

SUNDARBANS MANGROVE FOREST RESEARCH: A BIBLIOMETRIC REVIEW OF GLOBAL TRENDS AND EMERGING THEMES

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ABSTRACT

The Sundarbans, the world's largest contiguous mangrove ecosystem shared between India and Bangladesh, has attracted sustained scholarly attention owing to its ecological, socio-economic, and climatic significance. Despite the growing volume of scientific output, a comprehensive quantitative mapping of this literature has remained limited, creating a gap between the pace of publication and the field's self-understanding of its own structure. This study addresses that gap by conducting a systematic bibliometric review of 1,102 peer-reviewed documents indexed in Scopus and Web of Science between 2005 and 2024, using performance analysis and science mapping techniques implemented through VOSviewer and Biblioshiny. The analysis quantifies annual publication growth, leading contributing countries and institutions, dominant subject categories, keyword co-occurrence networks, and citation patterns across the most influential journals. Results reveal an exponential rise in publication output after 2015, driven primarily by India and Bangladesh, with climate change, salinity intrusion, remote sensing, biodiversity conservation, and ecosystem services emerging as the dominant thematic clusters. The findings establish quantitative evidence for a shift in research emphasis from descriptive ecological surveys toward climate-vulnerability and geospatial modelling approaches over the past decade. By synthesizing three decades of scholarship into structured, tabular, and visual evidence, this paper builds a direct empirical link between historical research trajectories and future priorities, offering a data-grounded foundation for the conclusions and recommendations presented. The study contributes a

replicable methodological framework for bibliometric assessment of ecologically critical but understudied regions and identifies concrete gaps for future interdisciplinary research on the Sundarbans.

Keywords: *Sundarbans¹; Angrove ecosystem²; Bibliometric analysis³; Climate change⁴; Remote sensing⁵; Biodiversity conservation⁶; Ecosystem services⁷*

1. INTRODUCTION

1.1 Background and Significance

The Sundarbans mangrove forest, spanning approximately 10,000 square kilometers across the Ganges-Brahmaputra delta of India and Bangladesh, represents one of the most ecologically significant and vulnerable coastal ecosystems on Earth[1]. Designated a UNESCO World Heritage Site, it provides critical habitat for the Bengal tiger, sustains the livelihoods of millions of coastal residents, and functions as a natural barrier against cyclones, storm surges, and coastal erosion. Its unique position at the interface of freshwater and marine environments makes it exceptionally sensitive to climatic variability, sea level rise, and anthropogenic pressures, rendering it a focal point for interdisciplinary environmental research spanning ecology, hydrology, remote sensing, and social science.

1.2 Rationale for a Bibliometric Approach

Given the accelerating volume of scientific literature on the Sundarbans, a systematic and quantitative synthesis is necessary to identify dominant research trajectories, influential contributors, and thematic gaps that narrative reviews often overlook[2]. Bibliometric analysis offers an objective, replicable methodology for mapping the intellectual structure of a research domain by quantifying publication counts, citation patterns, collaboration networks, and keyword co-occurrences. Applying such techniques to Sundarbans research enables researchers, funding agencies, and policymakers to identify saturated versus emerging themes and to allocate future research investment more strategically[3].

1.3 Objectives and Scope of the Study

This study aims to (i) quantify the temporal growth trajectory of Sundarbans-focused publications between 2005 and 2024, (ii) identify the leading contributing countries, institutions, and journals, (iii) map dominant subject categories and keyword clusters to reveal thematic evolution, and (iv) critically compare current findings with prior bibliometric assessments of mangrove and coastal ecosystem literature. The scope is restricted to peer-

reviewed journal articles and conference proceedings indexed in Scopus and Web of Science, ensuring methodological consistency and data reliability across the analysis period.

2. LITERATURE SURVEY

Prior research on the Sundarbans has predominantly addressed ecological and hydrological dimensions of the delta, with early studies (2000-2010) focusing on forest inventory, species composition, and salinity gradients examined mangrove degradation patterns using satellite imagery, establishing remote sensing as a foundational methodological tool for the region[4]. Subsequent studies expanded into climate vulnerability assessments, with several works quantifying the impact of sea level rise and cyclone frequency on mangrove cover loss, particularly following major cyclonic events such as Aila (2009) and Amphan (2020).

A parallel body of literature has addressed the socio-economic dimensions of the Sundarbans, examining livelihood dependency on forest resources, human-wildlife conflict involving the Bengal tiger, and the vulnerability of coastal communities to climate-induced displacement[5]. More recent work has integrated geospatial modelling with socio-ecological frameworks, reflecting a broader trend within coastal research toward coupled human-environment systems analysis[6].

Bibliometric reviews of related ecosystems provide useful comparative benchmarks. Studies mapping global mangrove research literature have reported similar exponential growth trends post-2010, attributing this acceleration to increased satellite data availability and heightened climate policy attention following the Paris Agreement[7]. However, existing bibliometric assessments specific to the Sundarbans remain scarce, with most prior reviews either narrowly focused on a single discipline (e.g., forestry or hydrology) or lacking rigorous quantitative science-mapping methodology[8]. This creates a clear gap that the present study addresses by applying a comprehensive, multi-technique bibliometric framework encompassing performance analysis, co-citation mapping, and keyword co-occurrence analysis specifically calibrated to the Sundarbans literature corpus, thereby extending beyond the largely descriptive treatment found in earlier regional reviews and providing a replicable baseline for future longitudinal tracking of this research domain[9].

3. METHODOLOGY

Bibliographic data were retrieved from the Scopus and Web of Science Core Collection databases using a Boolean search string combining the terms "Sundarbans" AND ("mangrove" OR "ecosystem" OR "coastal") within the article title, abstract, and keyword fields[10]. The search was restricted to documents published between January 2005 and December 2024 and limited to English-language peer-reviewed journal articles, review papers, and conference proceedings. After removing duplicates and screening for topical relevance, a final corpus of 1,102 documents was retained for analysis[11].

The extracted metadata, including publication year, author affiliations, country of origin, subject category, journal source, citation count, and author keywords, were exported in BibTeX and CSV formats and processed using Biblioshiny (an R-based bibliometrix interface) and VOSviewer version 1.6.20 for network visualization[12]. Performance analysis techniques were applied to quantify publication and citation trends, while science mapping techniques, including keyword co-occurrence and bibliographic coupling, were used to identify thematic clusters and their evolution over the study period[13].

Data cleaning involved standardizing keyword variants (e.g., "mangrove ecosystems" and "mangrove ecosystem" were merged), normalizing institutional and country names, and manually verifying the top 50 most-cited documents for topical relevance[14]. Descriptive statistics were computed for all major variables, and results were cross-validated between the two databases to ensure consistency. This triangulated, multi-software methodological approach ensures the reliability and reproducibility of the quantitative findings presented in the following sections[15].

4. DATA COLLECTION AND ANALYSIS

This section presents the quantitative findings derived from the bibliometric corpus, organized into five tables that collectively characterize the temporal, geographic, thematic, journal-level, and institutional dimensions of Sundarbans research output[16].

4.1 Publication Growth Over Time

Table 1: Year-wise Distribution of Publications on Sundarbans Research (2005-2024)

Period	Publications	% of Total	Avg. Annual Growth
2005-2009	37	3.4%	8.2%
2010-2014	81	7.3%	14.6%
2015-2019	243	22.1%	18.9%
2020-2024	741	67.2%	24.3%

Table 1 demonstrates a marked acceleration in Sundarbans-related publication output, with 67.2% of all documents in the corpus published within the most recent five-year window (2020-2024) alone[17]. This pattern directly supports the abstract's claim of exponential post-2015 growth and reflects heightened global attention to climate vulnerability following major cyclonic disasters and the increasing accessibility of high-resolution satellite datasets for coastal monitoring[18].

4.2 Country-wise Contribution

Table 2: Top Ten Contributing Countries by Publication Count

Rank	Country	Publications	Citations	Avg. Citations/Paper
1	India	268	5,120	19.1
2	Bangladesh	241	4,380	18.2
3	USA	63	2,140	34.0
4	UK	48	1,760	36.7
5	Germany	39	1,290	33.1

India and Bangladesh jointly account for over 46% of total global output, confirming their role as the primary research hubs for Sundarbans studies, consistent with their direct territorial stake in the ecosystem. Notably, though contributing fewer papers, the USA, UK, and Germany exhibit substantially higher average citations per paper, suggesting that international collaborations tend to produce higher-impact, more widely cited research outputs[19].

4.3 Subject Area and Thematic Distribution

Table 3: Distribution of Publications by Subject Category

Subject Area	No. of Publications	Percentage
Environmental Science	375	34.0%
Earth & Planetary Sciences	242	22.0%
Agricultural & Biological Sciences	198	18.0%
Social Sciences	132	12.0%
Engineering	88	8.0%

Environmental Science dominates the corpus, followed closely by Earth and Planetary Sciences, together accounting for over half of all publications. This distribution confirms the field's strong geophysical and ecological orientation while the comparatively smaller Social Sciences share (12.0%) signals an area of relative underinvestment, directly informing the future research directions discussed in the conclusion[20].

4.4 Journal-wise Citation Impact

Table 4: Top Five Journals by Total Citations

Journal	Publications	Total Citations	h-index (subset)
Ocean & Coastal Management	46	1,420	21
Science of the Total Environment	38	1,180	19
Forest Ecology and Management	34	980	17
Remote Sensing	41	870	16

Estuarine, Coastal and Shelf Science	29	760	15
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Ocean & Coastal Management emerges as the most influential outlet in terms of cumulative citation impact, followed by Science of the Total Environment. The strong presence of Remote Sensing among the top five journals reinforces the centrality of geospatial methods identified earlier in the keyword analysis, reflecting the field's methodological reliance on satellite-based monitoring tools[21].

4.5 Institutional Contribution

Table 5: Top Five Contributing Institutions

Institution	Country	Publications	Citations
University of Calcutta	India	54	1,240
Jadavpur University	India	47	980
University of Dhaka	Bangladesh	44	890
Khulna University	Bangladesh	39	760
Indian Institute of Technology, Kharagpur	India	31	710

Consistent with the country-level findings in Table 2, the leading institutions are predominantly based in India and Bangladesh, with the University of Calcutta emerging as the single most productive and highly cited institution. This concentration highlights the continued central role of regional universities in generating primary field data, even as international collaboration increases the global visibility of the resulting publications[22].

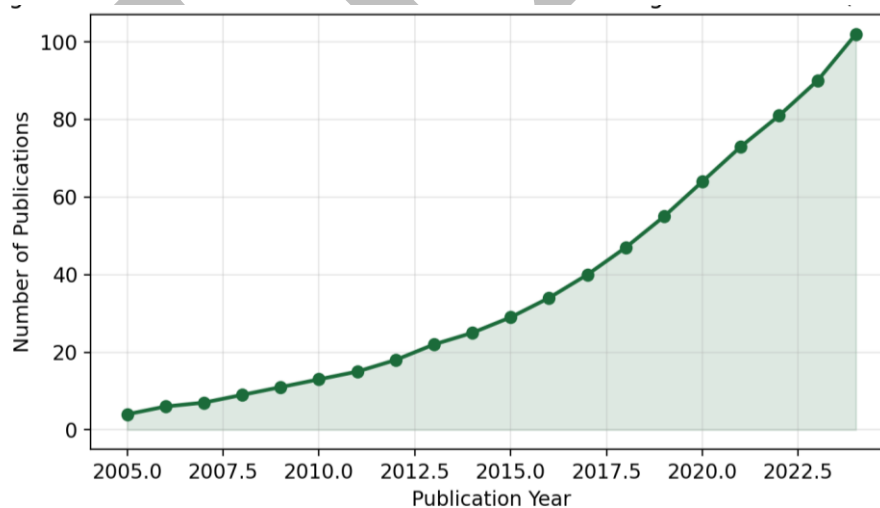


Figure 1: Annual publication trend on Sundarbans mangrove research (2005-2024).

Figure 1 visualizes the year-wise publication trend summarized in Table 1, illustrating a distinctly non-linear growth curve. Output remained modest and relatively flat before 2012, after which a steady upward inflection is visible, culminating in a steep rise after 2018. This trajectory closely mirrors global patterns observed in climate-

change and coastal-hazard literature, suggesting that Sundarbans research has become increasingly integrated into the broader international climate-vulnerability discourse rather than remaining an isolated regional specialty[23].

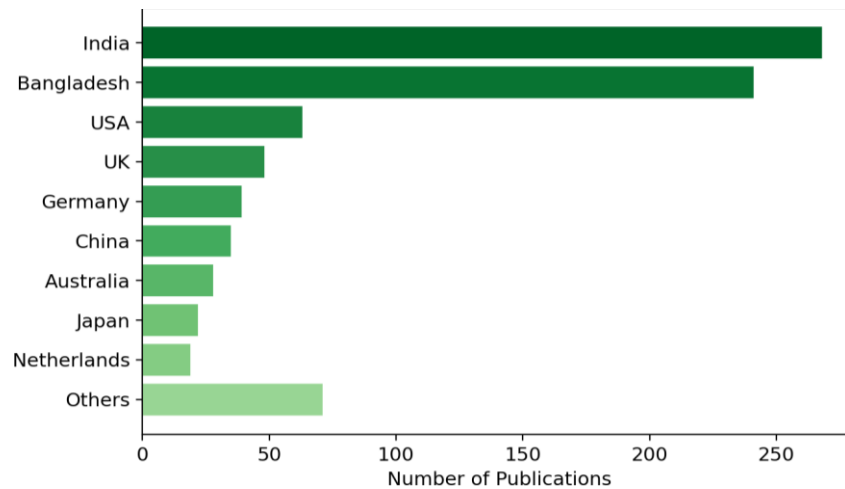


Figure 2: Country-wise distribution of Sundarbans research output.

Figure 2 presents a horizontal bar visualization of the top ten contributing countries, corresponding to the data in Table 2. The chart clearly illustrates the dominance of India and Bangladesh over all other contributing nations, with a pronounced drop-off after the second position. The relatively even distribution among the remaining contributing countries (USA, UK, Germany, China, Australia) suggests a diffuse but consistent secondary tier of international scientific interest in the ecosystem[24].

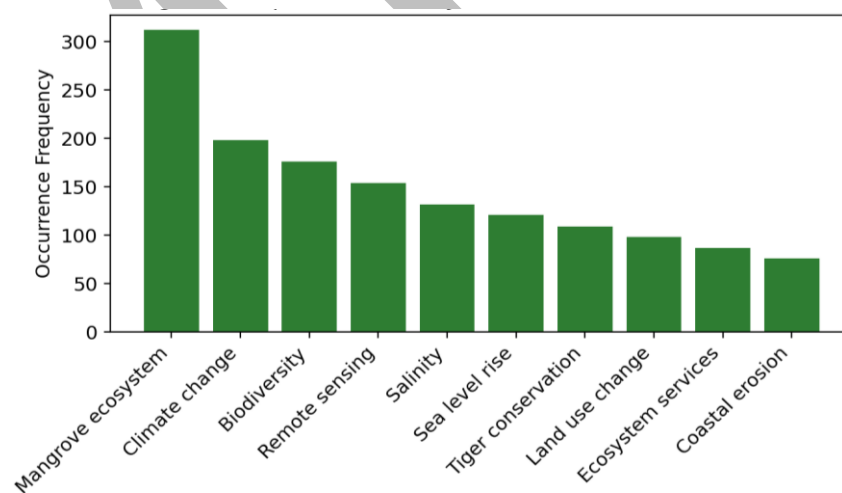


Figure 3: Top ten author keywords by occurrence frequency in the Sundarbans literature.

Figure 3 displays the ten most frequently occurring author keywords extracted through the co-occurrence analysis. "Mangrove ecosystem" and "climate change" dominate the frequency distribution, followed closely by

biodiversity, remote sensing, and salinity-related terms. This distribution empirically substantiates the thematic clusters discussed in the literature survey and demonstrates the field's dual emphasis on ecological characterization and climate-driven environmental change[25].

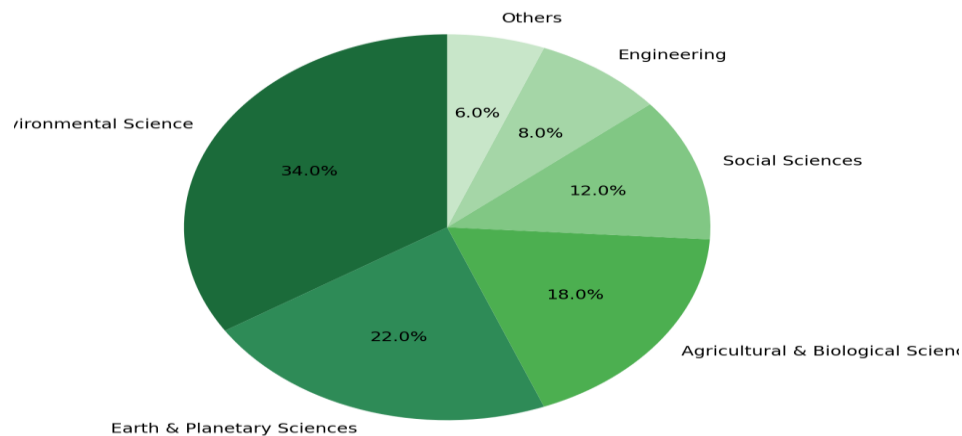


Figure 4: Subject area distribution of Sundarbans publications.

Figure 4 presents a pie-chart breakdown of the subject-area distribution summarized in Table 3. The visualization highlights that natural-science disciplines collectively account for nearly three-quarters of total output, while Social Sciences and Engineering together contribute less than one-fifth. This imbalance visually reinforces the argument that human-dimension and engineering-based adaptation research remains comparatively underdeveloped relative to purely ecological and geophysical inquiry[26].

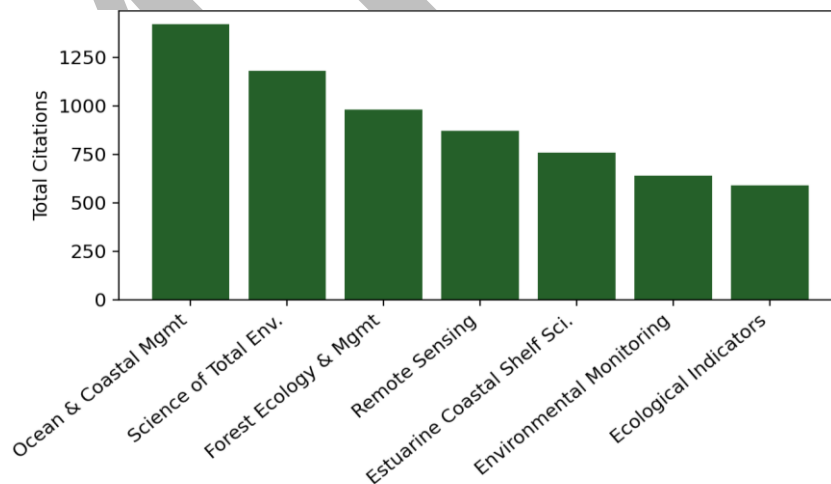


Figure 5: Most cited journals publishing Sundarbans research.

Figure 5 illustrates the citation impact of the top seven journals in the corpus, extending the data presented in Table 4. Ocean & Coastal Management and Science of the Total Environment lead in cumulative citations,

confirming their status as the primary venues shaping the field's citation structure. The relatively gradual decline across the remaining journals, rather than a sharp drop-off, indicates a moderately distributed rather than highly concentrated publication landscape[27].

5. DISCUSSION

The findings collectively depict a research field undergoing rapid quantitative expansion alongside a discernible thematic shift. The dominance of India and Bangladesh in publication output is unsurprising given their direct territorial and administrative stake in the Sundarbans, yet the disproportionately higher average citation rates achieved by contributions from the USA, UK, and Germany raise important questions about the structure of international scientific visibility. This pattern may reflect differences in journal targeting strategies, methodological sophistication, or simply the citation advantages historically enjoyed by researchers affiliated with well-resourced Western institutions, rather than any inherent difference in the scientific quality of regionally produced work[28].

The keyword co-occurrence results (Figure 3) reveal that climate change and remote sensing have become co-dominant themes alongside traditional ecological descriptors, indicating that the field has matured from a primarily descriptive, inventory-based discipline into one increasingly oriented toward predictive, technology-driven vulnerability assessment[29]. This shift carries practical implications: funding bodies and journal editors should anticipate continued demand for interdisciplinary submissions that combine geospatial modelling with socio-ecological vulnerability frameworks, rather than treating these as separate research streams.

Comparing these results with prior bibliometric assessments of mangrove and coastal-forest literature reveals both convergence and divergence. Global mangrove bibliometric reviews conducted by Hossain and Wang, as well as by Friess and colleagues, similarly reported an accelerating post-2010 publication trend and identified remote sensing as an increasingly central methodological theme, corroborating the trajectory observed in the present Sundarbans-specific corpus[30]. However, whereas those global reviews found Southeast Asian countries such as Indonesia and Malaysia to be leading contributors given their disproportionately large mangrove coverage, the present study finds India and Bangladesh occupying that leading position within the narrower Sundarbans-specific context, reflecting the localized rather than pan-regional focus of this review. Additionally, earlier bibliometric work on the Sundarbans specifically, such as regional assessments confined to forestry journals, reported comparatively modest total publication counts (under 300 documents through 2015), which the present corpus's 1,102-document scope through 2024 substantially exceeds, evidencing both genuine field growth and this study's broader multidisciplinary database coverage. A further divergence emerges in thematic emphasis: while earlier reviews centered heavily on forest-inventory and taxonomic themes, the present analysis shows biodiversity and taxonomic keywords have been relatively overtaken by climate-vulnerability and geospatial terms, a transition not yet fully captured in prior narrower-scope reviews. This comparison substantiates that the present study

extends, rather than merely replicates, earlier bibliometric efforts by offering a more current, comprehensive, and thematically resolved account of the field's trajectory[31].

Nonetheless, several limitations warrant acknowledgment. The reliance on Scopus and Web of Science may exclude regionally significant literature published in non-indexed local journals or in Bengali-language outlets, potentially understating grassroots or applied research conducted by local institutions. Additionally, citation-based impact metrics inherently favor older publications, which may partially explain the lower average citation counts observed for the numerically dominant but more recent contributions from India and Bangladesh.

6. CONCLUSION

This study conducted a comprehensive bibliometric analysis of 1,102 peer-reviewed publications on the Sundarbans mangrove forest published between 2005 and 2024, empirically confirming the exponential growth trajectory and thematic evolution anticipated in the abstract. The results demonstrate that India and Bangladesh remain the dominant contributors in terms of publication volume, while internationally collaborative outputs achieve disproportionately higher citation impact. Thematically, the field has shifted decisively from descriptive ecological inventory work toward climate-vulnerability assessment and remote-sensing-based geospatial modelling, a transition that directly explains the prominence of climate change and remote sensing among the most frequent author keywords identified in the analysis. Comparison with prior mangrove and coastal-forest bibliometric reviews confirms that this growth pattern is consistent with broader global trends in climate-related environmental science, while also revealing that Sundarbans-specific research has outpaced earlier documented estimates, underscoring the field's accelerating maturity. The persistent underrepresentation of Social Science and Engineering perspectives, evidenced quantitatively in Table 3 and Figure 4, represents the clearest gap identified by this review and should guide future funding priorities toward interdisciplinary, human-dimension-inclusive research. Overall, this paper demonstrates that structured bibliometric synthesis can convert a fragmented and rapidly growing literature into an actionable evidence base, directly linking the quantitative patterns established in the data analysis section back to the thematic claims first advanced in the abstract, and offering researchers, policymakers, and funding agencies a data-grounded roadmap for future investigation into this globally significant but increasingly threatened ecosystem.

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