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Mangroves in Disaster Risk Reduction: Global Trends and Knowledge Gaps

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ABSTRACT

Background. Mangrove ecosystems have increasingly been recognized as important components of disaster risk reduction (DRR), particularly in mitigating the impacts of coastal hazards such as tsunamis, storm surges, and coastal flooding. Alongside the growing influence of climate change adaptation and nature-based solutions, scholarly interest in mangroves has expanded across multiple disciplines. However, the overall development, thematic orientation, and existing gaps within mangrove-based DRR research remain insufficiently synthesized. The study's objective was to examine the evolution, disciplinary structure, dominant themes, and underrepresented areas of global research on mangroves in the context of DRR. Materials and methods. This study employed a bibliometric approach to analyze peer-reviewed journal articles and review papers indexed in the Scopus database between 2000 and 2026. Descriptive analysis, keyword co-occurrence networks, thematic mapping, thematic evolution analysis, and geographic collaboration analysis were conducted using Biblioshiny and supporting analytical tools to identify publication trends, subject area distributions, core journals, thematic structures, and spatial research patterns. Results. The findings reveal a substantial increase in mangrove-based DRR research over time, particularly following major coastal disasters and during the recent climate-resilience era. The literature is dominated by environmental and earth sciences and primarily framed around ecological protection, ecosystem services, and hazard mitigation. In contrast, governance, preparedness, social vulnerability, and policy-oriented dimensions remain weakly represented. Thematic evolution indicates a shift toward climate-related and ecosystem-based approaches, alongside persistent conceptual gaps. Conclusions. This study concludes that while mangroves are well-established as ecological assets in DRR studies, their role as socio-ecological infrastructures remains underexplored. Advancing mangrove-based DRR requires greater integration of governance, preparedness, and social perspectives to enhance policy relevance and support sustainable coastal resilience.

Keywords: Mangroves, DRR, coastal hazards, climate resilience, research trends

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INTRODUCTION

Coastal regions are among the most vulnerable areas to natural hazards such as tsunamis, storm surges, and coastal flooding, particularly under accelerating climate change and sea-level rise (Schipper & Pelling, 2006; Thomas & López, 2015). These hazards disproportionately affect communities in low-lying coastal zones of the Global South, where environmental exposure intersects with social, economic, and governance challenges. Consequently, DRR has become a central concern in coastal management, climate adaptation, and sustainability agendas, as reflected in global policy frameworks such as the Sendai Framework for DRR (Aitsi-Selmi et al., 2015).

Mangrove ecosystems have increasingly been recognized not only for their ecological value but also for their potential role in reducing coastal disaster risks. Mangroves are often framed as natural barriers capable of attenuating wave energy, reducing storm surge impacts, and mitigating coastal erosion. At the local and regional levels, applied studies have documented mangrove conservation and restoration initiatives as strategies for coastal protection and environmental sustainability, including community-based and institutional programs in coastal Aceh, Indonesia (Anhar et al., 2024; Muslih et al., 2025). Ecological assessments of mangrove structure and

composition further reinforce their importance in maintaining coastal ecosystem stability (Ashri et al., 2023), while recent studies on blue carbon potential highlight mangroves' relevance to climate change mitigation agendas (Yanti et al., 2025).

Following major coastal disasters, most notably the 2004 Indian Ocean tsunami, scholarly attention to mangroves expanded rapidly, with research emphasizing their protective functions within disaster-prone coastal environments (Rahman et al., 2018). More recently, mangroves have been incorporated into broader conceptual frameworks such as ecosystem-based adaptation and nature-based solutions for climate resilience.

However, despite this growing body of work, research on mangroves and DRR remains fragmented across disciplinary boundaries. Existing studies are heavily dominated by ecological and biophysical perspectives, while social, governance, communication, and cultural dimensions, which are central to effective DRR, receive comparatively limited attention (Agyepong & Liang, 2023; Demiroz & Haase, 2019).

Disaster resilience is increasingly understood as a multidimensional process shaped not only by environmental protection but also by social capital, cultural practices, communication, and knowledge transmission (Ronan & Johnston, 2005; Rotarangi & Stephenson, 2014; Ungar, 2008). Then, disaster preparedness services, including those targeting vulnerable populations, play an essential role in reducing disaster impacts and enhancing adaptive capacity (Istiarsyah et al., 2023). However, the extent to which these dimensions are integrated into mangrove-based DRR research remains unclear.

In parallel, a growing body of disaster scholarship highlights the role of language, narratives, and communication in shaping resilience and post-disaster recovery. Studies have shown that cultural narratives, local knowledge, and communicative practices can strengthen community resilience and risk awareness in disaster contexts (Crawford, 2024; Cyrulnik, 2021; Federici, 2020). Bibliometric studies in related disaster domains, such as disaster education, risk communication, and resilience research, have demonstrated the value of mapping thematic structures and research trajectories to identify conceptual gaps and emerging trends (Canlas, 2023; Demiroz & Haase, 2019; Rana, 2020). Other bibliometric studies in disaster-related fields, such as disaster mitigation education and inclusive education, have also demonstrated the usefulness of bibliometric mapping for identifying research trends, thematic gaps, and future research directions (Kamarullah & Yanti, 2024; Suboh et al., 2024). Nevertheless, similar large-scale bibliometric analyses focusing specifically on mangroves within DRR remain limited.

Bibliometric analysis provides a systematic and transparent approach to examining the evolution, thematic structure, and knowledge gaps of a research field by analyzing publication patterns, keywords, and scholarly outputs at scale (Aria & Cuccurullo, 2017; Donthu et al., 2021). By applying bibliometric techniques, it is possible to move beyond individual case studies and synthesize broader intellectual trends that shape how mangroves are conceptualized in DRR research.

Therefore, this study aims to conduct a bibliometric analysis of global research on mangroves in the context of DRR from 2000 to 2026. By examining publication trends, subject area distributions, core journals, and keyword-based thematic structures, this study seeks to clarify how mangroves have been framed within DRR research and to identify underexplored areas, particularly those related to social, cultural, and governance dimensions of resilience.

Accordingly, this study addresses the following research questions:

RQ1: How has global research on mangroves and DRR evolved between 2000 and 2026?

RQ2: What subject areas and journals have contributed most prominently to mangrove-based DRR research?

RQ3: What dominant and emerging themes characterize the literature on mangroves and DRR?

RQ4: Which thematic areas remain underrepresented in existing mangrove-based DRR research?

METHOD

Research Design

This study employed a bibliometric analysis to map the development, thematic structure, and research trends of scholarly publications addressing the role of mangroves in DRR. Bibliometric methods are suitable for systematically analyzing large bodies of literature, identifying influential research themes, publication patterns, and knowledge gaps within a specific field (Aria & Cuccurullo, 2017; Donthu et al., 2021).

Data Source

The bibliographic data were retrieved exclusively from the Scopus database, which is widely recognized for its comprehensive coverage of peer-reviewed journals and its suitability for bibliometric studies in environmental and interdisciplinary research (Mongeon & Paul-Hus, 2016). Using a single database ensured data consistency and avoided duplication issues commonly associated with multi-database retrieval.

The literature search was conducted in January 2026 using the following query applied to the Title, Abstract, and Author Keywords fields (TITLE-ABS-KEY): *mangrove AND ("DRR" OR tsunami* OR "storm surge" OR "flood mitigation" OR "coastal protection" OR "risk reduction" OR "hazard mitigation").* The search was limited to publications from 2000 to 2026, reflecting both the pre- and post-2004 Indian Ocean tsunami periods, which marked a significant turning point in coastal disaster risk research.

To ensure conceptual alignment with the research focus, the following criteria were applied. For inclusion criteria, the documents should be peer-reviewed journal articles and review papers; published in English; and explicitly address mangroves in relation to DRR, coastal hazard mitigation, or protective functions. Meanwhile, the documents are excluded if they are conference papers, book chapters, editorials, or notes. Too, studies where mangroves were mentioned only as background ecosystems without explicit linkage to hazards, risk reduction, or mitigation, are skipped. Then, documents that are purely about ecological, biodiversity, or pollution studies, lacking a disaster-related analytical framing, are also eliminated. After applying these criteria, a total of 998 documents were retained for analysis.

Data Analysis

Bibliometric analysis was conducted using Biblioshiny, a web-based interface of the bibliometrix R package (Aria & Cuccurullo, 2017). This tool was selected due to its transparency, reproducibility, and suitability for descriptive and thematic bibliometric analyses. The analysis included: annual publication trends, distribution of subject areas, most productive journals, keyword co-occurrence analysis based on author keywords, and thematic mapping to identify dominant and emerging research themes. To improve interpretability, keyword co-occurrence analysis was performed using a minimum occurrence threshold, allowing the identification of central thematic clusters within mangrove-based DRR research.

Furthermore, bibliometric maps and figures generated through Biblioshiny were used to visualize thematic structures and research trends. The results were interpreted qualitatively to explain shifts in research emphasis, particularly the transition from ecological protection narratives toward DRR and nature-based solutions. Emphasis was placed on identifying underrepresented themes, such as social, governance, and policy dimensions of mangrove-based DRR.

FINDINGS

This study analyzed a total of 998 peer-reviewed publications on mangroves in the context of DRR indexed in the Scopus database between 2000 and 2026. The dataset consisted exclusively of journal articles and review papers, ensuring a focus on validated scholarly contributions. Overall, the publications were authored by a diverse group of researchers across multiple countries and disciplines, reflecting the interdisciplinary nature of mangrove-based DRR research.

Table 1. Main Descriptive Information of Mangrove-Based DRR Research (2000–2026)

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2000:2026
Sources (Journals, Books, etc.)	416
Documents	998
Annual Growth Rate %	9,85
Document Average Age	7,06
Average citations per doc	50,44
References	0
DOCUMENT CONTENTS	
Keywords Plus (ID)	4752
Author's Keywords (DE)	2707
AUTHORS	
Authors	3975
Authors of single-authored docs	0
AUTHORS COLLABORATION	
Single-authored docs	0
Co-Authors per Doc	10,5
International co-authorships %	39,48
DOCUMENT TYPES	
article	903
review	95

Table 1 presents the main descriptive information of the dataset, including the number of documents, publication types, sources, authors, and keywords. The overview provides a general profile of the corpus analyzed and serves as a foundation for the subsequent results on publication trends, subject areas, thematic structures, and geographic distribution

Annual Publication Trends (2000-2026)

Figure 1 illustrates the annual scientific production of journal articles and review papers on mangroves in the context of DRR published between 2000 and 2026. Overall, the publication trend demonstrates a clear long-term increase, indicating growing scholarly attention to mangroves as part of DRR research.

During the early period from 2000 to 2004, the number of publications remained very low, with only one to three articles published annually. This phase represents an initial stage in which mangroves were primarily discussed within broader coastal and environmental contexts, rather than being explicitly framed as components of DRR. A noticeable increase emerged after 2005, coinciding with the aftermath of the 2004 Indian Ocean tsunami. From this point onward, annual publication output began to rise more consistently, reflecting heightened academic interest in natural coastal protection and hazard mitigation.

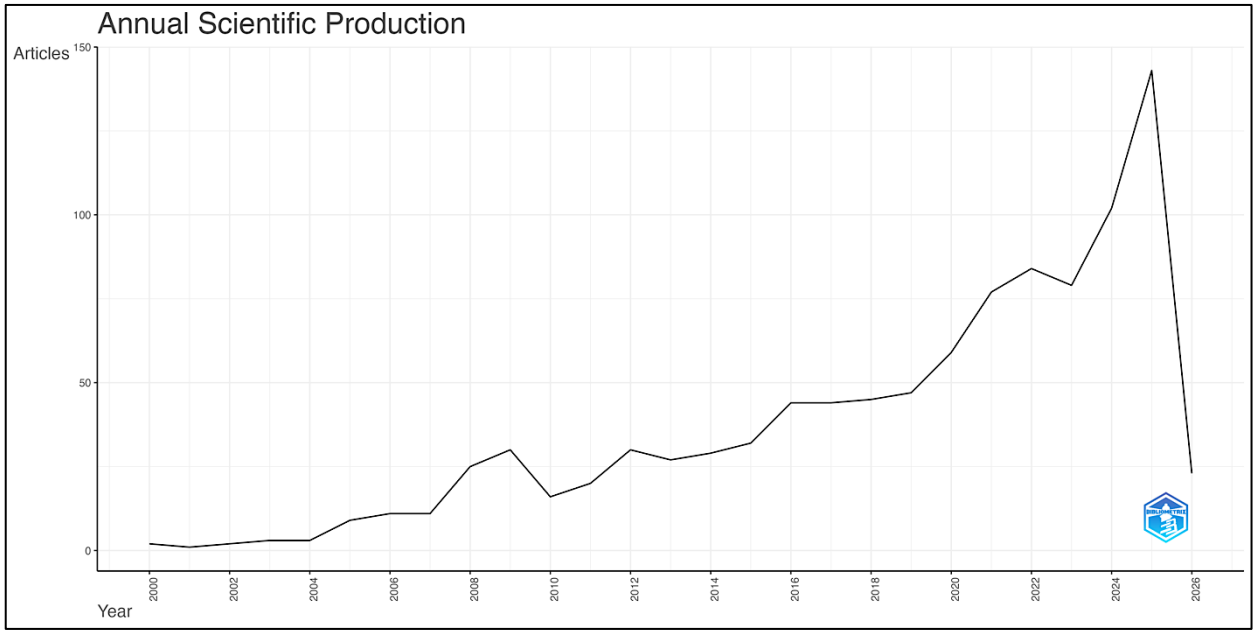


Figure 1. Annual scientific production of journal articles and reviews on mangroves in DRR studies (2000–2026)

Between 2010 and 2015, publication growth became more stable, with moderate fluctuations, suggesting a consolidation phase in which mangrove-related disaster research expanded across multiple disciplines. A more pronounced increase is evident after 2016, followed by a sharp acceleration from 2020 onwards. This recent surge corresponds with the increasing prominence of climate change adaptation, coastal resilience, and nature-based solutions in DRR discourse.

The highest publication output was recorded in 2024, marking the peak of scholarly production within the study period. The apparent decline observed in 2026 should be interpreted with caution, as it likely reflects incomplete indexing for the most recent year rather than an actual decrease in research activity. Overall, the temporal pattern indicates a transition from sporadic early research toward sustained and rapidly growing scholarly engagement, highlighting the increasing recognition of mangroves as relevant components in DRR strategies.

Subject Area Distribution of Mangrove-Based DRR Studies

Figure 2 presents the distribution of publications on mangroves in DRR across subject areas based on Scopus classification. The results indicate that the literature is strongly dominated by environmental and earth-related disciplines. Environmental Science accounts for the largest share of publications (31.3%), highlighting the central role of ecological and environmental perspectives in mangrove-based DRR research. This is followed by Agricultural and Biological Sciences (20.9%) and Earth and Planetary Sciences (18.6%), reflecting a strong emphasis on ecosystem dynamics, coastal geomorphology, and biophysical processes related to hazard mitigation.

In contrast, Social Sciences represent a comparatively smaller proportion (7.2%) of the total publications. Engineering-related studies contribute 6.1%, indicating limited engagement with applied design, infrastructure, and technical mitigation approaches within mangrove-based DRR research. Other subject areas, including Biochemistry, Energy, Computer Science, and Economics, each account for relatively minor shares, individually contributing less than 3% of the total output.

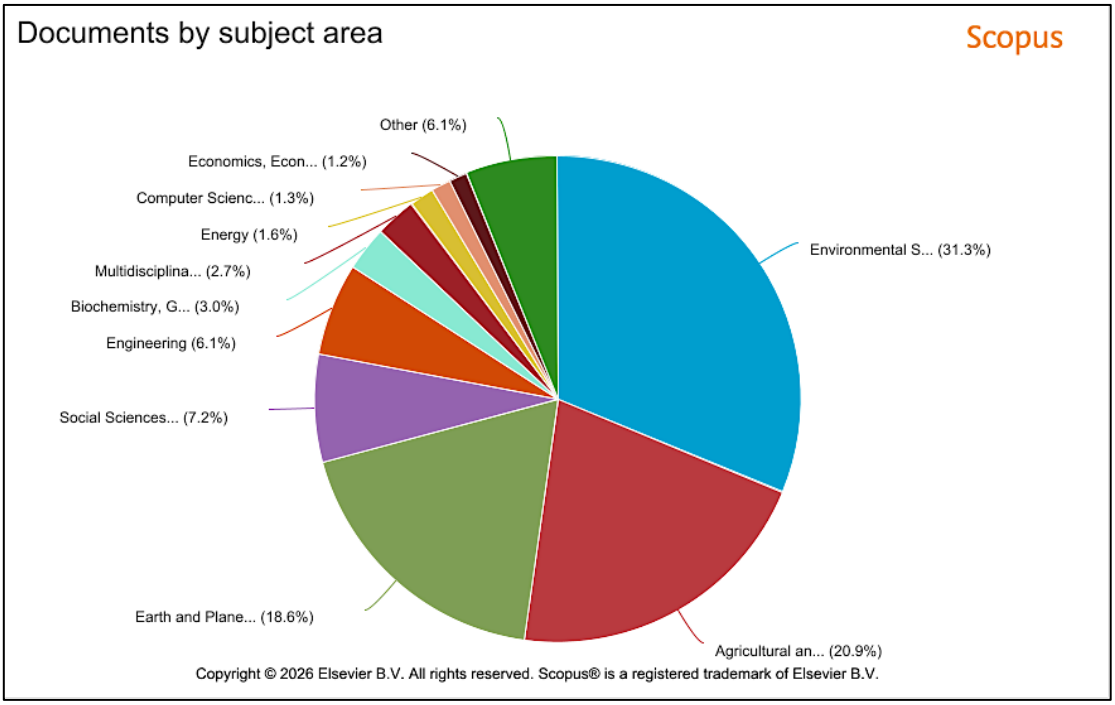


Figure 2. Distribution of publications by subject area in mangrove-based DRR studies (2000–2026)

Overall, the subject area distribution demonstrates that research on mangroves in DRR is predominantly grounded in natural and environmental sciences, with substantially less representation from social, economic, and technological disciplines. This disciplinary pattern provides an empirical basis for identifying imbalances in the existing literature, which are further examined in subsequent thematic analyses.

Most Productive Journals

Figure 3 presents the most productive journals publishing research on mangroves in the context of DRR between 2000 and 2026. The results indicate that scholarly output in this field is concentrated within a limited number of coastal, environmental, and interdisciplinary journals. *Ocean and Coastal Management* emerges as the leading publication outlet, contributing 36 documents, followed closely by *Estuarine, Coastal and Shelf Science* with 34 documents. These two journals together represent the primary platforms for disseminating mangrove-based DRR research, reflecting their strong focus on coastal processes, ecosystem management, and applied environmental studies.

Other prominent journals include *Science of the Total Environment* (20 documents) and *PLOS ONE* (19 documents), indicating the relevance of mangrove-related DRR research within broader environmental science and multidisciplinary research contexts. *Journal of Coastal Conservation and Regional Studies in Marine Science* each contributed 18 documents, further underscoring the importance of conservation-oriented and regional marine science journals in this research area.

Additional contributions were observed in *Estuaries and Coasts and Journal of Coastal Research* (both 15 documents), as well as *Coastal Engineering and Ecological Engineering* (each 14 documents). The presence of engineering-focused journals, although less dominant, suggests some engagement with applied and technical perspectives related to coastal protection and ecosystem-based mitigation.

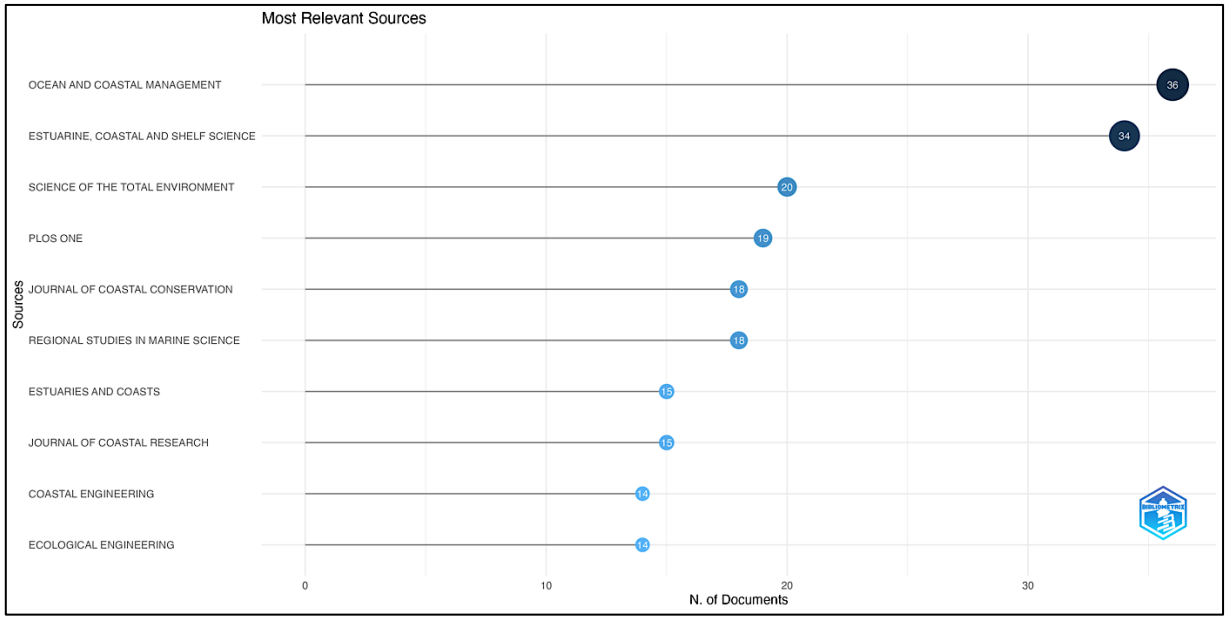


Figure 3. Most productive journals publishing mangrove-based DRR studies (2000–2026)

Overall, the distribution of publications across journals demonstrates that mangrove-based DRR research is primarily disseminated through specialized coastal and environmental journals, with relatively limited diffusion into broader social science or policy-oriented outlets.

Keyword Co-occurrence Analysis

Figure 4 illustrates the keyword co-occurrence network of mangrove-based DRR research based on author keywords. The network reveals a clustered thematic structure, indicating that research in this field is organized around several interconnected but distinguishable thematic groups. At the center of the network, the keywords "*mangrove*" and "*mangroves*" appear as the most dominant and highly connected nodes, reflecting their central role across all thematic clusters. These core keywords are strongly linked to "*climate change*," "*tsunami*," "*storm surge*," and "*sea level rise*," indicating that mangrove research is closely associated with coastal hazard mitigation and climate-related risks.

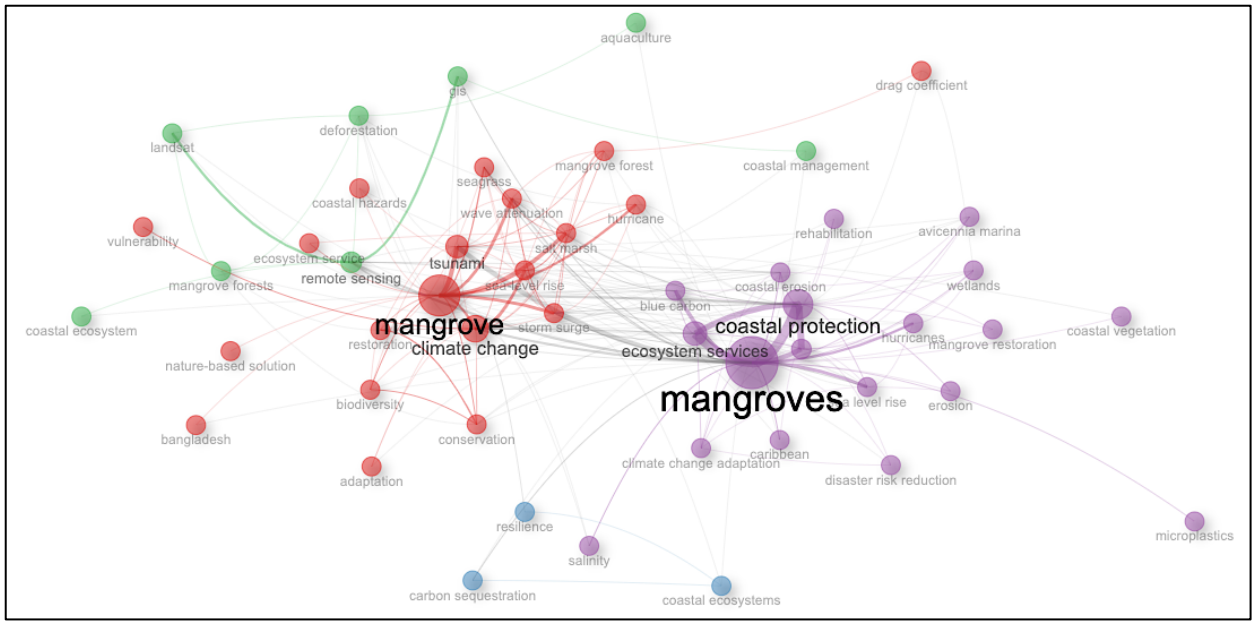


Figure 4. Keyword co-occurrence network of mangrove-based DRR research based on author keywords

One prominent cluster emphasizes hazard-related processes and protective functions, including keywords such as *tsunami*, *wave attenuation*, *hurricane*, and *coastal hazards*. This cluster highlights the biophysical framing of mangroves as natural barriers against extreme coastal events. A second cluster is organized around ecosystem-based perspectives, with keywords such as *ecosystem services*, *coastal protection*, *biodiversity*, and *conservation*, reflecting the integration of mangroves into ecosystem service and conservation-oriented discourses.

Additional clusters reveal supporting thematic areas, including remote sensing and spatial analysis (e.g., *remote sensing*, *GIS*, *Landsat*), as well as restoration and rehabilitation themes (e.g., *mangrove restoration*, *rehabilitation*, *wetlands*). Smaller clusters related to *carbon sequestration*, *blue carbon*, and *resilience* are present but less densely connected, indicating more limited integration within the broader DRR literature.

Overall, the co-occurrence network demonstrates that mangrove-based DRR research is characterized by a strong focus on ecological and hazard-related themes, with comparatively weaker connectivity to social, governance, and preparedness-related concepts.

Thematic Structure and Evolution of Research Topics

a. Thematic Structure of Mangrove-Based DRR Research

Figure 5 presents the thematic map of mangrove-based DRR research, positioning themes according to their centrality (relevance) and density (development). The map reveals a differentiated thematic structure consisting of motor, basic, niche, and emerging or declining themes.

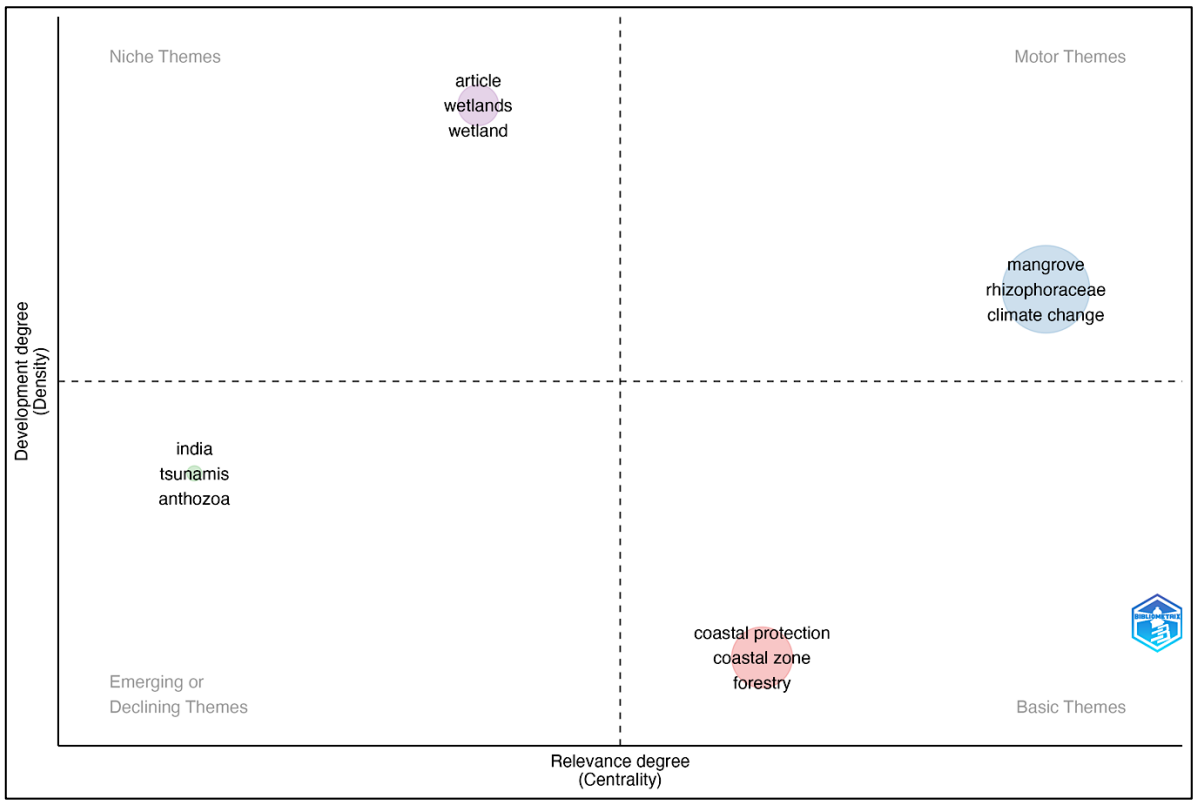


Figure 5. Thematic map of research themes in mangrove-based DRR studies

The motor themes, located in the upper-right quadrant, are dominated by the cluster comprising mangrove, *Rhizophoraceae*, and climate change. These themes demonstrate both high centrality and high density, indicating that they are well-developed and play a central role in structuring

the research field. Their prominence reflects sustained scholarly attention to mangrove ecosystems within the context of climate-related coastal risks.

The basic themes, situated in the lower-right quadrant, include coastal protection, coastal zone, and forestry. These themes exhibit high relevance but relatively lower internal development, suggesting that they serve as foundational concepts widely connected to other topics but are explored in less depth. Their position indicates a broad applicability across studies rather than a concentrated thematic focus. In contrast, the niche themes, located in the upper-left quadrant, are represented by keywords such as wetlands and wetland. These themes show high internal development but limited connectivity to the broader research field, indicating specialized or context-specific lines of inquiry. The emerging or declining themes, positioned in the lower-left quadrant, include terms such as tsunamis, India, and *Anthozoa*. These themes display both low centrality and low density, suggesting either a decline in prominence or the early stages of thematic development within mangrove-based DRR research.

Overall, the thematic structure indicates a research field anchored by ecological and climate-oriented core themes, supported by broadly connected but less developed coastal management concepts, alongside several specialized and peripheral research directions.

b. Thematic Evolution Across Research Periods (2000–2026)

Figure 6 illustrates the thematic evolution of mangrove-based DRR research across three consecutive periods: 2000–2004, 2005–2014, and 2015–2026. The evolution map highlights the shifts in thematic focus and continuity over time.

During the initial period (2000–2004), research themes were limited in number and primarily centered on mangrove forests and coastal erosion. These early themes reflect an exploratory stage in which mangroves were examined mainly in relation to coastal geomorphology and environmental degradation, with limited explicit linkage to DRR. Then, in the second period (2005–2014), the thematic structure became more diversified. Keywords such as tsunami, storm surge, mangroves, and biodiversity emerged as central nodes, indicating an expansion of research focus toward extreme coastal hazards and ecosystem responses. This period represents a transitional phase in which mangroves began to be more explicitly framed within disaster-related contexts. Moreover, the most recent period (2015–2026) exhibits a marked increase in thematic complexity and connectivity. Dominant themes include mangroves, ecosystem services, coastal protection, remote sensing, and climate change adaptation. The appearance and strengthening of these themes suggest a shift toward integrated approaches combining ecological functions, technological tools, and climate-oriented perspectives.

Across the three periods, the evolution map demonstrates a progression from localized and geomorphological concerns toward broader, more interconnected themes related to climate resilience, ecosystem services, and coastal protection. This temporal development reflects the maturation and expansion of mangrove-based DRR research over time.

Geographic Distribution and International Collaboration

Figure 7 presents the global geographic distribution and international collaboration patterns of mangrove-based DRR research. The collaboration map illustrates both the spatial concentration of research output and the networked nature of international scholarly collaboration in this field. The results show that research production and collaboration are globally distributed, with strong concentrations in countries located in the Asia-Pacific, North America, and Europe. Prominent collaboration hubs are visible among countries with extensive coastlines and high exposure to coastal hazards, including the United States, China, India, Australia, and several Western European countries. These countries appear as central nodes with numerous collaborative linkages, indicating their dominant role in international research networks.

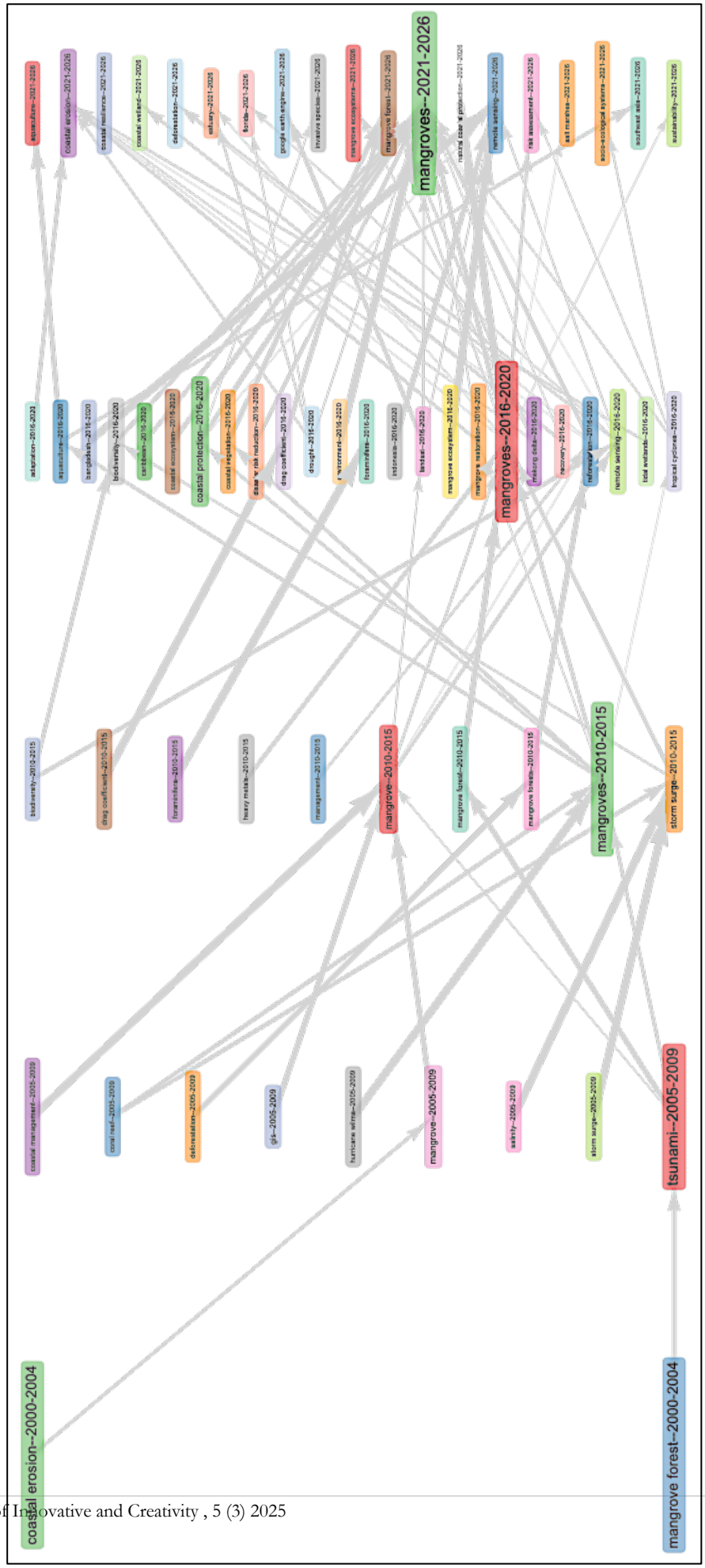


Figure 6. Thematic evolution of mangrove-based DRR studies (2000-2026)

Substantial collaborative connections are also observed between countries in the Global North and regions in the Global South, particularly across South and Southeast Asia, parts of Africa, and Latin America. This pattern suggests that while research leadership and publication output are often anchored in high-income countries, empirical research sites and regional case studies are frequently located in disaster-prone coastal regions elsewhere.

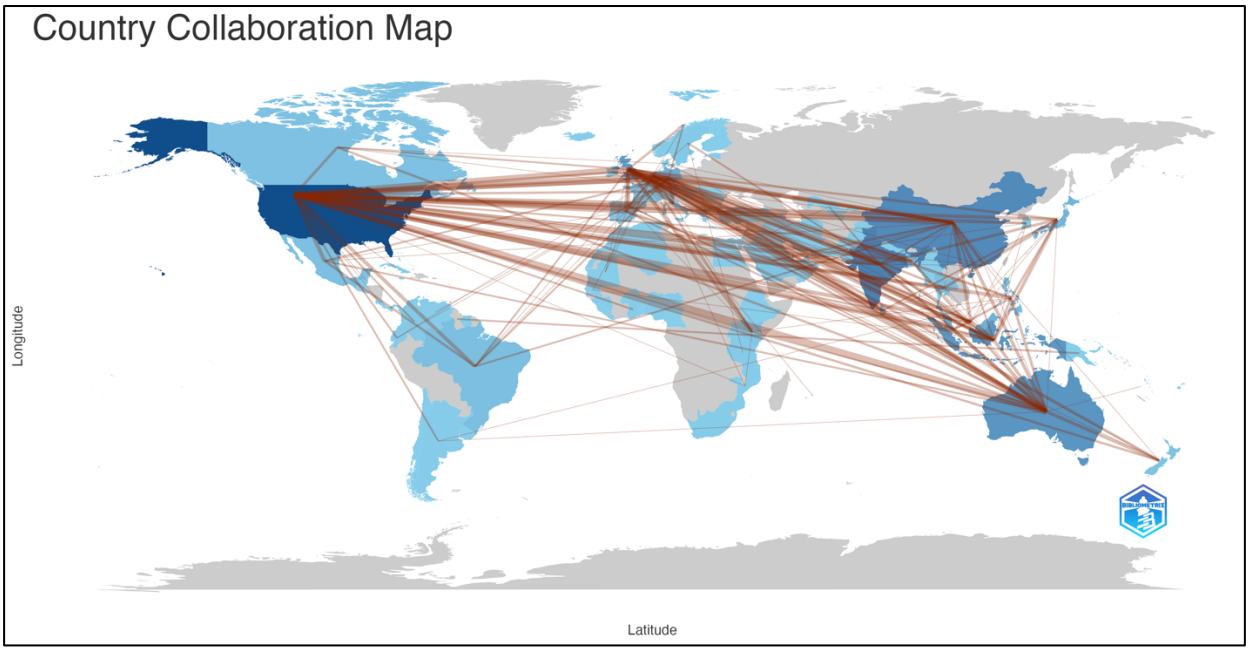


Figure 7. Global country collaboration map of mangrove-based DRR research (2000–2026)

Despite the broad geographic spread, collaboration density remains uneven. Several regions with high vulnerability to coastal hazards exhibit relatively fewer international connections, indicating potential imbalances between areas of high disaster exposure and centers of knowledge production. Overall, the geographic distribution highlights a globally connected but asymmetrical research landscape, characterized by strong international collaboration alongside regional disparities in research participation.

DISCUSSION

Evolution of Mangrove-Based DRR Studies

The temporal evolution of mangrove-based DRR research reflects a broader transformation in how coastal ecosystems are conceptualized within global risk and resilience frameworks. As demonstrated by the steady growth in publications since 2000 and the sharp acceleration after the mid-2000s, mangroves have progressively shifted from being treated as peripheral ecological features to becoming central elements in disaster-related scientific inquiry. This evolution aligns closely with global disaster milestones and policy shifts, particularly the heightened awareness following the 2004 Indian Ocean tsunami and the subsequent consolidation of DRR as a global development priority (Aitsi-Selmi et al., 2015; Rahman et al., 2018).

In the early phase of the literature (2000–2004), mangrove research was largely embedded within environmental and geomorphological studies, focusing on coastal erosion, habitat degradation, and ecosystem structure. Disaster-related considerations during this period were indirect and largely implicit, reflecting what Demiroz and Haase (2019) describe as a pre-resilience phase in disaster research, where hazards were treated as isolated physical events rather than socially mediated risks. Mangroves were examined primarily as natural coastal features rather than as components of integrated risk reduction systems.

The post-2005 expansion of mangrove-related DRR research marks a critical epistemic shift. The emergence of keywords such as *tsunami*, *storm surge*, and *wave attenuation* indicates that extreme events functioned as catalytic moments, redirecting scholarly attention toward the protective capacities of coastal ecosystems. This transition mirrors broader patterns in disaster studies, where catastrophic events often reorient research agendas toward prevention and mitigation rather than response alone (Ronan & Johnston, 2005; Shaw et al., 2009). Mangroves increasingly came to be framed as "natural infrastructure," capable of reducing hazard impacts while delivering co-benefits related to biodiversity and climate mitigation.

The most pronounced growth phase after 2015 coincides with the global consolidation of climate change adaptation, nature-based solutions, and resilience-oriented policy frameworks. The Sendai Framework for DRR explicitly emphasizes ecosystem-based approaches, creating a policy environment that legitimized and amplified research on mangroves as tools for disaster mitigation (Aitsi-Selmi et al., 2015). Simultaneously, climate-related discourses reframed coastal hazards as chronic and compounding risks rather than episodic disasters, further elevating the relevance of mangroves within long-term adaptation strategies (Rana, 2020; Schipper & Pelling, 2006).

However, while publication growth suggests conceptual maturation, the evolution of the field also reveals structural asymmetries. The geographic distribution of publications and collaborations shows that research leadership remains concentrated in a limited number of countries, primarily in North America, Europe, and parts of East Asia. This pattern reflects a familiar imbalance in global knowledge production, where regions most exposed to coastal hazards, such as South and Southeast Asia, small island states, and parts of Africa, often serve as empirical sites rather than epistemic centers (Martín-Martín et al., 2018; Wagner et al., 2017). As a result, mangrove-based DRR research risks reproducing a form of extractive knowledge production, where local contexts are analyzed through external conceptual lenses.

From a DRR perspective, this imbalance has substantive implications. DRR is inherently context-sensitive, requiring alignment between environmental conditions, governance structures, and community practices (Kapucu & Khosa, 2013; Pratiwi et al., 2023). When research trajectories are disproportionately shaped by external actors, there is a risk that mangrove-based solutions are promoted as universally applicable, without sufficient attention to local institutional capacity, social norms, and preparedness mechanisms. Thus, while the temporal evolution of the field reflects growing recognition of mangroves in DRR, it also exposes the need to move beyond event-driven and externally anchored research paradigms toward more locally embedded and policy-relevant approaches.

In this sense, the evolution identified in RQ1 is not merely a story of quantitative growth but one of conceptual narrowing and selective expansion. Mangroves have gained prominence, but largely within ecological and hazard-centric framings, leaving critical social and governance dimensions underdeveloped. This observation provides a necessary foundation for interpreting the disciplinary concentration identified in the next section.

Disciplinary Concentration and Knowledge Silos in Mangrove-Based DRR Studies

The subject area and journal distribution of mangrove-based DRR research reveal a pronounced disciplinary concentration that fundamentally shapes how mangroves are understood and operationalized within DRR discourse. The dominance of *Environmental Science, Agricultural and Biological Sciences*, and *Earth and Planetary Sciences* indicates that the field remains firmly anchored in natural science epistemologies. While this orientation has generated valuable insights into ecosystem dynamics and biophysical protection mechanisms, it has simultaneously constrained the analytical scope of mangrove-based DRR research.

This concentration is reinforced institutionally through publication patterns. The most productive journals, such as *Ocean and Coastal Management*, *Estuarine, Coastal and Shelf Science*, and *Science of the Total Environment*, privilege ecological, geomorphological, and environmental management perspectives. These outlets serve as intellectual gatekeepers, shaping research agendas by favoring studies that emphasize measurable environmental functions over social processes or governance

arrangements. As Scholten et al. (2021) argue, publication ecosystems play a decisive role in stabilizing disciplinary boundaries and rewarding particular forms of knowledge production.

The marginal representation of *Social Sciences and Engineering* within the dataset is particularly significant for DRR. DRR is not solely a technical or ecological challenge; it is deeply institutional, political, and behavioral (Agyepong & Liang, 2023; Allen et al., 2020). Preparedness, risk communication, policy implementation, and community engagement are central determinants of disaster outcomes, yet these dimensions remain weakly integrated into mangrove-based research. As a result, mangroves are frequently positioned as passive protective elements rather than as components of socio-ecological systems embedded within governance frameworks.

This disciplinary imbalance reflects what Rau et al. (2018) describe as the "invisibility problem" of interdisciplinary sustainability research, where social dimensions are acknowledged rhetorically but marginalized analytically. In the context of mangrove-based DRR, this leads to an implicit assumption that ecological restoration or conservation will automatically translate into risk reduction benefits. Such assumptions overlook the critical role of governance capacity, land-use regulation, enforcement mechanisms, and local participation in determining whether mangrove ecosystems can function effectively as protective infrastructures (Pratiwi et al., 2023; Schipper & Pelling, 2006).

Moreover, the limited presence of policy-oriented and governance journals suggests that mangrove-based DRR research has yet to fully engage with decision-making processes. This disconnect is problematic given that DRR is ultimately enacted through policies, institutions, and planning frameworks rather than through ecosystems alone. Without stronger engagement with public administration, development studies, and disaster governance literature, mangrove research risks remaining descriptive rather than transformative.

Importantly, this disciplinary concentration should not be interpreted as a failure of environmental science but as a structural limitation of the current research configuration. Bibliometric studies in disaster education and preparedness have shown similar patterns, where ecological or technical dimensions dominate at the expense of social integration (Saregar et al., 2022; Suboh et al., 2024). These patterns suggest that the challenge lies not in individual research choices but in the absence of integrative frameworks that bridge ecological knowledge with institutional and social analysis.

Positioning mangroves beyond ecology, hence, requires a deliberate reorientation of research agendas. Mangroves should be examined not only as ecosystems that attenuate waves or store carbon, but as governance-dependent assets whose protective value is mediated by land tenure arrangements, regulatory enforcement, community stewardship, and preparedness education. Studies on disaster preparedness services and inclusive DRR initiatives demonstrate that environmental interventions are most effective when embedded within broader institutional and social systems (Istiarsyah et al., 2023; Kapucu & Khosa, 2013).

In addressing RQ2, the findings thus point to a critical need for epistemic expansion. Integrating social sciences, policy analysis, and governance perspectives into mangrove-based DRR research is not an optional enhancement but a necessary condition for translating ecological potential into sustained risk reduction outcomes. This insight sets the stage for subsequent discussion of thematic dominance and underrepresented research areas, where the consequences of disciplinary silos become even more evident.

Dominant Framings of Mangroves in DRR

The keyword co-occurrence network and thematic structure analyses provide clear evidence that mangrove-based DRR research is dominated by a limited set of conceptual framings. These framings primarily position mangroves as biophysical protective systems, providers of ecosystem services, and climate-related mitigation assets. While these perspectives have been instrumental in legitimizing mangroves within DRR discourse, they also shape the boundaries of inquiry by privileging certain dimensions of risk while marginalizing others.

One dominant framing evident in the literature is the representation of mangroves as natural barriers against coastal hazards. Keywords such as tsunami, storm surge, wave attenuation, and coastal protection form highly connected clusters, indicating that hazard mitigation remains a central analytical focus. This orientation reflects a broader shift in DRR research following major catastrophic events, particularly the 2004 Indian Ocean tsunami, which catalyzed global interest in ecosystem-based approaches to disaster mitigation (Rahman et al., 2018; Schipper & Pelling, 2006). Within this framing, mangroves are primarily evaluated in terms of their capacity to reduce physical hazard intensity, often through site-specific or comparative ecological assessments.

Closely related to this hazard-centric perspective is the strong emphasis on ecosystem services. The thematic prominence of terms such as ecosystem services, biodiversity, coastal protection, and blue carbon suggests that mangrove research has increasingly aligned with sustainability and climate policy agendas. This alignment has strengthened the policy visibility of mangroves by linking DRR to climate mitigation and conservation co-benefits (Rana, 2020; Thomas & López, 2015; Yanti et al., 2025). However, as the thematic map indicates, ecosystem services are frequently treated as intrinsic properties of mangrove systems rather than as outcomes mediated by governance structures, land-use practices, and institutional capacity.

Technological framings further reinforce the ecological orientation of the field. The recurring appearance of keywords related to remote sensing, GIS, and satellite-based monitoring reflects the widespread use of spatial technologies to assess mangrove extent, degradation, and exposure to hazards. These methods have significantly advanced large-scale and comparative analyses, enabling global and regional assessments of mangrove vulnerability. Nevertheless, the dominance of remote sensing approaches also introduces a methodological bias toward variables that are spatially observable and quantifiable, often at the expense of socially embedded processes such as preparedness planning, enforcement of conservation regulations, and community engagement (Cobo et al., 2011; Gutiérrez-Salcedo et al., 2018).

From a DRR perspective, the dominance of these framings reveals an implicit technocratic logic within mangrove-based research. Mangroves are frequently conceptualized as functional solutions whose effectiveness can be optimized through ecological restoration or technological monitoring. Such an approach aligns with early resilience research that emphasized system stability and hazard absorption, but it underplays the role of social systems in shaping disaster outcomes (Demiroz & Haase, 2019; Ronan & Johnston, 2005). In practice, the protective value of mangroves depends not only on ecological integrity but also on land tenure arrangements, enforcement of coastal zoning, maintenance regimes, and the integration of ecosystems into disaster preparedness strategies.

The limited visibility of preparedness-related concepts in the keyword network underscores this imbalance. Preparedness encompassing early warning systems, evacuation planning, risk communication, and education is a core pillar of DRR frameworks (Aitsi-Selmi et al., 2015; Shaw et al., 2021). Yet, mangrove-based studies rarely examine how mangrove conservation or restoration initiatives are linked to institutional preparedness or community-level risk awareness. As a result, mangroves are often discussed as passive protective features rather than as active components of preparedness and resilience-building processes.

This dominant framing has important implications for governance and policy. When mangroves are treated primarily as ecological infrastructures, policy interventions tend to focus on conservation targets, restoration metrics, or carbon accounting, while overlooking governance challenges such as inter-agency coordination, stakeholder conflict, and local compliance. Studies on disaster governance emphasize that risk reduction outcomes are contingent upon institutional coherence and public engagement, not merely the presence of protective measures (Kapucu & Khosa, 2013; Pratiwi et al., 2023). The current framing, thus, limits the capacity of mangrove-based DRR research to inform policy design and implementation in complex coastal settings.

In addressing RQ3, the findings indicate that mangrove-based DRR research has converged around a coherent but narrow set of dominant framings. These framings have successfully established mangroves as valuable ecological assets within DRR discourse, yet they have not fully integrated the social, institutional, and governance dimensions that determine whether ecological potential translates

into reduced disaster risk. This conceptual concentration sets the stage for examining the thematic absences and underdeveloped areas identified in the next section.

Conceptual Blind Spots and Underrepresented Themes

While mangrove-based DRR (DRR) research has expanded significantly in volume and thematic coherence, the results reveal several persistent underrepresented themes that constitute critical conceptual blind spots. These gaps are not incidental; rather, they reflect structural limitations in how mangroves are conceptualized within the broader DRR knowledge system. By examining peripheral clusters in the keyword co-occurrence network and low-centrality themes in the thematic map, this section addresses RQ4 by identifying areas that remain weakly developed despite their recognized importance in DRR theory and practice.

One of the most pronounced gaps concerns governance and institutional arrangements. Keywords related to policy implementation, regulatory frameworks, institutional coordination, or land tenure are largely absent from dominant and basic thematic clusters. This absence is striking given that governance is widely acknowledged as a foundational determinant of disaster risk outcomes (Aitsi-Selmi et al., 2015; Kapucu & Khosa, 2013). Mangrove conservation and restoration efforts are deeply embedded in governance processes, including coastal zoning, enforcement mechanisms, and inter-agency collaboration. However, the limited engagement with these dimensions suggests that mangrove-based DRR research often assumes institutional effectiveness rather than interrogating it.

This governance gap has direct implications for policy relevance. DRR policies increasingly promote ecosystem-based approaches, yet implementation frequently encounters institutional fragmentation, conflicting mandates, and weak enforcement capacity. Without explicit attention to governance dynamics, mangrove-based research risks producing recommendations that are ecologically sound but administratively infeasible. Similar patterns have been identified in other DRR-related bibliometric studies, where technical and environmental solutions dominate at the expense of institutional analysis (Demiroz & Haase, 2019; Saregar et al., 2022). As a result, the translation of mangrove research into actionable DRR policy remains limited.

A second major blind spot relates to preparedness and community capacity. Preparedness is a core pillar of DRR frameworks, encompassing early warning systems, evacuation planning, risk communication, and public education (Ronan & Johnston, 2005; Shaw et al., 2021). Despite this centrality, preparedness-related concepts appear only weakly, if at all, in the thematic structure of mangrove-based DRR research. Mangroves are rarely examined as components of integrated preparedness systems, such as evacuation corridors, risk communication strategies, or community-based disaster planning.

This omission reflects a broader tendency to treat mangroves as passive protective features rather than as elements within socially mediated preparedness processes. Empirical studies have shown that preparedness and institutional readiness often play a more decisive role in disaster outcomes than physical protection alone (Kapucu & Khosa, 2013; Pratiwi et al., 2023). By neglecting preparedness, mangrove-based DRR research risks overstating the protective capacity of ecosystems while underestimating the role of human agency, institutional learning, and anticipatory action.

Social vulnerability and equity represent another underdeveloped dimension. The thematic analysis reveals minimal engagement with socioeconomic differentiation, gender, livelihoods, or marginalization, despite extensive evidence that disaster impacts are unevenly distributed across social groups (Nel & Righarts, 2008; Ungar, 2008). Coastal communities that depend on mangrove ecosystems for livelihoods are often characterized by poverty, insecure land tenure, and limited political representation. Yet, these conditions are rarely integrated into mangrove-based DRR analyses, resulting in a depoliticized understanding of risk reduction.

The absence of vulnerability-focused perspectives has important consequences. Ecosystem-based interventions, including mangrove restoration, can generate trade-offs, such as restricted access to resources or displacement of traditional users. Without incorporating social vulnerability and equity considerations, mangrove-based DRR research may inadvertently support policies that exacerbate existing inequalities. DRR literature consistently emphasizes that resilience is not a universal condition

but a socially differentiated process shaped by power relations and access to resources (Nel & Righarts, 2008; Ungar, 2008).

Education and awareness constitute a further blind spot within the literature. Disaster education is widely recognized as a long-term investment in resilience, enabling individuals and communities to interpret risk information and respond effectively to hazards (Kitagawa, 2015; Shaw et al., 2009). However, mangrove-based DRR research rarely explores how knowledge about mangrove functions, risks, or conservation is communicated to communities, embedded within formal education systems, or integrated into public awareness campaigns. This gap limits opportunities to link ecological interventions with sustained behavioral change and local stewardship.

Collectively, these underrepresented themes point to a deeper epistemological issue: the dominance of ecosystem-centered rather than risk-centered approaches. By prioritizing ecological variables and technological assessments, the literature has underplayed the social, institutional, and political conditions that shape disaster risk. This orientation constrains the ability of mangrove-based DRR research to engage meaningfully with governance, preparedness, and policy-making processes, which are central to effective DRR (Aitsi-Selmi et al., 2015; Kapucu & Khosa, 2013).

In answering RQ4, the findings indicate that advancing mangrove-based DRR research requires more than thematic expansion. It necessitates a conceptual reorientation that positions mangroves as socio-ecological infrastructures embedded within governance systems, preparedness practices, and social contexts. Addressing these blind spots would enable a more holistic understanding of how mangroves contribute to DRR and would enhance the relevance of research for policy and practice in disaster-prone coastal regions.

Implications for DRR, Governance, and Coastal Policy

The findings of this study carry important implications for DRR practice and coastal policy, particularly in how mangrove ecosystems are conceptualized and operationalized within risk governance frameworks. While mangroves are increasingly promoted as nature-based solutions for coastal protection, the results suggest that their effectiveness in reducing disaster risk depends less on ecological presence alone than on the institutional, social, and policy contexts in which they are embedded.

First, the dominance of ecological and hazard-centric framings implies that mangrove-based DRR interventions are often designed and evaluated through biophysical indicators, such as wave attenuation capacity, forest density, or carbon storage. While these indicators are valuable, they provide an incomplete basis for DRR decision-making. The frameworks of DRR emphasize that risk emerges from the interaction between hazards, exposure, vulnerability, and capacity (Aitsi-Selmi et al., 2015). From this perspective, mangroves should be understood not merely as ecological buffers but as components of risk governance systems that require coordination across sectors, scales, and institutions.

Second, the limited integration of governance and preparedness dimensions highlights a gap between research and policy implementation. Coastal policies that promote mangrove restoration frequently encounter challenges related to land tenure conflicts, competing development priorities, and weak enforcement mechanisms. Without explicit attention to governance capacity, mangrove-based policies risk remaining aspirational rather than operational. Studies on disaster governance consistently show that institutional coherence, regulatory clarity, and stakeholder engagement are decisive factors in determining whether risk reduction measures are sustained over time (Kapucu & Khosa, 2013; Pratiwi et al., 2023).

Third, the marginalization of preparedness and education within mangrove-based DRR research constrains the potential for long-term resilience building. Preparedness-oriented policies, such as early warning systems, evacuation planning, and risk communication, are central to reducing disaster impacts, yet they are rarely linked to ecosystem-based interventions in the literature (Ronan & Johnston, 2005; Shaw et al., 2021). Integrating mangroves into preparedness strategies could strengthen community understanding of risk, reinforce protective behaviors, and enhance the legitimacy of conservation initiatives through local participation.

The findings also suggest that current policy narratives may overestimate the universality of mangrove-based solutions. While mangroves can contribute significantly to coastal risk reduction, their protective value is context-dependent and mediated by social vulnerability and governance conditions. DRR policies that frame mangroves as stand-alone solutions risk obscuring underlying drivers of risk, such as unplanned coastal development, socioeconomic inequality, and limited institutional capacity (Nel & Righarts, 2008; Schipper & Pelling, 2006). A more nuanced policy approach would position mangroves as complementary measures within integrated DRR strategies rather than as substitutes for governance reform or preparedness investment.

Finally, the results underscore the need for greater alignment between mangrove-based research and policy-relevant knowledge production. Bibliometric evidence from this study indicates that mangrove-based DRR research remains largely confined to environmental and coastal science outlets, limiting its visibility within policy and governance arenas. Encouraging interdisciplinary research that bridges ecological science with public administration, disaster management, and education could enhance the translation of research findings into actionable DRR policies (Rau et al., 2018; Suboh et al., 2024).

Overall, the implications of this study point toward a necessary shift in how mangroves are positioned within DRR and coastal policy. Moving beyond an ecosystem-centered perspective toward a governance- and preparedness-oriented framing would enable mangrove-based interventions to contribute more effectively to sustainable and equitable DRR in coastal regions.

Methodological Contribution and Limitation

This study offers several methodological contributions to DRR (DRR) and mangrove-related research by applying large-scale bibliometric mapping to synthesize the evolution, structure, and gaps of the field. By systematically analyzing peer-reviewed journal articles and review papers indexed in the Scopus database over a 26-year period, the study provides a comprehensive overview of how mangroves have been positioned within DRR research. This approach complements conventional narrative reviews by enabling the identification of dominant themes, disciplinary concentrations, and underrepresented research areas based on empirical publication patterns rather than selective interpretation (Aria & Cuccurullo, 2017; Gutiérrez-Salcedo et al., 2018).

A key methodological contribution lies in the integration of multiple bibliometric techniques, including descriptive analysis, keyword co-occurrence networks, thematic mapping, and thematic evolution analysis. Together, these techniques allow for a multidimensional examination of the research field, capturing not only publication growth and disciplinary distribution but also the conceptual structure and temporal dynamics of research themes. Such integrative mapping has been increasingly recognized as valuable for assessing the maturity and direction of disaster-related research domains (Demiroz & Haase, 2019; Suboh et al., 2024).

Despite these contributions, several limitations should be acknowledged. First, the analysis relies exclusively on publications indexed in the Scopus database. While Scopus offers broad international coverage and robust metadata, it does not capture all relevant scholarship, particularly regionally published journals, non-English literature, and policy-oriented outputs. As a result, research produced in highly disaster-prone regions may be underrepresented, reinforcing existing geographic and linguistic biases in global knowledge production (Martín-Martín et al., 2018).

Second, the study focuses solely on journal articles and review papers, excluding conference proceedings, reports, and gray literature. Although this decision enhances the reliability and academic rigor of the dataset, it also limits the inclusion of practice-oriented and policy-relevant documents that often play a significant role in DRR and coastal management. Consequently, some applied insights and locally grounded experiences may not be fully reflected in the analysis.

Third, bibliometric analysis inherently emphasizes patterns of publication and keyword usage rather than the substantive quality or contextual depth of individual studies. The identification of dominant and underrepresented themes should therefore be interpreted as indicative of research trends rather than definitive assessments of research importance or effectiveness. Bibliometric

findings are best understood as a starting point for deeper qualitative and empirical investigations rather than as standalone evaluations of knowledge adequacy (Cobo et al., 2011).

Finally, thematic interpretations depend on the consistency and accuracy of author-provided keywords and indexing practices. Variations in terminology, disciplinary conventions, and keyword selection may influence network structures and thematic classifications. While these limitations are common to bibliometric studies, they underscore the need for cautious interpretation and triangulation with other review methods.

Overall, the methodological approach adopted in this study provides a robust framework for mapping mangrove-based DRR research while acknowledging the constraints inherent in bibliometric analyses. Recognizing these limitations helps contextualize the findings and supports their appropriate use in guiding future research and policy discussions.

Future Research Contributions

The findings of this study indicate that future research on mangroves in DRR must move beyond incremental ecological refinement toward more integrative, policy-relevant, and socially grounded approaches. The bibliometric patterns identified in this analysis suggest several priority directions that can strengthen the contribution of mangrove-based research to effective DRR and coastal resilience.

First, future studies should explicitly integrate governance and institutional analysis into mangrove-based DRR research. Rather than treating mangrove ecosystems as context-neutral solutions, research should examine how governance arrangements, such as land tenure systems, regulatory enforcement, inter-agency coordination, and stakeholder participation, shape the effectiveness and sustainability of mangrove-based interventions. Comparative and case-based studies that link ecological outcomes with institutional capacity would provide critical insights into why similar mangrove initiatives produce divergent DRR outcomes across contexts (Aitsi-Selmi et al., 2015; Kapucu & Khosa, 2013).

Second, there is a clear need to strengthen the connection between mangrove-based interventions and disaster preparedness. Future research should investigate how mangroves are incorporated into preparedness planning, including early warning systems, evacuation strategies, and community-based risk communication. Examining mangroves as part of integrated preparedness infrastructures, rather than as isolated protective features, would align research more closely with core DRR principles and enhance its practical relevance (Ronan & Johnston, 2005; Shaw et al., 2021).

Third, addressing social vulnerability and equity should become a central research priority. Future studies should explore how mangrove conservation and restoration initiatives interact with livelihoods, access to resources, and social differentiation within coastal communities. Incorporating perspectives from social sciences and development studies would enable more nuanced assessments of who benefits from mangrove-based DRR policies and under what conditions, thereby reducing the risk of unintended negative impacts on marginalized groups (Nel & Righarts, 2008; Ungar, 2008).

Fourth, greater attention should be given to education, awareness, and knowledge transfer related to mangroves and DRR. Research on disaster education has demonstrated the long-term value of embedding risk knowledge within formal education systems and community learning processes (Kitagawa, 2015; Shaw et al., 2009). Future mangrove-based DRR research could examine how ecological knowledge is communicated, institutionalized, and translated into preparedness behaviors, contributing to sustained resilience rather than short-term hazard mitigation.

Fifth, methodological diversification represents an important direction for future research. While remote sensing and spatial analysis will remain essential tools, combining these approaches with qualitative methods, participatory research, and policy analysis would enable richer insights into the socio-ecological dynamics of mangrove-based DRR. Mixed-methods designs can help bridge the gap between large-scale ecological assessments and localized governance realities, enhancing the interpretive depth of future studies (Cobo et al., 2011; Gutiérrez-Salcedo et al., 2018).

Finally, future bibliometric and review studies could extend the scope of analysis by incorporating regional databases, non-English literature, and gray policy documents to capture a

broader spectrum of knowledge production. Such efforts would help address existing geographic and linguistic biases and provide a more inclusive understanding of how mangrove-based DRR is conceptualized and practiced globally (Martín-Martín et al., 2018).

In summary, advancing mangrove-based DRR research requires a strategic shift toward interdisciplinary, governance-aware, and preparedness-oriented inquiry. By situating mangroves within broader socio-ecological and institutional systems, future research can better support the design of equitable, effective, and sustainable DRR strategies in coastal regions.

CONCLUSIONS

This study examined global research on mangroves in the context of DRR through a systematic bibliometric analysis of peer-reviewed literature published between 2000 and 2026. By mapping publication trends, disciplinary distributions, thematic structures, and geographic patterns, the study provides a comprehensive overview of how mangroves have been positioned within DRR research and identifies key gaps that constrain the field's contribution to policy and practice.

The findings indicate a substantial growth in mangrove-based DRR research, particularly following major coastal disasters and during the recent expansion of climate adaptation and nature-based solution agendas. However, this growth has been accompanied by a strong disciplinary concentration in environmental and earth sciences, reinforced by publication patterns in specialized coastal and ecological journals. As a result, mangroves are predominantly framed as biophysical protective systems and ecosystem service providers, while governance, preparedness, social vulnerability, and institutional dimensions remain underrepresented.

By highlighting these imbalances, the study demonstrates that the effectiveness of mangroves in DRR cannot be understood solely through ecological or technical perspectives. Instead, mangroves should be conceptualized as socio-ecological infrastructures whose protective value is mediated by governance arrangements, preparedness practices, and social contexts. Advancing research in this direction is essential for translating ecological potential into sustainable and equitable DRR outcomes. Methodologically, the study illustrates the value of bibliometric mapping for synthesizing complex and interdisciplinary research fields. While acknowledging limitations related to database coverage and publication types, the analysis offers an evidence-based foundation for future research agendas and policy discussions.

Overall, this study contributes to DRR scholarship by repositioning mangroves beyond ecology and emphasizing the need for interdisciplinary, governance-aware, and preparedness-oriented approaches. Strengthening these dimensions will enhance the relevance of mangrove-based research for DRR policy and support more integrated and context-sensitive coastal resilience strategies.

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