2013, followed by Wang J (h-index: 19; NP: 48 starting since 2001); Li J (h-index: 15; NP: 46 starting since 2005); Wang Z (h-index: 17; NP: 42 starting since 2013); Li Y (h-index: 15; NP: 41 starting since 2012). Last but not the least the 10th rank holder was Liu Y with 12 h-index, appearing in 37 research documents since 2006. As an overall, these top 10 most productive authors published 510 articles, deliberating 12.41% of all merged publications, clearing out all the duplicities.

Table 5 is the summarized tabulation on top ten papers along with total citations per year, journal details and author details. The highest cited article is “Status and Distribution of Mangrove Forests of the World Using Earth Observation Satellite Data” by Giri et al. (2011), having TC per

year 2347, accounting the average citations as 156.47, was published in “Global Ecology and Biogeography”. The second rank holder is Murray et al. (2022) who had published “The Global Distribution and Trajectory of Tidal Flats”, acquiring 768 TC per year, accounting for approximately average TC of 109.71 in “Nature”. 10th rank holder is Shepard et al. (2011) having TC per year is 694, accounting for 43.38 average TC per year that is the lowest one for the publication “The Gulf: A Young Sea in Decline” in “Marine Pollution Bulletin”. Table 6 illustrates the top ten most productive journals from 1995 to 2025 where, several attributes on journal wise article frequency along with percentage values, Impact Factor (IF), subject fields are accounted specifically. The range of published documents varies with a maximum value of 188 to minimum one at 55 among the top most productive journals, referenced from SCOPUS (2025). *IOP Conference Series: Earth and Environmental Science* is the top most productive one among the others with total documents of 188, impact factor of 0.30, mean citation of 5.36. Among the top ten most productive journals, it delivers 3.62% to the overall, specifically focusing *Environmental Science; Earth Systems*. *Remote Sensing* is the second most productive one, accounting total 161 documents along with 45.14 of mean citation having IF as 4.1 (2024) in the field of *Remote Sensing; Earth Observation*, delivering 3.10% to the overall publications. Among this productive ones, *Science of The Total Environment* has the highest level of Impact Factor of 8.0, covering only 2.08 % of articles, followed by *Ocean and Coastal Management* (IF 5.4);

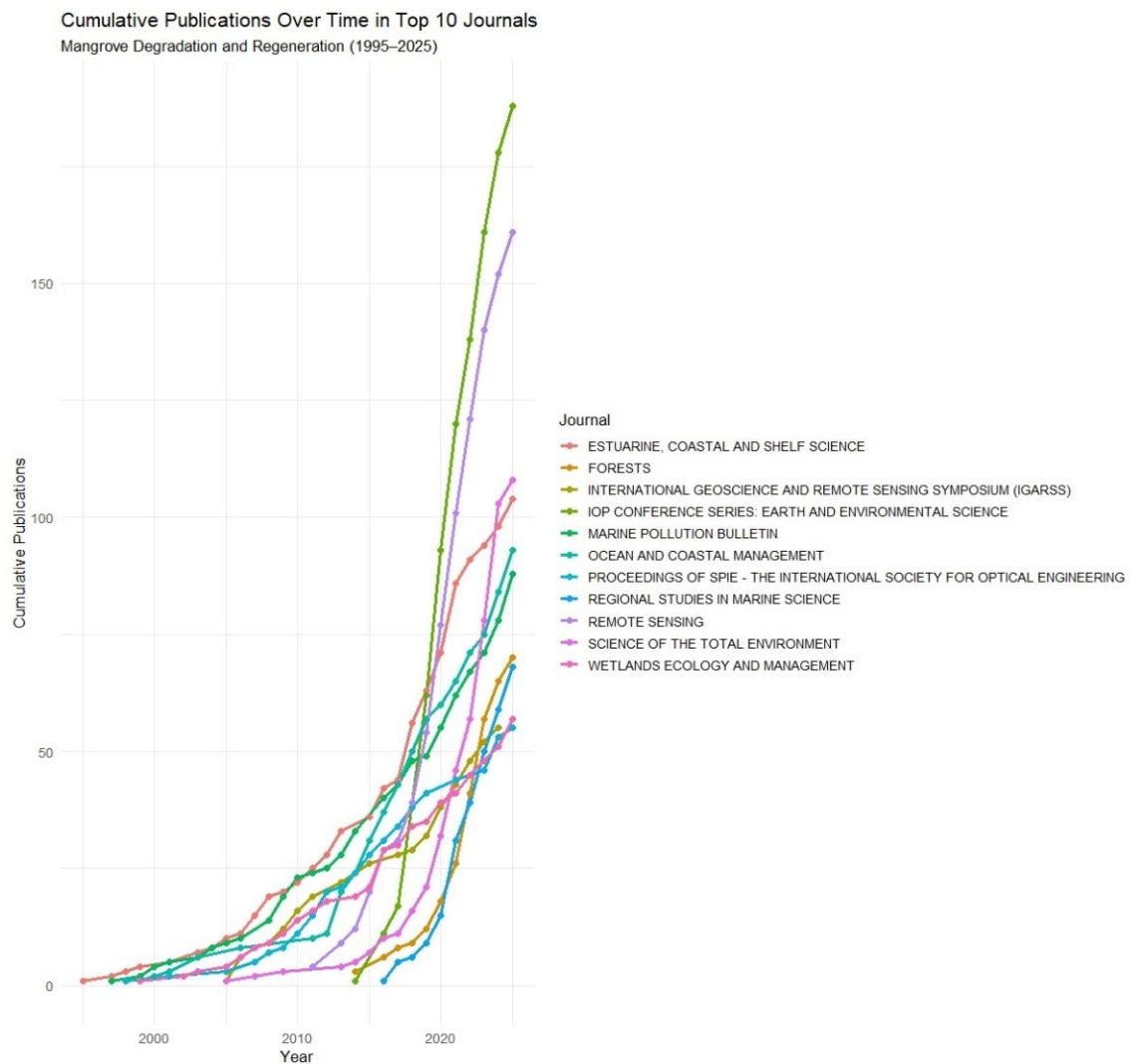


Fig. 5. Cumulative publications over time in the top ten journals (1995–2025). The figure shows a steady increase in research output on mangrove degradation and regeneration, particularly after 2010, with journals such as *Science of the Total Environment*, *Remote Sensing* and *Ocean and Coastal Management* showing the highest cumulative growth. (Data Source: SCOPUS, 2025).

Marine Pollution Bulletin (IF 4.9); *Remote Sensing* (IF 4.1); *Estuarine, Coastal and Shelf Science* (IF 2.6); *Forests* (IF: 2.5); *Regional Studies in Marine Science* (IF: 2.4); *Wetlands Ecology and Management* (IF: 1.6). Emergence of subject field got also revealed from this output (Table 6), where Environmental Science; Earth Systems held the primary productive subject field followed by the others such as Remote Sensing; Earth Observation, Environmental Science; Pollution, Marine Science; Estuarine Studies, Coastal Management; Policy, Marine Pollution; Coastal Ecology, Forestry; Ecosystems, Marine Science, Wetlands; Ecology and Remote Sensing; Geoscience.

Fig. 5 illustrates the cumulative number of publications on ‘mangrove degradation and regeneration’ from 1995 to 2025, across the top ten most contributing journals (see Table 6). The most prolific journal, *IOP Conference Series: Earth and Environmental Science*, began publishing on the topic after 2010 and experienced an exponential rise in publications after 2017, culminating in the highest cumulative count by 2025. *Remote Sensing*, another leading contributor, entered the field around 2010 and displayed a steep

rise in publication output especially after 2018, indicating a rapid adoption of geospatial technologies in mangrove research. *Estuarine, Coastal and Shelf Science*, a traditional marine journal, shows a consistent and steady contribution since the early 2000s, with a notable slope from 2015 onwards. *Ocean and Coastal Management* maintained a moderate pace of publication until around 2016, after which a steep incline is visible. Other sources like *Forests*, *Regional Studies in Marine Science*, and *Wetlands Ecology and Management* started contributing later and show varied trajectories. The cumulative trends suggest that post 2015 marks a turning point, indicating widening interdisciplinary interest in mangrove research.

Deliberation on the top ten most productive organizations on sorted datasets is visualized through Fig. 6 where, size of each bubble represents the publication volume, while the horizontal axis reflects the average citations per publication, providing insight into both productivity and scholarly impact. *National University of Singapore* stands out with a high average citation count (above 70) followed by *Xiamen University* and *Sun Yat-sen University*, both from China,

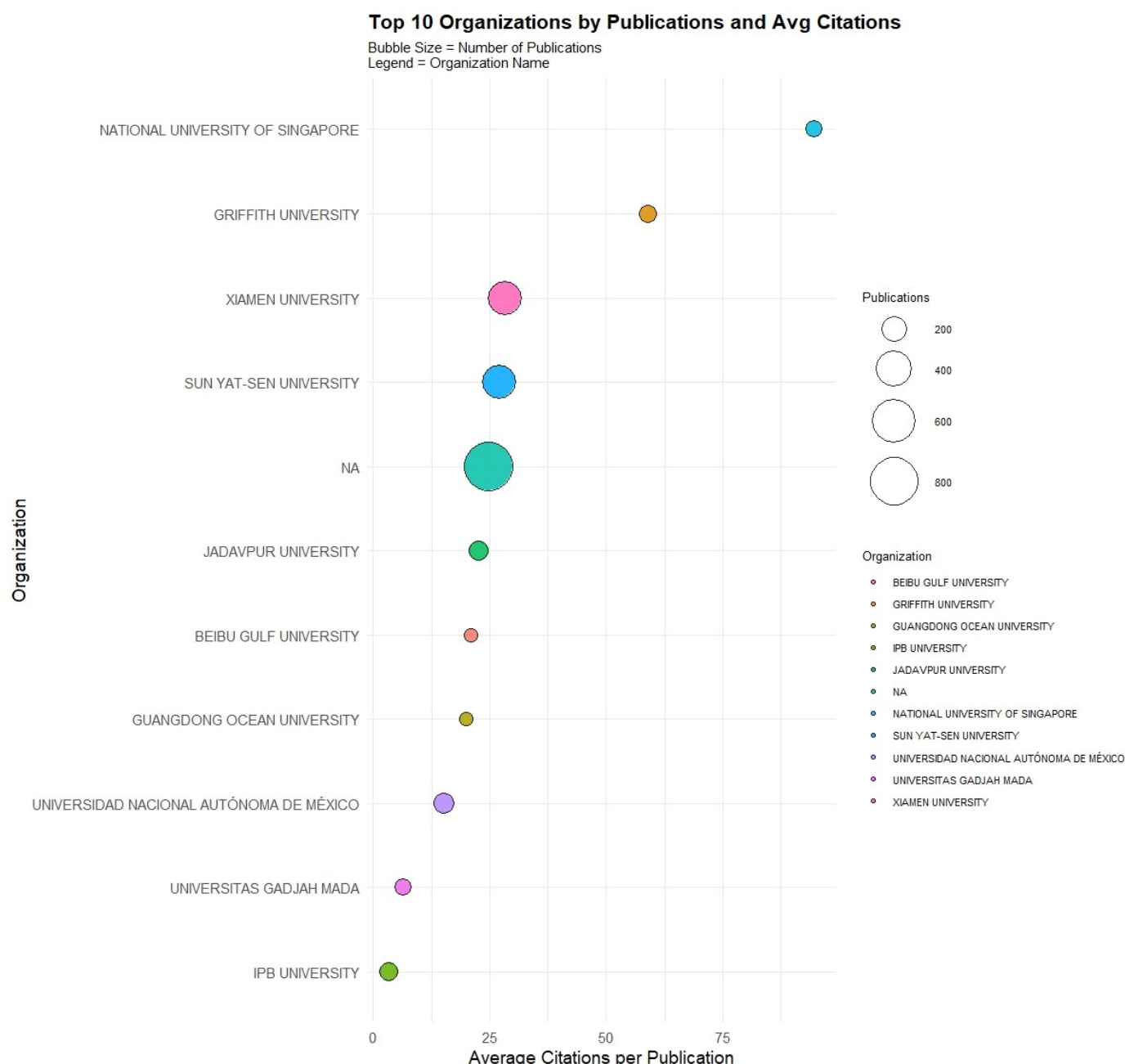


Fig. 6. Top ten productive organizations by publications and received citations. 1. “National University Of Singapore” (Singapore), 2. “Griffith University” (Australia), 3. “Xiamen University” (China), 4. “Sun Yat-Sen University” (China), 5. “Jadavpur University” (India), 6. “Beibu Gulf University” (China), 7. “Guangdong Ocean University” (China), 8. “Universidad Nacional Autónoma De México” (Mexico), 9. “Universitas Gadjah Mada” (Indonesia), 10. “IPB University” (Indonesia); “NA” means not reported by SCOPUS database (Data Source: [SCOPUS, 2025](#)).

contributed significantly in terms of volume, with Xiamen University having one of the largest publication bubbles and maintaining a solid citation average (~30). “NA” appears as the largest bubble, indicating the highest number of publications but with a lower average citation (~20) and Other institutions such as *Jadavpur University (India)*, *Beibu Gulf University*, *Guangdong Ocean University*, *Universidad Nacional Autónoma de México*, *Universitas Gadjah Mada*, and *IPB University* show varying combinations of productivity and impact. In an over all, this chart reveals a regional concentration of highly diversified research leadership in East

and Southeast Asia, with China, Singapore, and Australia being prominent contributors.

Table 7 represents rank wise highly cited countries along with total and average number of citations. India holds the first position, covering 566 number of articles having 10002 as total citations, accounting for 17.7 average citations that is quite lower than the others. However, the average citation is highest for Singapore (87.0), followed by Netherlands (60.4), Australia (59.2), USA (56.3), Italy (54.2), Germany (45.1), France (40.6) and others. Lowest number of articles covered in Italy with 1896 articles.

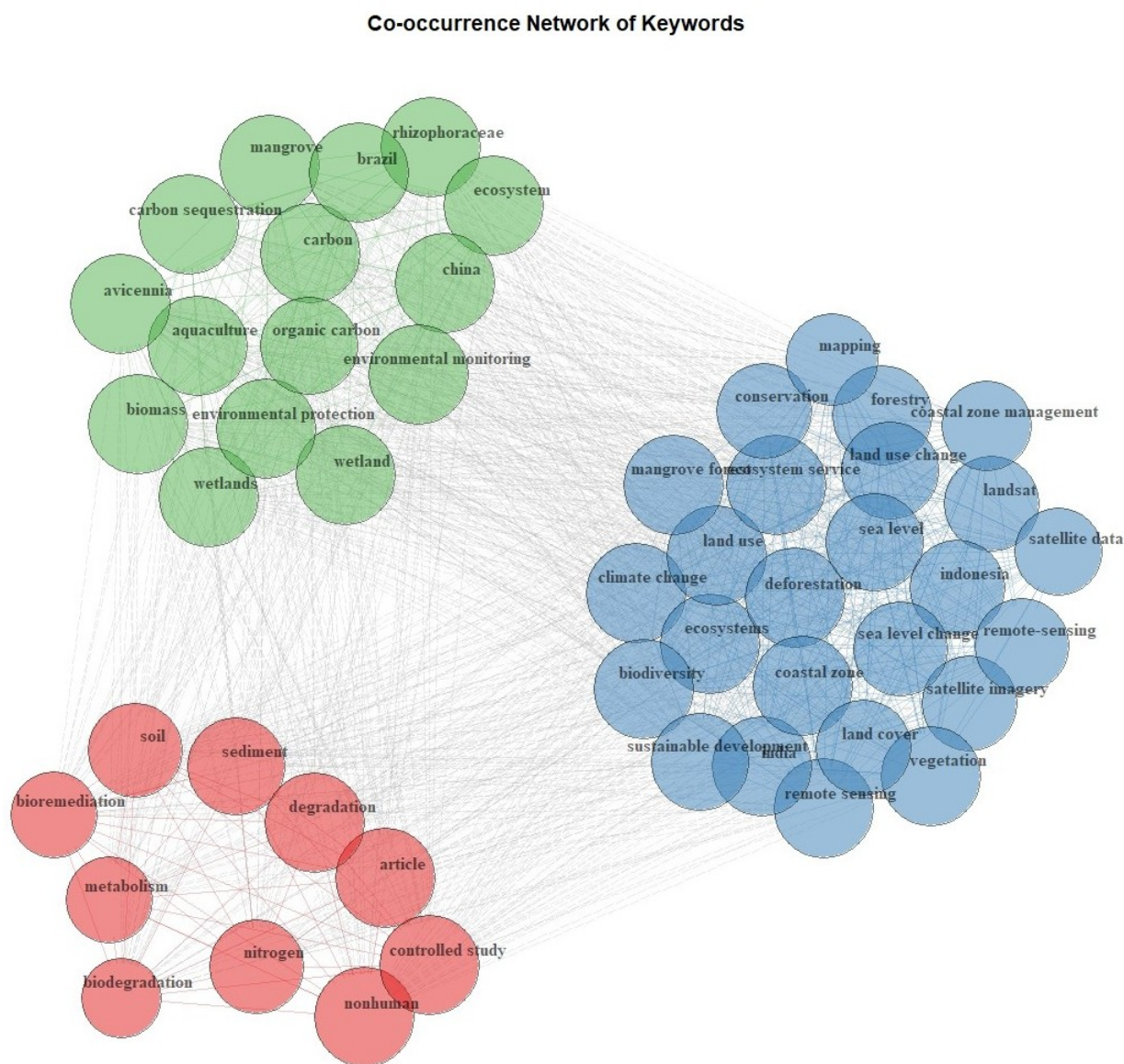


Fig. 7. Co-occurrence network on most frequently used keywords (Top 50) (Source: [SCOPUS, 2025](#)).

Table 7. Ranked highly cited countries along with total and average citations.

Countries	Articles	Total Citations	Average Citations
USA	557	31359	56.3
Australia	292	17300	59.2
China	767	15979	20.8
India	566	10002	17.7
Germany	114	5144	45.1
Brazil	246	5079	20.6
UK	142	4544	32
Singapore	52	4525	87.0
Belgium	94	4114	43.8
Indonesia	521	4085	7.84
Malaysia	144	3879	26.9
Netherlands	64	3867	60.4
France	95	3861	40.6
Mexico	138	3546	25.7
Japan	131	3372	25.7
Hong Kong	61	2286	37.5
Bangladesh	89	2130	23.9
Italy	35	1896	54.2
Thailand	83	1879	22.6
Canada	50	1804	36.1

4.3 Top Most Keywords and Author Keywords Analysis

Co-occurrence network of the most frequently used keywords derived from the merged bibliometric data on mangrove-related research is visualized after Fig. 7, where Each node (circle) represents a keyword, and the edges (lines) connecting them indicate co-occurrence relationships. The node size corresponds to the frequency of the keyword. Blue cluster is the largest and most central cluster that consists of terms such as “climate change”, “ecosystem services”, “mangrove forest”, “deforestation”, “biodiversity”, and “sustainable development”. Keywords such as “land use change”, “coastal zone”, “satellite imagery”, and “remote sensing” also appear prominently which shows strong concern in geospatial analysis, land cover monitoring, and environmental sustainability, global environmental concerns and policy-related ecosystem management. Green cluster is dominated by “carbon”, “carbon sequestration”, “wetland”, “organic carbon”, “biomass”, “aqua-

Co-occurrence Network of Top 50 Author Keywords

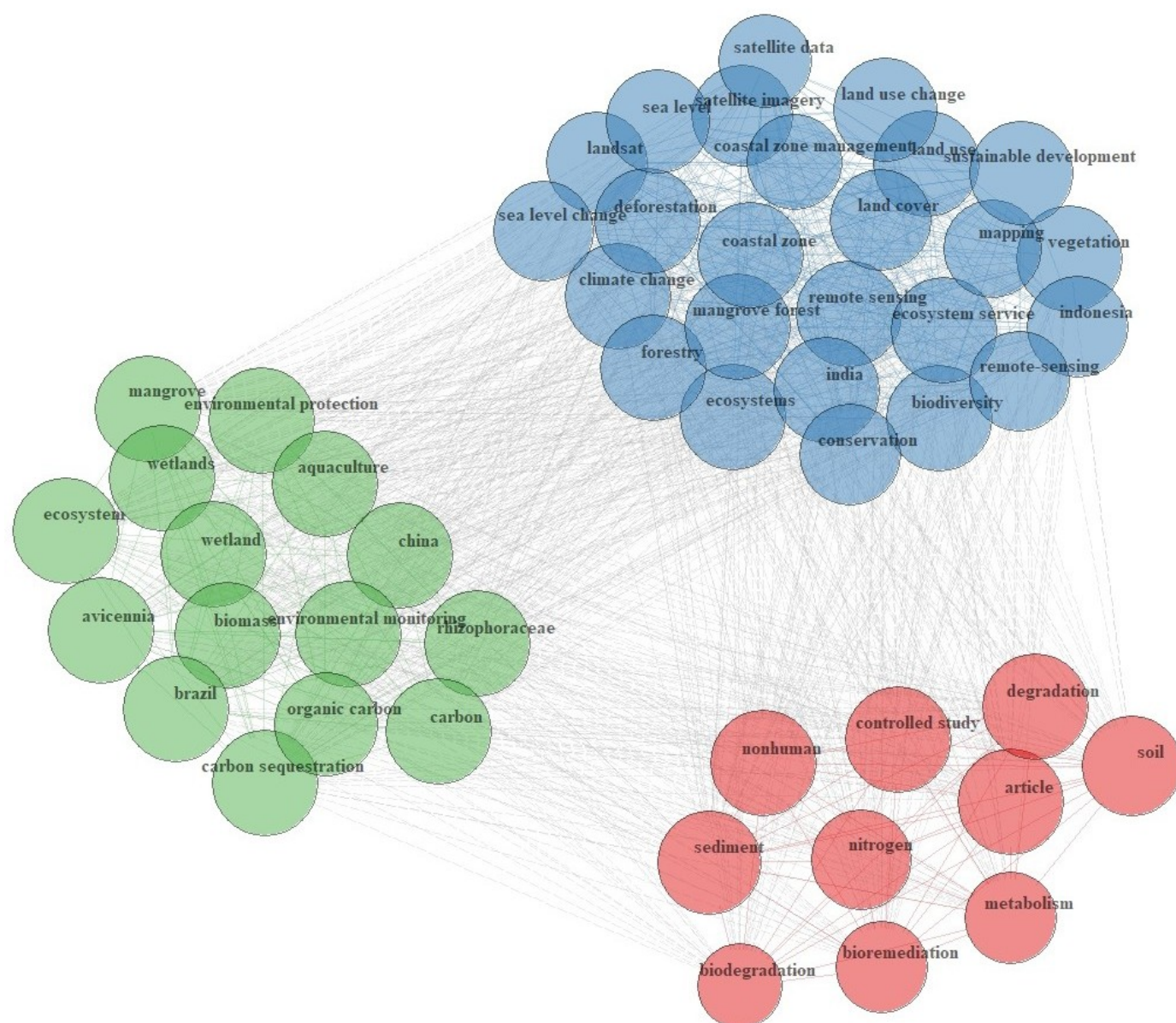


Fig. 8. Co-occurrence network on most frequently used author keywords (Top 50) (Source: [SCOPUS, 2025](#)).

culture”, and “environmental protection”, emphasizing research on carbon storage potential of mangroves, blue carbon, and wetland conservation.

Red cluster is composed of terms like “degradation”, “soil”, “sediment”, “bioremediation”, “nitrogen”, “biodegradation”, “metabolism”, “controlled study”, and “nonhuman”. Apparently, This network (Fig. 7) reveals three distinct thematic areas in mangrove research: (1) environmental monitoring & services, (2) carbon cycling & wetland function, and (3) pollution & bioremediation.

Fig. 8 corresponds to co-occurrence network on most frequently used Top 50 author keywords which enables the fact that there is existence of interdisciplinary nature of mangrove research, spanning from remote sensing and GIS to ecology, soil science, and biogeochemistry. Blue cluster

emphasizes global environmental change and monitoring efforts, especially in relation to mangroves and their ecological functions. Green cluster interprets focus on carbon dynamics, wetland ecology, and mangrove species, giving nature based solutions to climate change issues. Red cluster focuses on mangrove degradation, pollution impacts, and remediation techniques.

This trend analysis (Fig. 9) highlights the evolution of mangrove research from traditional ecological studies to technology-enabled and climate-focused investigations. The rising frequency of terms like machine learning, NDVI, ecosystem services, and sea level rise marks a paradigm shift toward data-driven, policy-relevant, and multidisciplinary approaches. Moreover, the diversity of terms emphasizes the broadening scope of mangrove research, span-

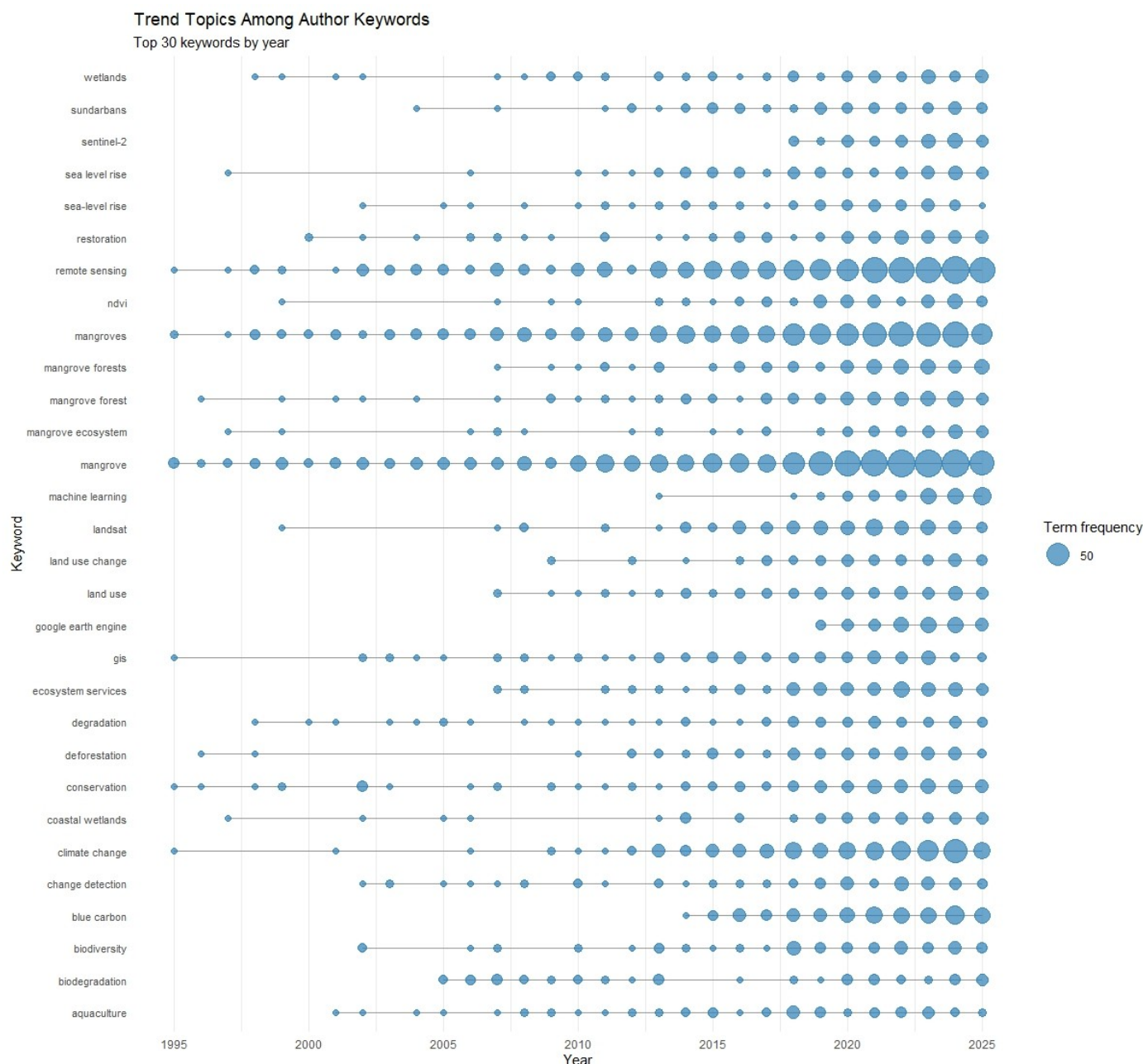


Fig. 9. Trend topics among author keywords. The bubble chart shows the evolving prominence of key research themes, with recent years highlighting increased focus on **remote sensing**, **NDVI**, **machine learning**, and **blue carbon**. (Source: SCOPUS, 2025).

ning from biodiversity and restoration to carbon dynamics and remote sensing. “Sundarbans” consistently appears from early years to 2025, highlighting its importance as a case study region in mangrove research. “GIS”, “land use change”, and “Landsat” represent the increasing reliance on spatial data tools and long-term satellite observation. Declining topics are “biodegradation”, “aquaculture”, “biogeography” getting limited attention and “degradation”, “deforestation”, and “conservation” as moderate relevance.

4.4 Country-wise Co-Authorship Network Mapping

Country wise co-authorship network mapping has been made using bibliometric approach at VOSviewer where,

maximum number of countries per document is set to 25 and minimum is 5, that is why, 86 meets the threshold of total 187 countries. Fig. 10 depicts the collaboration level among the countries with respect to total number of publications. Size of node corresponds to the total number of publications associated with countries; larger the node greater the research output. This network mapping reveals a highly collaborative and involvement of international research in the extended field of mangrove research. Dominant countries are China, USA and Australia both in terms of publication deliberations and global research involvement and collaboration. Nine clusters have been segregated for this output mapping. USA, China, Brazil, France, Australia, India, UK, Indonesia, Bangladesh are the most influential and

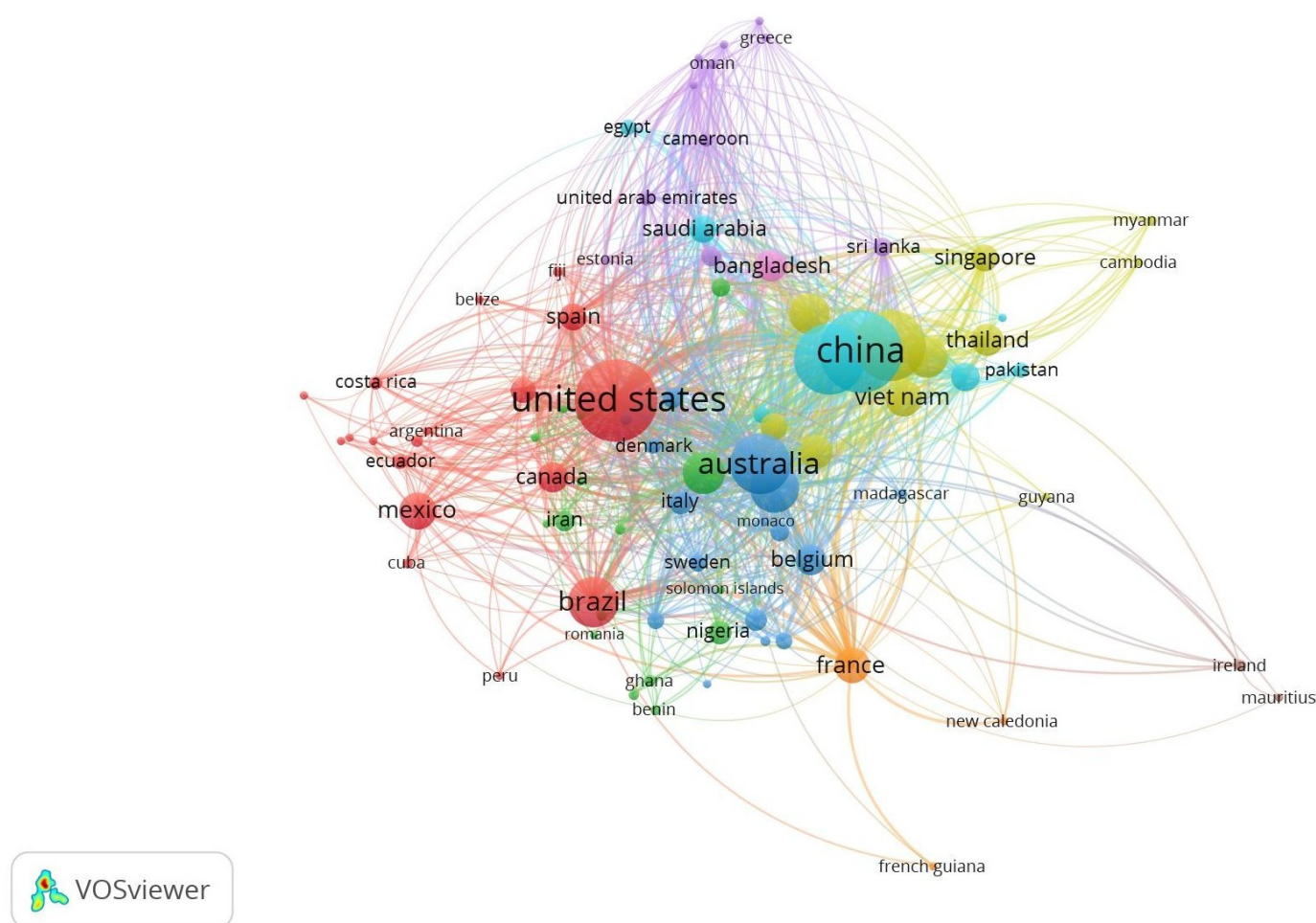


Fig. 10. Top country-wise co-authorship network mapping on merged datasets. The map, generated using **VOSviewer**, illustrates international research collaboration patterns, highlighting strong co-authorship links among leading countries such as **China**, the **United States**, **Australia**, **France**, and **Brazil**. (Data Source: [SCOPUS](#), 2025).

productive in this sense. Among the collaborators, USA has the highest level of links (77), total link strength (1120) covering 898 mangrove degradation and regeneration related research documents. Primary association is built with USA are Brazil, Canada, France, Spain, Sri Lanka, Singapore.

4.5 Thematic Evolution and Mapping

This alluvial plot ([Fig. 11](#)) visualizes the temporal flow and evolution (1995–2005; 2006–2015; 2016–2025) of the most frequent author keywords in mangrove-related research. In recent phase (2016–2025), strong emergence is implemented through several keywords such as “Blue carbon”, “Google Earth Engine”, “GIS”, “remote sensing”, “Sea level rise”, “restoration”. Most persistent keywords throughout these three decades are “mangroves”, “mangrove”, “mangrove forest”, “mangrove forests”. Widened utilized keywords are following: “Climate change”, “conservation”, “ecosystem services”, and “land use”.

Thematic mapping on author keywords for the selected span (1995–2025) ([Fig. 12](#)) suggests four clusters named as *Niche themes*, *Motor themes*, *Emerging or Declining themes* and *Basic themes*. Results show that “remote sensing”, “forestry”, “land use”, “satellite imagery”. “mangrove forest” overlaps the Basic and Emerging or Declining themes.

“mangrove”, “rhizophoraceae”, “ecosystems”, “article” and “climate change” overlaps both Basic and Motor themes. “controlled study”, “sediment”, “degradation”, “biodegradation”, “metabolism” belong to Niche theme.

5 Conclusions

This study investigated research trends across the globe and correlation among several academic verses through peer reviewed publications on key aspects (primary keywords) related to degradation and regeneration of mangroves ([Table 1](#)) since 1995 to 2025. These keywords are set to retrieve the peer reviewed research documents at Scopus database. After retrieval, merging and cleaning procedure were run to get the comprehensive and holistic resultant database that assess relevant parameters on summary on publication outputs, author details, journals, author metrics such as h-index, g-index, impact factor of journals, citation counts, average number of citations, keywords, author keywords, institution and countries as well. All these metrics along with significant and suitable interconnected visualizations and statistical analyses give relevant insights on past trends, recent emergence and future orientation in the field of degradation and regeneration aspects of mangrove studies. In accordance with the resultant outputs, this study enumer-

Evolution of Top Author Keywords in Mangrove Research (1995–2025)

Alluvial Plot by Time Block

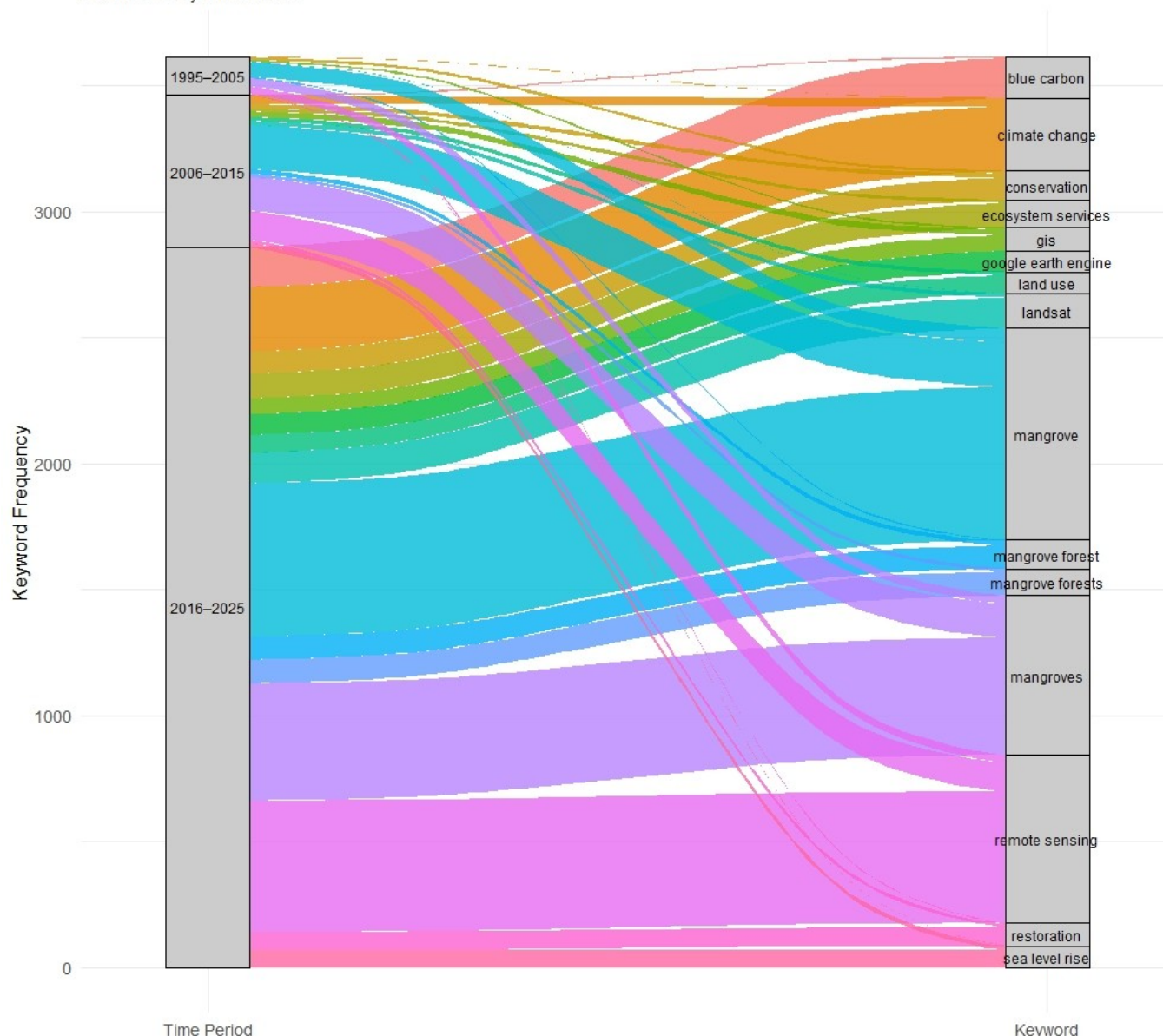


Fig. 11. Thematic evolution through alluvial plot of top author keywords in mangrove research (1995–2025), generated from R Studio. The alluvial plot illustrates the shifting prominence of research themes across three time periods, showing an early focus on **mangroves**, **restoration**, and **deforestation**, evolving toward recent emphasis on **remote sensing**, **climate change**, **blue carbon**, and **ecosystem services**.

ates that during the first phase (1995–2015) major themes concentrated to mangrove and its degradation, regeneration aspects however, during the next phase (2016–2025), it oriented its pathway to remote sensing applications and Google Earth Engine platform analysis in these aspects and carbon stock concept as the trending concept in mangrove studies across the globe. Keyword insights show its true nature where first phase (1995–2005) consists of studies on ‘blue carbon’; next (2006–2015) composed of ‘climate change’, ‘gis’, ‘ecosystem services’, ‘conservation’ and ‘climate change’; (2016–2025) phase belongs to ‘mangroves’, ‘mangrove forest’, ‘sea level rise’ and ‘restoration’. Considerably, this bibliometric analysis also boosts the substan-

tial research advancements by the scholars and other dignitaries from developed as well as developing countries. More specifically, USA have contributed significantly in this manner being the topmost country, primarily associated with Brazil, Canada, France, Spain, Sri Lanka, Singapore. Apart from USA, China, Brazil, France, Australia, India, UK, Indonesia, Bangladesh are the most influential and productive in this sense. India got 4th rank, availing 10002 total citations from 566 of total articles and Bangladesh got 17th position, availing 89 total citations from 2130 of total articles. Despite increased research activity in India, total citations are considerable low in nature and it has to be increased as this country along with Bangladesh is the abode

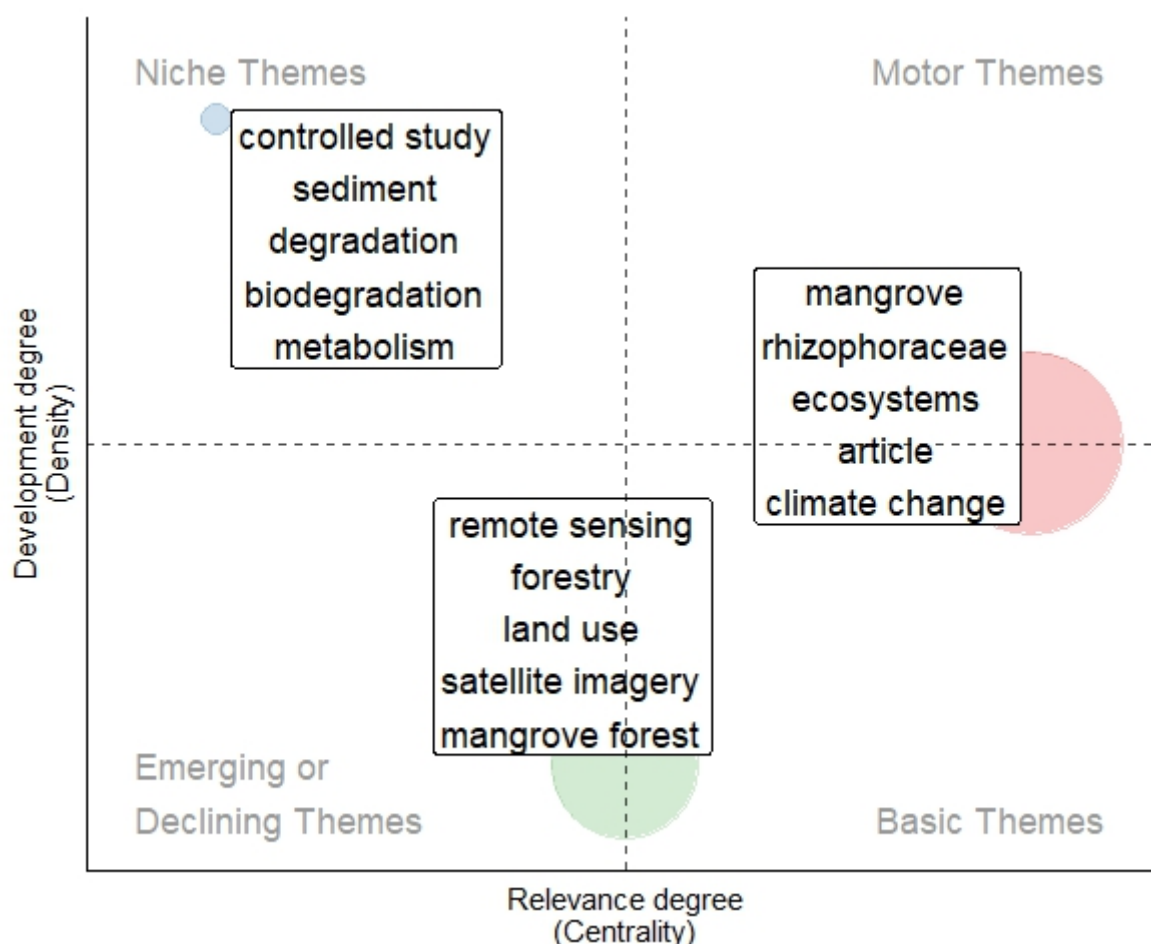


Fig. 12. Thematic map on author keywords (1995–2025). The map, generated from R Studio, classifies themes into four quadrants (**motor themes**, **niche themes**, **emerging or declining themes**, and **basic themes**), based on their **centrality** (relevance) and **density** (development). (Source: SCOPUS, 2025).

to world's largest mangrove forest. International collaboration and engagement of enormous research projects on Sundarbans and mangrove studies can harness the expertise level and resources so that both countries can undertake significant researches amidst several local challenges and perspectives. As the concluding remarks, it can be recommended that future research on possible factors influencing the degradation and sustainability towards regeneration is important to be focused and dripped from researchers to policy makers. Afterwards, policymakers can make policies according to evidences addressing all regional to global level challenges and circumstances. Trending topics from the past and recent bibliometric studies offer valuable insights on sustainability of mangrove forests through regeneration, ecosystem services and Remote Sensing application into the dynamic mangrove-scape. Importance of interdisciplinary and multidisciplinary collaboration along with international engagement for possible resources and expertise in research projects, policy making studies are fully desirable. Cooperation among researchers, experts from different genre, policy makers, stakeholders is necessitated to aware the locals and layman to protect the valuable mangrove ecosystem by approaching and brainstorming on sustainable management for future generations, restoration of

native mangrove species and application on conservational strategies.

Acknowledgments

The authors are grateful to the University Grant Commission (UGC) for providing the Fellowship to the First Author as NET SRF. The authors have extended their deep appreciation and indebtedness to Jadavpur University for providing the logistics and infrastructure.

CRediT statement

SC: Conceptualization, Methodology, Investigation, Data curation, Data analysis, writing – original draft and editing the reviewed draft manuscript. **GB:** Supervision and reviewing the draft manuscript.

Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose.

Data availability

Data will be made available on request.

Funding Statement

This study has not received any funds.

Ethics

Not Applicable.

Consent to Participate

Not Applicable.

Consent to Publish declarations

Not Applicable.

References

- Adisa, O.M., Masinde, M., Botai, J.O., Botai, C.M., 2020. Bibliometric analysis of methods and tools for drought monitoring and prediction in africa. *Sustainability* 12, 6516. <https://doi.org/10.3390/su12166516>.
- Ali, M.J., 2021-05. Understanding the 'g-index' and the 'e-index'. *Seminars in Ophthalmology* 36, 139–139. <https://doi.org/10.1080/08820538.2021.1922975>.
- Alongi, D.M., 2014. Carbon cycling and storage in mangrove forests. *Annual Reviews of Marine Science* 6, 195–219. <https://doi.org/10.1146/annurev-marine-010213-135020>.
- Aria, M., Cuccurullo, C., 2017. bibliometrix: An r-tool for comprehensive science mapping analysis. *Journal of Informetrics* 11, 959–975. <https://doi.org/10.1016/j.joi.2017.08.007>.
- Aznar-Sánchez, J.A., Belmonte-Ureña, L.J., López-Serrano, M.J., Velasco-Muñoz, J.F., 2018. Forest ecosystem services: An analysis of worldwide research. *Forests* 9, 453. <https://doi.org/10.3390/f9080453>.
- Barbier, E.B., Koch, E.W., Silliman, B.R., Hacker, S.D., Wolanski, E., Primavera, J., Reed, D.J., 2008. Coastal ecosystem-based management with nonlinear ecological functions and values. *Science* 319, 321–323. <https://doi.org/10.1126/science.1150349>.
- Beddu, M.A., Idrus, R., Samawi, F., Paradiman, A.Z., Jafar, I., 2025. Recent research trends in mangrove management systems (2014–2023) and predictions of future research; a bibliometric analysis. *Watershed Ecology and the Environment* <https://doi.org/10.1016/j.wsee.2025.04.003>.
- Begum, F., Bruyn, L.L., Kristiansen, P., Islam, M.A., 2021. Institutionalising co-management activities for conservation of forest resources: Evidence from the sundarban mangrove forest management of bangladesh. *Journal of Environmental Management* 298, 113504. <https://doi.org/10.1016/j.jenvman.2021.113504>.
- Bindu, G., Rajan, P., Jishnu, E.S., Joseph, K.A., 2020. Carbon stock assessment of mangroves using remote sensing and geographic information system. *The Egyptian Journal of Remote Sensing and Space Science* 23, 1–9. <https://doi.org/10.1016/j.ejrs.2018.04.006>.
- Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R.M., Thomas, N., Tadono, T., Rebelo, L.M., 2022. Global mangrove extent change 1996–2020: global mangrove watch version 3.0. *Remote Sensing* 14, 3657. <https://doi.org/10.3390/rs14153657>.
- Callon, M., Courtial, J.P., Turner, W.A., Bauin, S., 1983. From translations to problematic networks: An introduction to co-word analysis. *Social Science Information* 22, 191–235. <https://doi.org/10.1177/053901883022002003>.
- 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, 01810. <https://doi.org/10.1002/eap.1810>.
- Cardoso-Fernandes, J., Teodoro, A.C., Lima, A., 2019. Remote sensing data in lithium (li) exploration: A new approach for the detection of li-bearing pegmatites. *International Journal of Applied Earth Observation and Geoinformation* 76, 10–25. <https://doi.org/10.1016/j.jag.2018.11.001>.
- Chamberland-Fontaine, S., Estrada, G.T., Heckadon-Moreno, S., Hickey, G.M., 2022. Enhancing the sustainable management of mangrove forests: The case of punta galeta, panama. *Trees, Forests and People* 8, 100274. <https://doi.org/10.1016/j.tfp.2022.100274>.
- Chen, G., Mo, Y., Gu, X., Wang, W., Cui, B., 2022. Mapping the spatio-temporal dynamics of global mangrove crabs to reveal its status and challenges: A bibliometric evaluation of research output during 1980–2016. *Watershed Ecology and the Environment* 4, 100–111. <https://doi.org/10.1016/j.wsee.2022.09.002>.
- Chen, G., Xiao, L., 2016. Selecting publication keywords for domain analysis in bibliometrics: A comparison of three methods. *Journal of Informetrics* 10, 212–223. <https://doi.org/10.1016/j.joi.2016.01.006>.
- Chen, X., Lun, Y., Yan, J., Hao, T., Weng, H., 2019. Discovering thematic change and evolution of utilizing social media for healthcare research. *BMC Medical Informatics and Decision Making* 19, 39–53. <https://doi.org/10.1186/s12911-019-0757-4>.
- Chow, J., 2018. Determinants of household fuelwood collection from mangrove plantations in coastal bangladesh. *Forest Policy and Economics* 96, 83–92. <https://doi.org/10.1016/j.forpol.2018.08.007>.
- Cissell, J.R., Delgado, A.M., Sweetman, B.M., Steinberg, M.K., 2018. Monitoring mangrove forest dynamics in campeche, mexico, using landsat satellite data. *Remote Sensing Applications: Society and Environment* 9, 60–68. <https://doi.org/10.1016/j.rsase.2017.12.001>.
- Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E., Herrera, F., 2011. An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the fuzzy sets theory field. *Journal of Informetrics* 5, 146–166. <https://doi.org/10.1016/j.joi.2010.10.002>.
- Dahdouh-Guebas, F., 2011. World atlas of mangroves. *Hum Ecol* 39, 107–109. <https://doi.org/10.1007/s10745-010-9366-7>.
- Dasgupta, S., Islam, M.S., Huq, M., Huque Khan, Z., Hasib, M.R., 2019. Quantifying the protective capacity of mangroves from storm surges in coastal bangladesh. *PloS One* 14, 0214079. <https://doi.org/10.1371/journal.pone.0214079>.
- Diniz, C., Cortinhas, L., Nerino, G., Rodrigues, J., Sadeck, L., Adami, M., Souza-Filho, P.W.M., 2019. Brazilian mangrove status: Three decades of satellite data analysis. *Remote Sensing* 11, 808. <https://doi.org/10.3390/rs11070808>.
- Djamaluddin, R., 2019. Growth pattern in tropical mangrove trees of bunaken national park, north sulawesi, indonesia. *Biodiversitas Journal of Biological Diversity* 20. <https://doi.org/10.13057/biodiv/d200630>.
- Donato, D.C., Kauffman, J.B., Murdiyarto, D., Kurnianto, S., Stidham, M., Kanninen, M., 2011. Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience* 4, 293–297. <https://doi.org/10.1038/ngeo1123>.
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W.M., 2021. How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research* 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>.
- Duan, P., Wang, Y., Yin, P., 2020. Remote sensing applications in monitoring of protected areas: A bibliometric anal-

- ysis. *Remote Sensing* 12, 772. <https://doi.org/10.3390/rs12050772>.
- Duke, N.C., 2011. Mangroves, in: *Encyclopedia of Modern Coral Reefs: Structure, Form and Process*, p. 655–663.
- Egghe, L., 2006. Theory and practise of the g-index. *Scientometrics* 69, 131–152. <https://doi.org/10.1007/s11192-006-0144-7>.
- Elsevier, 2020. Content coverage guide. *Scopus*, 1–24.
- Fatoyinbo, T.E., Lagomasino, D., Lee, S.K., Trettin, C., 2023. Mangrove forest carbon stock and potential emissions from mangrove loss across coastal geographies of africa. *Forests* 14, 824. <https://doi.org/10.3390/f14040824>.
- Fourqurean, J., Johnson, B., Kauffman, J.B., Kennedy, H., Lovelock, C., Megonigal, J.P., 2014. COASTAL BLUE CARBON: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows. *Conservation International, Intergovernmental Oceanographic Commission of UNESCO, Virginia, USA: Conservation International, Intergovernmental Oceanographic Commission of UNESCO*.
- Gao, C., Ruan, T., 2018. Bibliometric analysis of global research progress on coastal flooding 1995–2016. *Chinese Geographical Science* 28, 998–1008. <https://doi.org/10.1007/s11769-018-0996-9>.
- Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Duke, N., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography* 20, 154–159. <https://doi.org/10.1111/j.1466-8238.2010.00584.x>.
- Hamilton, S.E., Casey, D., 2016. Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (cgmf-21). *Global Ecology and Biogeography* 25, 729–738. <https://doi.org/10.1111/geb.12449>.
- He, Q., 1999. Knowledge discovery through co-word analysis. *Library Trends* 48, 133–159.
- Huang, L., Zhang, Y., Guo, Y., Zhu, D., Porter, A.L., 2014. Four-dimensional science and technology planning: A new approach based on bibliometrics and technology roadmapping. *Technological Forecasting and Social Change* 81, 39–48. <https://doi.org/10.1016/j.techfore.2012.09.010>.
- Huang, Q., Lu, Y., 2018. Urban heat island research from 1991 to 2015: a bibliometric analysis. *Theoretical and Applied Climatology* 131, 1055–1067. <https://doi.org/10.1007/s00704-016-2025-1>.
- Huxham, M., Dencer-Brown, A., Diele, K., Kathiresan, K., Nagelkerken, I., Wanjiru, C., 2017. Mangroves and people: Local ecosystem services in a changing climate, in: V.H. Rivera-Monroy et al. (eds.). *Mangrove Ecosystems: A Global Biogeographic Perspective*. Springer. https://doi.org/10.1007/978-3-319-62206-4_8.
- Jennerjahn, T.C., 2020. Relevance and magnitude of ‘blue carbon’ storage in mangrove sediments: Carbon accumulation rates vs. stocks, sources vs. sinks. *Estuarine, Coastal and Shelf Science* 247, 107027. <https://doi.org/10.1016/j.ecss.2020.107027>.
- Jia, M., Wang, Z., Zhang, Y., Mao, D., Wang, C., 2018. Monitoring loss and recovery of mangrove forests during 42 years: The achievements of mangrove conservation in china. *Int. J. Appl. Earth Observ. Geoinf* 73, 535–545. <https://doi.org/10.1016/j.jag.2018.07.025>.
- Kauffman, J.B., Heider, C., Norfolk, J., Payton, F., 2014. Carbon stocks of intact mangroves and carbon emissions arising from their conversion in the dominican republic. *Ecological Applications* 24, 518–527. <https://doi.org/10.1890/13-0640.1>.
- Komiyama, A., Ong, J.E., Pongparn, S., 2008. Allometry, biomass, and productivity of mangrove forests: A review. *Aquatic Botany* 89, 128–137. <https://doi.org/10.1016/j.aquabot.2007.12.006>.
- Kroon, N., Céu Alves, M., Martins, I., 2021. The impacts of emerging technologies on accountants’ role and skills: Connecting to open innovation—a systematic literature review. *J. Open Innovation: Technology, Market, and Complexity* 7, 163. <https://doi.org/10.3390/joitmc7030163>.
- Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T.V., Dech, S., 2011. Remote sensing of mangrove ecosystems: A review. *Remote Sensing* 3, 878–928. <https://doi.org/10.3390/rs3050878>.
- Kusumaningtyas, M.A., Hutahaeen, A.A., Fischer, H.W., Pérez-Mayo, M., Ransby, D., Jennerjahn, T.C., 2019. Variability in the organic carbon stocks, sources, and accumulation rates of indonesian mangrove ecosystems. *Estuarine, Coastal and Shelf Science* 218, 310–323. <https://doi.org/10.1016/j.ecss.2018.12.007>.
- Liang, S., Hu, W., Liu, J., Su, S., Chen, G., Chen, S., Chen, B., 2023. Mapping mangrove sustainability in the face of sea level rise and land use: A case study on leizhou peninsula, china. *J. Env. Mgt* 325, 116554. <https://doi.org/10.1016/j.jenvman.2022.116554>.
- Lu, W., Liu, Z., Huang, Y., Bu, Y., Li, X., Cheng, Q., 2020. How do authors select keywords? a preliminary study of author keyword selection behavior. *Journal of Informetrics* 14, 101066. <https://doi.org/10.1016/j.joi.2020.101066>.
- Luo, J., Sun, Z., Lu, L., Xiong, Z., Cui, L., Mao, Z., 2022. Rapid expansion of coastal aquaculture ponds in southeast asia: Patterns, drivers and impacts. *J. Env. Mgt* 315, 115100. <https://doi.org/10.1016/j.jenvman.2022.115100>.
- Mao, Z., Chen, J., Hao, Z., Pan, D., Tao, B., Zhu, Q., 2013. A new approach to estimate the aerosol scattering ratios for the atmospheric correction of satellite remote sensing data in coastal regions. *Remote Sensing of Environment* 132, 186–194. <https://doi.org/10.1016/j.rse.2013.01.015>.
- Marrone, M., Linnenluecke, M.K., 2020. Interdisciplinary research maps: A new technique for visualizing research topics. *Plos One* 15, 0242283. <https://doi.org/10.1371/journal.pone.0242283>.
- Mohd Razali, S., Radzi, M.A., Marin, A., Samdin, Z., 2021. A bibliometric analysis of tropical mangrove forest land use change from 2010 to 2020. *Environment, Development and Sustainability*, 1–18. <https://doi.org/10.1007/s10668-021-01935-7>.
- Muhuri, P.K., Shukla, A.K., Abraham, A., 2019. Industry 4.0: A bibliometric analysis and detailed overview. *Engineering Applications of Artificial Intelligence* 78, 218–235. <https://doi.org/10.1016/j.engappai.2018.11.007>.
- Mujtaba, B.G., Cavico, F.J., 2013. Corporate social responsibility and sustainability model for global firms. *J. Leadersh. Account. Ethics* 10, 58–75. URL: <https://escholarship.org/uc/item/1ch8200w>.
- Müller, A.M., Ansari, P., Ebrahim, N.A., Khoo, S., 2016. Physical activity and aging research: a bibliometric analysis. *Journal of Aging and Physical Activity* 24, 476–483. URL: <https://hal.science/hal-01246065v1>.
- Murray, N.J., Worthington, T.A., Bunting, P., Duce, S., Hagger, V., Lovelock, C.E., Lyons, M.B., 2022. High-resolution mapping of losses and gains of earth’s tidal wetlands. *Science* 376, 744–749. <https://doi.org/10.1126/science.abm9583>.
- Nagelkerken, I.S.J.M., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Somerfield, P.J., 2008. The habi-

- tat function of mangroves for terrestrial and marine fauna: a review. *Aquatic Botany* 89, 155–185. <https://doi.org/10.1016/j.aquabot.2007.12.007>.
- de Oliveira Gomes, L.E., Sanders, C.J., Nobrega, G.N., Vescovi, L.C., Queiroz, H.M., Kauffman, J.B., Bernardino, A.F., 2021. Ecosystem carbon losses following a climate-induced mangrove mortality in Brazil. *Journal of Environmental Management* 297, 113381. <https://doi.org/10.1016/j.jenvman.2021.113381>.
- Oostdijk, M., Santos, M.J., Whigham, D., Verhoeven, J., Silvestri, S., 2018. Assessing rehabilitation of managed mangrove ecosystems using high resolution remote sensing. *Estuarine, Coastal and Shelf Science* 211, 238–247. URL: <https://www.sciencedirect.com/science/article/pii/S0272771417300434>.
- Pastor-Guzman, J., Dash, J., Atkinson, P.M., 2018. Remote sensing of mangrove forest phenology and its environmental drivers. *Remote Sensing of Environment* 205, 71–84. URL: <https://www.sciencedirect.com/science/article/pii/S0034425717305333>.
- Paul, J., Criado, A.R., 2020. The art of writing literature review: What do we know and what do we need to know? *International Business Review* 29, 101717. <https://doi.org/10.1016/j.ibusrev.2020.101717>.
- Pendleton, L., Donato, D.C., Murray, B.C., Crooks, S., Jenkins, W.A., Sifleet, S., Baldera, A., 2012. Estimating global “blue carbon” emissions from conversion and degradation of vegetated coastal ecosystems. *PLoS ONE* 7, 43542. <https://doi.org/10.1371/journal.pone.0043542>.
- Pham, L.T., Vo, T.Q., Dang, T.D., Nguyen, U.T., 2019. Monitoring mangrove association changes in the can gio biosphere reserve and implications for management. *Remote Sensing Applications: Society and Environment* 13, 298–305. <https://doi.org/10.1016/j.rsase.2018.11.009>.
- Richards, D.R., Friess, D.A., 2016. Rates and drivers of mangrove deforestation in southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences* 113, 344–349. <https://doi.org/10.1073/pnas.1510272113>.
- Robertson, A.I., Duke, N.C., 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. *Marine Biology* 96, 193–205.
- Sathirathai, S., 1998. Economic valuation of mangroves and the roles of local communities in the conservation of natural resources: case study of Surat Thani, South of Thailand. *EEPSEA research report series/IDRC*. Regional Office for Southeast and East Asia, Economy and Environment Program for Southeast Asia. URL: <http://www.idre.org.sg/eepsea>.
- SCOPUS, 2025. URL: <http://www.scopus.com/home.url>.
- Shepard, C.C., Crain, C.M., Beck, M.W., 2011. The protective role of coastal marshes: a systematic review and meta-analysis. *PLoS ONE* 6, 27374. <https://doi.org/10.1371/journal.pone.0027374>.
- Sidik, F., Lawrence, A., Wagey, T., Zamzani, F., Lovelock, C.E., 2023. Blue carbon: A new paradigm of mangrove conservation and management in Indonesia. *Marine Policy* 147, 105388. <https://doi.org/10.1016/j.marpol.2022.105388>.
- Staben, G., Lucieer, A., Scarth, P., 2018. Modelling lidar derived tree canopy height from landsat tm, etm+ and oli satellite imagery—a machine learning approach. *Int. J. Appl. Earth Observ. Geoinf* 73, 666–681. <https://doi.org/10.1016/j.jag.2018.08.013>.
- Tasneem, S., Ahsan, M.N., 2024. A bibliometric analysis on mangrove ecosystem services: Past trends and emerging interests. *Ocean & Coastal Management* 256, 107276. <https://doi.org/10.1016/j.ocecoaman.2024.107276>.
- Temmerman, S., Meire, P., Bouma, T.J., Herman, P.M., Ysebaert, T., Vriend, H.J., 2013. Ecosystem-based coastal defence in the face of global change. *Nature* 504, 79–83. <https://doi.org/10.1038/nature12859>.
- UNEP, 2014. *The importance of mangroves to people: A call to action*, UNEP World Conservation Monitoring Centre, Cambridge.
- Van Eck, N., Waltman, L., 2010. Software survey: Vosviewer, a computer program for bibliometric mapping. *Scientometrics* 84, 523–538. <https://doi.org/10.1007/s11192-009-0146-3>.
- Wang, L., Jia, M., Yin, D., Tian, J., 2019a. A review of remote sensing for mangrove forests: 1956–2018. *Remote Sensing of Environment* 231, 111223. <https://doi.org/10.1016/j.rse.2019.111223>.
- Wang, L., Zhang, G., Wang, Z., Liu, J., Shang, J., Liang, L., 2019b. Bibliometric analysis of remote sensing research trend in crop growth monitoring: A case study in China. *Remote Sensing* 11, 809. <https://doi.org/10.3390/rs11070809>.
- Yang, Y., Wu, M., Cui, L., 2012. Integration of three visualization methods based on co-word analysis. *Scientometrics* 90, 659–673. <https://doi.org/10.1007/s11192-011-0541-4>.
- Yu, D., Xu, Z., Wang, X., 2020. Bibliometric analysis of support vector machines research trend: a case study in China. *International Journal of Machine Learning and Cybernetics* 11, 715–728. <https://doi.org/10.1007/s13042-019-01028-y>.
- Zabolotskikh, E.V., Mitnik, L.M., Chapron, B., 2013. New approach for severe marine weather study using satellite passive microwave sensing. *Geophysical Research Letters* 40, 3347–3350. <https://doi.org/10.1002/grl.50664>.
- Zare-Farashbandi, F., Geraei, E., Siamaki, S., 2014. Study of co-authorship network of papers in the journal of research in medical sciences using social network analysis. *J. Research in Medical Sciences: the Official J. Isfahan Univ. Medical Sciences* 19, 41.