



Review



Coastal Land Use Transitions and Their Cascading Impacts on Ecosystem Resilience: A Global Bibliometric Review

Chengwei Li¹ and Shubo Fang^{2,*}¹ Shanghai Key Laboratory of Urban Design and Urban Science, NYU Shanghai, Shanghai 200124, China² Texas Institute for Applied Environmental Research, Tarleton State University, The Texas A&M University System, Stephenville, TX 76402, USA* Correspondence: sfang@tarleton.edu**How To Cite:** Li, C.; Fang, S. Coastal Land Use Transitions and Their Cascading Impacts on Ecosystem Resilience: A Global Bibliometric Review. *Regional Ecology and Management* 2026, 1(1), 7. <https://doi.org/10.53941/rem.2026.100007>

Received: 28 January 2026

Revised: 19 March 2026

Accepted: 10 April 2026

Published: 24 April 2026

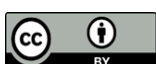
Abstract: Coastal zones act as dynamic socio-ecological interfaces facing compounded pressures from climate change, urban growth, and land-use transformation. Despite abundant literature, research often remains compartmentalized, addressing biophysical and socioeconomic drivers separately. This study systematically examines the evolution of coastal land-use and resilience research using CiteSpace, a bibliometric analysis tool. Results identify nine major clusters, with land-use dynamics, climate impacts, and management forming the field's core structure. Three dominant evolutionary trajectories emerged: (1) the integration of land-use and ecosystem dynamics as foundational resilience drivers; (2) a shift toward climate risk, variability, and adaptation-oriented analysis; and (3) the rise of governance and community-focused perspectives prioritizing socio-ecological resilience. However, significant structural biases remain, especially regarding data availability in the Global South. This review underscores the need for coherent frameworks that reconceptualize coastal systems as coupled socio-ecological interfaces. To advance long-term sustainability, future research must bridge methodological gaps by integrating multi-scale monitoring, from regional trends to neighborhood-level human expansion, with inclusive, justice-oriented adaptation strategies.

Keywords: coastal land use; ecosystem resilience; socio-ecological systems; bibliometric analysis; LUCC

1. Introduction

The coastal zone serves as a transitional interface between terrestrial and marine ecosystems [1] making it one of Earth's most intensively coupled human-natural systems. These regions host a disproportionate share of the global population and economic activity within a narrow strip. Specifically, it accommodates over one-third of the world's population and nearly half of the world's urban population [2,3]. By 2018, over 1.7 billion people resided within 50 km of the coast, with 1.09 billion living in high-risk zones within 10 km [4,5]. Currently, as this concentration of population and economic activity accelerates, projections suggest that hundreds of millions more will inhabit low-elevation coastal zones (LECZs) by 2050 [4]. Consequently, rapid coastal urbanization, industrial clustering, and extensive land reclamation are fundamentally reshaping coastal land-use and land-cover (LULC) dynamics, driving environmental challenges such as shoreline retreat, wetland destruction, and coastal squeeze [6,7]. Climate change stressors, sea-level rise, and intensified storms further amplify these anthropogenic disruptions, making coastal zones critical areas of global concern and risk.

Crucially, these anthropogenic land-use transitions are intricately intertwined with major biophysical coastal processes, including sea-level rise (SLR), shoreline erosion, wetland degradation, and habitat fragmentation [8,9].



Copyright: © 2026 by the authors. This is an open access article under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Publisher's Note: Scilight stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Over the past century, large areas of natural coastal ecosystems have been irreversibly transformed by agriculture, aquaculture, and urban sprawl [10]. Historical analysis suggests that 25–50% of global coastal wetlands were converted to agriculture or aquaculture in the 20th century, with an additional 20–45% projected to be lost due to sea-level rise by 2100 [11]. However, these transformative trajectories exhibit profound spatial heterogeneity. Empirically, land reclamation for industry and aquaculture dominates in China and parts of Southeast Asia [12], while West Africa has experienced rapid, informal urban expansion along with significant forest fragmentation [13]. Meanwhile, in the EU, the extended low-elevation zone now accounts for over 15% of total urban area by 2023 [14]. Recent studies have moved beyond descriptive monitoring to incorporate scenario-based modeling, revealing that while global trajectories share commonalities, regional outcomes are highly heterogeneous and driven by distinct socioeconomic and governance frameworks [15–18].

However, coastal zones no longer face merely isolated environmental pressures, such as gradual sea-level rise or localized nutrient pollution. Instead, they are increasingly facing compounded extreme events, where ongoing landscape degradation synergizes with disturbances such as intensified storm surges and successive hurricanes. As a consequence, beyond direct spatial transformation, such profound coastal LULC changes trigger cascading ecological impacts across multiple biophysical dimensions [19]. Structurally, the conversion of natural habitats into impervious surfaces intensifies fragmentation and restricts ecosystem migration, exacerbating coastal squeeze [20], particularly where hard infrastructure restricts landward ecosystem migration under sea-level rise [15]. Functionally, these changes reshape biogeochemical and hydrological cycles. Wetland loss impairs carbon sequestration and flood attenuation [21], while altered surface permeability and hydrological connectivity further modify groundwater-surface water exchanges [22] and nutrient fluxes [23], with downstream consequences for primary productivity and trophic structure [24]. Ultimately, these coupled disturbances degrade water quality, modify microclimates, and critically diminish the inherent capacity of coastal ecosystems to buffer against and recover from compounding climatic stressors [25].

Further, regarding compounding disturbances, ecosystem resilience has emerged as an indispensable conceptual framework for assessing how coastal systems maintain their functional integrity [26,27]. Resilience in this coastal context encompasses not only the capacity to absorb sudden shocks but also the capacity to adapt, reorganize, and maintain essential ecological functions amid long-term environmental challenges [28–30]. Existing studies show that intensive land conversion not only decreases ecosystem performance but also gradually erodes intrinsic stabilizing feedbacks, pushing coastal ecosystems toward critical tipping points where abrupt regime shifts may happen [31,32]. This phenomenon often incurs a resilience debt or budget, in which short-term economic gains from coastal exploitation mask long-term, potentially irreversible losses in ecological stability and adaptive capacity [33]. Consequently, while interventions such as nature-based solutions (NbS) and strategic retreat can partially restore connectivity, their success depends on alignment with underlying biophysical processes [34,35]. However, their effectiveness still depends significantly on local context, especially regarding temporal dynamics, spatial scale, and alignment with underlying biophysical processes.

Methodologies for assessing coastal resilience are evolving from static frameworks (e.g., PSR, DPSIR) to integrated, spatially explicit quantitative models [36,37]. Advances in high-resolution remote sensing data and the application of novel process-based models have significantly deepened our understanding of LULC dynamics and cascading impacts [38,39]. For instance, combining high-resolution remote sensing with process-based models (e.g., InVEST, ARIES, MIMES, CLUE-S, SLEUTH, DIVA, SLAMM) now allows for projecting resilience across various climate and LULC scenarios [40–42]. However, significant gaps remain. For example, current studies often treat land-use impacts as linear and reversible, underestimating feedback amplification and threshold effects [25,31]. Specifically, critical mechanistic studies, such as how landscape fragmentation increases system vulnerability, nonlinear threshold effects, or how hydrological connectivity gradually weakens the inherent stabilizing feedbacks of coastal wetlands, are dispersed across isolated disciplinary fields, from geography to biogeochemistry, rather than being integrated into a unified socio-ecological perspective. However, previous literature reviews have largely failed to summarize this interdisciplinary scatter. Furthermore, the integration of land-system science with resilience theory remains fragmented; resilience research often treats land-use dynamics as static background factors, thereby obscuring how land transformation actively reshapes adaptive space [32]. They overlooked mapping how the different land transformation processes (e.g., coastal squeeze, habitat degradation, wetland reclamation) interact to induce systemic resilience loss, and they ignored the shift from descriptive land-cover monitoring to dynamic resilience modeling. Therefore, this study objectively maps existing disciplinary research, tracks critical thematic turning points, and synthesizes the dispersed mechanistic links between coastal land-use dynamics and ecosystem resilience.

To address this critical knowledge-synthesis gap, the main aim of the study is to conduct a comprehensive bibliometric analysis of global research on coastal LULC and ecosystem resilience using the Web of Science Core

Collection database. By employing CiteSpace-based knowledge mapping techniques, we quantitatively analyze publication trends, keyword co-occurrence networks, thematic clusters, and citation bursts to reveal the intellectual evolution of the field. Specifically, the research is designed to address three main objectives: (i) to quantify the knowledge-based evolution of the field, specifically identifying how research paradigms have shifted from descriptive LULC monitoring toward dynamic socio-ecological resilience modeling; (ii) to synthesize and characterize how coastal land transformation affects ecosystem resilience across various spatial scales and socio-ecological contexts; and (iii) to evaluate the integration of LUCC with resilience application, identifying critical geographic or mechanistic directions to propose context-specific adaptation pathways (e.g., NbS) against extreme coastal events. Ultimately, the findings aim to provide a coherent, evidence-based framework for advancing science-based coastal planning and proactive climate adaptation strategies under accelerating global change.

2. Data Acquisition and Methodology

2.1. Bibliometric Approach and Analytical Tool

This study employs bibliometric analysis to quantitatively map the intellectual structure and thematic evolution of the coastal land use and resilience knowledge domain [43]. We utilized CiteSpace (6.4.R2), a dynamic visualization tool optimized for detecting critical turning points, research hotspots, and emerging trends within complex scientific fields [44,45]. By applying co-citation analysis and pathfinder network scaling, CiteSpace facilitates the visualization of structural relationships among authors, institutions, and keywords, enabling a comprehensive exploration of the field's dynamic mechanisms [46,47].

2.2. Data Source and Search Strategy

Bibliographic data were retrieved from the Web of Science Core Collection (WoSCC) to ensure high-quality and standardized citation data [48]. The keyword selection was systematically structured around the spatial domain, driver mechanisms, and systemic outcomes to ensure both thoroughness and specificity. However, the initial broad search produced many irrelevant publications from unrelated fields, requiring the addition of more specific keywords to clearly define the socio-ecological research context (refined search). A two-stage retrieval strategy was implemented to balance breadth and precision:

- (1) Broad Search: A preliminary search using TS = (“coastal land use*” OR “coastal land use change*”) AND TS = (“ecosystem resilience*” OR “ecological resilience*”) yielded 5057 records. This dataset was utilized to analyze long-term global publication trends. After refinement by Web of Science categories, non-English records, non-article and non-review document types, and publications before 2005 were excluded, leaving a dataset of 4916 publications.
- (2) Refined Search: To identify specific interaction mechanisms, a detailed query was created using expanded terms, including TS = (“coast” OR “littoral” OR “shoreline*” OR “estuary*” OR “bay area*” OR “intertidal zone*”) AND TS = (“land use*” OR “land cover*” OR “LULC” OR “LUCC” OR “coastal urbanization” OR “land transition*” OR “land reclamation”) AND TS = (“resilience*” OR “coastal resilience*” OR “ecosystem resilience*” OR “ecological resilience*” OR “adaptive capacity” OR “recovery capacity” OR “ecosystem stability”). This search returned 798 core records spanning 2005 to 2025.

2.3. Screening and Eligibility Criteria

To ensure data quality, the dataset was restricted to peer-reviewed articles and review papers published in English. Duplicates were removed automatically. Non-scholarly document types, including editorials, conference proceedings, and book chapters, were excluded. Following a rigorous manual review of titles and abstracts to remove duplicates and irrelevant entries (e.g., unrelated engineering or medical studies), a final dataset of 765 high-quality publications was selected for detailed analysis.

2.4. Analytic Configuration in CiteSpace

The bibliometric analysis was configured with the following parameters to ensure network clarity and structural significance:

- (1) Time slicing: Data were segmented into 1-year intervals (January–December 2025).
- (2) Node selection: A dual strategy was applied using the g-index ($k = 20$) and a Top N threshold of 50 to extract the most representative and highly cited nodes within each time slice, effectively balancing network scale and legibility.

- (3) Network pruning: The Pathfinder and Pruning Sliced Networks algorithms were employed to crop the merged network, eliminating redundant links and highlighting critical structural paths.
- (4) Clustering: Keyword co-occurrences were clustered using the Log-Likelihood Ratio (LLR) algorithm, which is known for producing distinct, high-quality labels with high intra-class similarity, to identify distinct research themes, with institutions, countries, and keywords set as primary node types for visualization.

2.5. Analytical Techniques and Network Metrics

To systematically map the field's intellectual structure, this study employed four analytical modules in CiteSpace (6.4.R2) [44,45]. First, Collaboration network analysis was conducted using co-authorship matrices at the country, institution, and author levels to measure social cooperation. In these networks, node size represents publication volume, while link thickness indicates collaboration intensity. Second, Keyword co-occurrence analysis was utilized to map conceptual hotspots. The structural importance of nodes within this network was quantified using Betweenness Centrality. Nodes with a centrality score > 0.1 are identified as critical structural hubs that bridge different research domains, visually represented by purple rings. Third, Document co-citation and clustering analysis were applied to delineate major thematic groupings. Clusters were extracted using the Log-Likelihood Ratio (LLR) algorithm, which ensures high intra-cluster similarity and inter-cluster distinctiveness, evaluated by the Modularity (Q -value) and Silhouette (S -score) metrics. Across all generated networks, the Q scores were consistently greater than 0.3 (like keywords value = 0.4368), and the S scores exceeded 0.7 (like keywords value = 0.7499), statistically confirming that the network structures are significant and the clustering results are highly convincing. Finally, burst detection analysis was performed using Kleinberg's burst-detection algorithm. This technique identifies sudden, statistically significant spikes in keyword frequency or citation rates within specific time windows, providing a robust basis for identifying emerging research frontiers and paradigm shifts.

3. Bibliometric Review Results

3.1. Bibliometric Review of LUCC and Coastal Resilience

3.1.1. Annual Publication Trend

Research output has demonstrated a consistent upward trend since 2005, with a significant acceleration after 2019 (Figure 1). To systematically understand this evolution, the timeline was divided into distinct stages: the Preparation Stage (2005–2010), the Increase Stage (2010–2015), the Expansion Stage (2015–2019), and the Boost Stage (2020–Present). These classifications depend on a dual-criteria approach: quantitative inflection points in yearly publication volumes and growth rates, as well as qualitative paradigm shifts driven by key global policy frameworks and technological advances. Specifically, the exponential growth in post-2015 is not merely a natural academic progression. Rather, it reflects a reactive scientific response to major global policy milestones (e.g., the Paris Agreement and the UN Sustainable Development Goals). On the other hand, the sharp increase in publications directly reflects the growing frequency of compound coastal hazards in the real world, indicating that land-use resilience has shifted from a theoretical niche to an urgent, policy-driven imperative.

- (1) Preparation Stage (2005–2010): Low output (< 50 papers/year), focused on descriptive assessments of wetland loss.
- (2) Expansion Stage (2015–2019): Following the Paris Agreement, research diversified into interdisciplinary domains, coupling climate scenarios with land-use models.
- (3) Boost Stage (2020–Present): An intense increase driven by the urgency of climate agendas and the availability of big data, considering coastal regions as critical cases for coupled land-sea system studies.

3.1.2. Study Location

We divided the papers collected in the first stage into Total and those selected for subsequent analyses (e.g., keyword analysis), which were classified as Typical. They originated from 160 and 118 countries and regions worldwide, respectively. Uncovering the spatiotemporal trends of Total research, the highest volumes were published in Asia (27%), Europe (35%), and North America (21%), with smaller volumes in Africa (5%), Oceania (7%), and South America (5%), indicating that this research topic has received global attention (Figure 2). Research in this field has been primarily (Top 10) concentrated in the United States (USA), China, the United Kingdom (UK), Australia, Canada, Germany, Spain, France, Italy, and the Netherlands. China, the US, and the UK account for 15%, 16%, and 7% of all research on this topic, respectively. Australia was the fourth largest country in publications (4%). Western European countries, including the United Kingdom, Germany, France, Italy, and the Netherlands, also exhibit high

publication intensities, consistent with their strong research infrastructures, active engagement in Integrated Coastal Zone Management (ICZM), and policy-driven focus on coastal resilience under climate change.

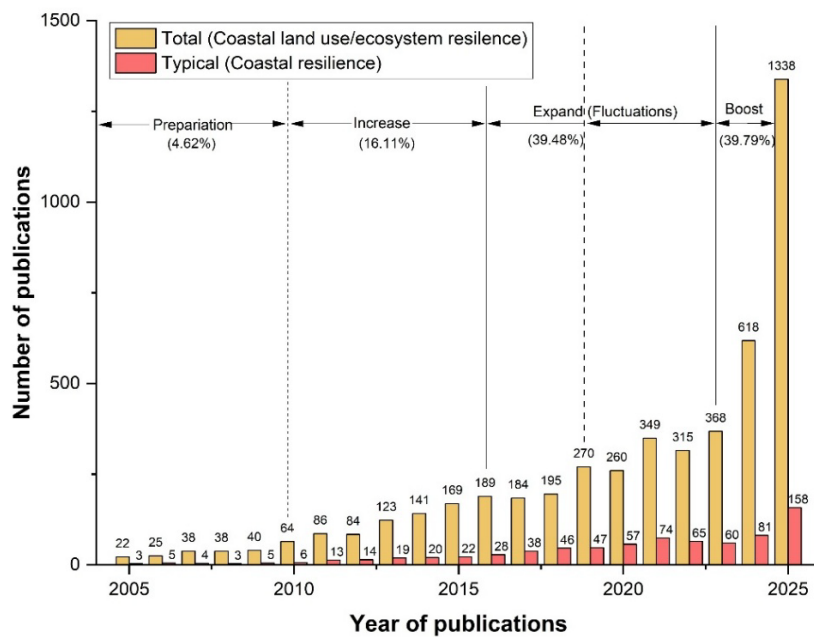


Figure 1. Trends in publications from January 2005 to April 2025. Papers collected in the first stage are categorized as Total, whereas those selected for subsequent analyses (e.g., keyword analysis) are classified as Typical.

By contrast, many regions in Africa, South America, and Southeast Asia have low publication proportion despite high coastal exposure and socio-ecological vulnerability. This suggests geographic biases in the global knowledge base, with areas under significant coastal pressures and climate risks underrepresented in the total literature. These disparities may be attributed to variations in research capacity, funding, data accessibility, and integration into international research networks. Another reason was that database retrieval in the study was limited to English-language journals, which may have contributed to the limited geographical distribution represented in this review. Overall, the observed global distribution underscores that research on coastal land-use change and its impact on ecosystem resilience is shaped not only by environmental risk but also by uneven scientific capacity and institutional support.

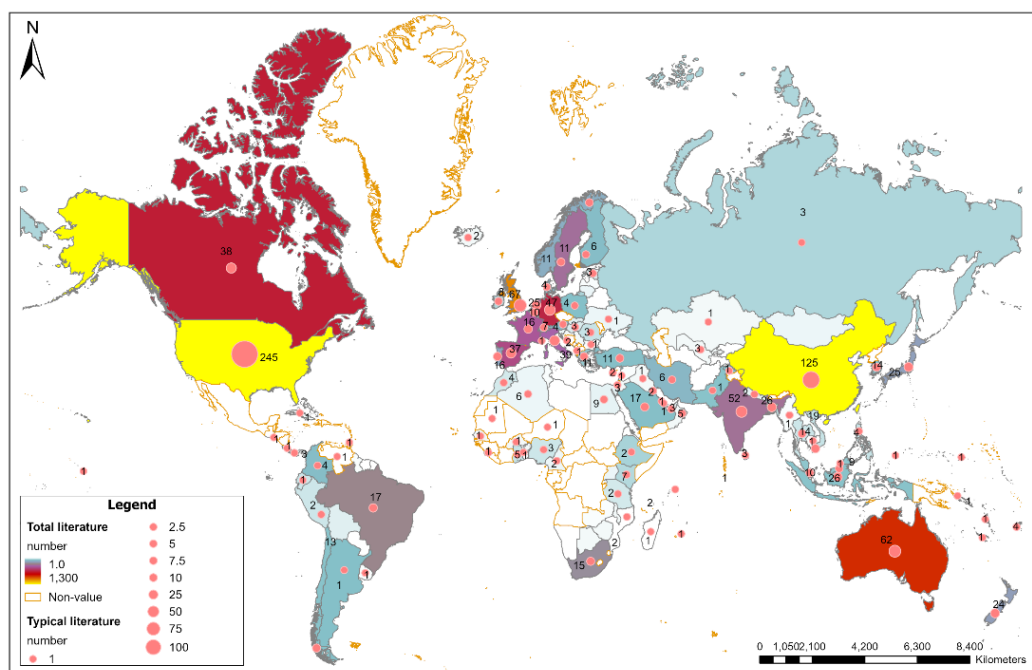


Figure 2. Global distribution of the retrieved studies. Numbers and circle size represent the number of typical papers published. The redder and yellower the color, the more publications there are. Light blue indicates fewer posts.

3.1.3. Quantitative Analysis of Significant Countries/Regions

Figure 3 shows the collaborative distribution among countries/regions, focusing on typical studies and their collaboration network. Significantly, the network exhibits a highly centralized yet polycentric structure, dominated by the United States and the People's Republic of China (China), which serve as the primary hubs in terms of both publication volume and collaborative intensity (Figure 3). European countries, particularly England, Germany, Italy, France, and Spain, form a tightly interconnected sub-network and play crucial bridging roles linking transatlantic and global research collaborations. For degree centrality, which reflects the number of direct international collaboration ties per country, the USA has the highest degree centrality (52), followed by England (41) and Germany (38). In addition, China (37) and Australia (33) also demonstrate extensive international engagement. Betweenness centrality further underscores the structural importance of the United States (0.47), followed by Germany (0.26), China (0.22), and England (0.21), highlighting their key intermediary positions in facilitating international knowledge exchange. Australia and Italy also show notable bridging capacity. In contrast, several emerging countries, including Chile, India, and Mexico, exhibit strong citation bursts, indicating rapid increases in engagement during specific periods. Overall, the collaboration network reflects an increasingly globalized research landscape, characterized by core-periphery interactions, regional cooperation clusters, and the growing participation of emerging research economies. The visualization shows that the Global South (e.g., African coastal nations and Small Island Developing States), which are arguably the most vulnerable to coastal squeeze and LULC degradation, remains structurally marginalized in global scientific collaboration. This disconnect between research capacity and actual climate vulnerability highlights an urgent need to decolonize coastal resilience research.

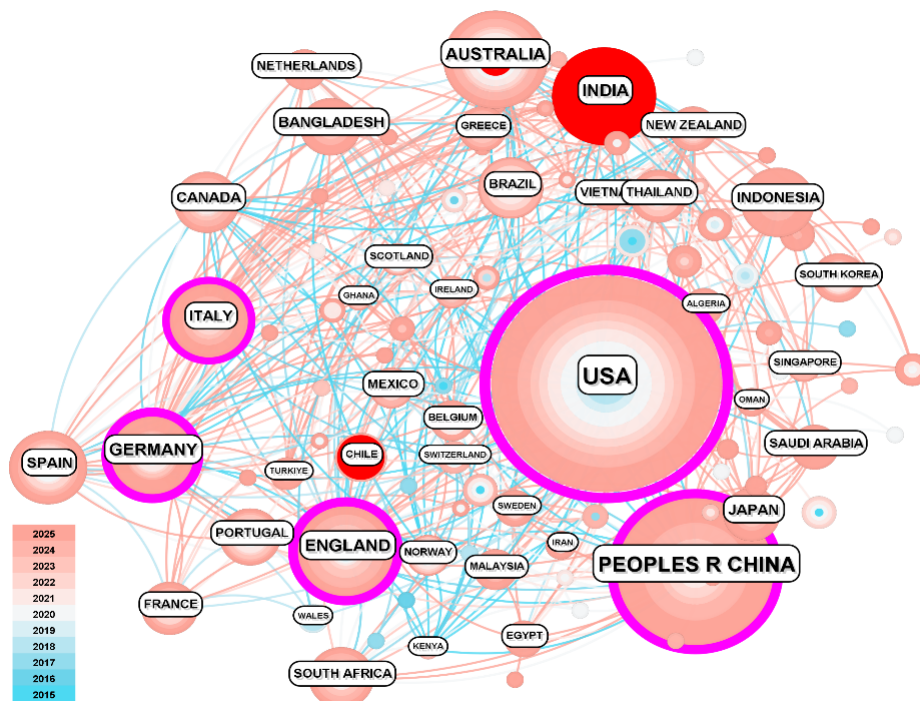


Figure 3. Map of the cooperation networks among countries in the field. Node size and color corresponded to the volume of publications, whereas the thickness of the connecting lines illustrated the extent of collaborative intensity among nations. The more papers published, the larger the node. In addition, node colors indicate the publication date of the articles, with red hues indicating older publications.

3.1.4. Institutions Performances

Figure 4 illustrates the distribution of institutions and their connections. As shown in Figure 3, the same network diagram form is used for research networks across different research institutions (Figure 4). The institutional collaboration network reveals a highly stratified topology, characterized not by a proliferation of isolated nodes but by the dominance of a few macro-institutional hubs. Notably, multi-campus university systems, institutions such as the University of California System, the State University of Florida, and Texas A&M University, exhibit greater network centrality than individual institutions, highlighting the agglomeration effect of system-level organizations in shaping global research collaboration. Beyond academia, government-affiliated

research agencies, including the United States Geological Survey (USGS) and the U.S. Department of the Interior, serve as critical boundary organizations. These entities exhibit high betweenness centrality, bridging distinct university clusters and enabling the translation of scientific research into applied, policy-relevant knowledge. Chinese institutions, dominated by the Chinese Academy of Sciences (CAS), East China Normal University (ECNU), and the University of Chinese Academy of Sciences (UCAS), form a densely connected cluster with strong internal homophily. At the global scale, cross-regional collaboration follows a core-periphery structure, primarily mediated by a select group of high-degree nodes. North American university systems and government agencies serve as global brokers, connecting institutions across East Asia, the Asia-Pacific, and emerging regions. Finally, the network exhibits a globalized collaboration pattern characterized by dominant North American leadership, growing East Asian involvement, and enhanced interconnectivity among different institutions and nations.

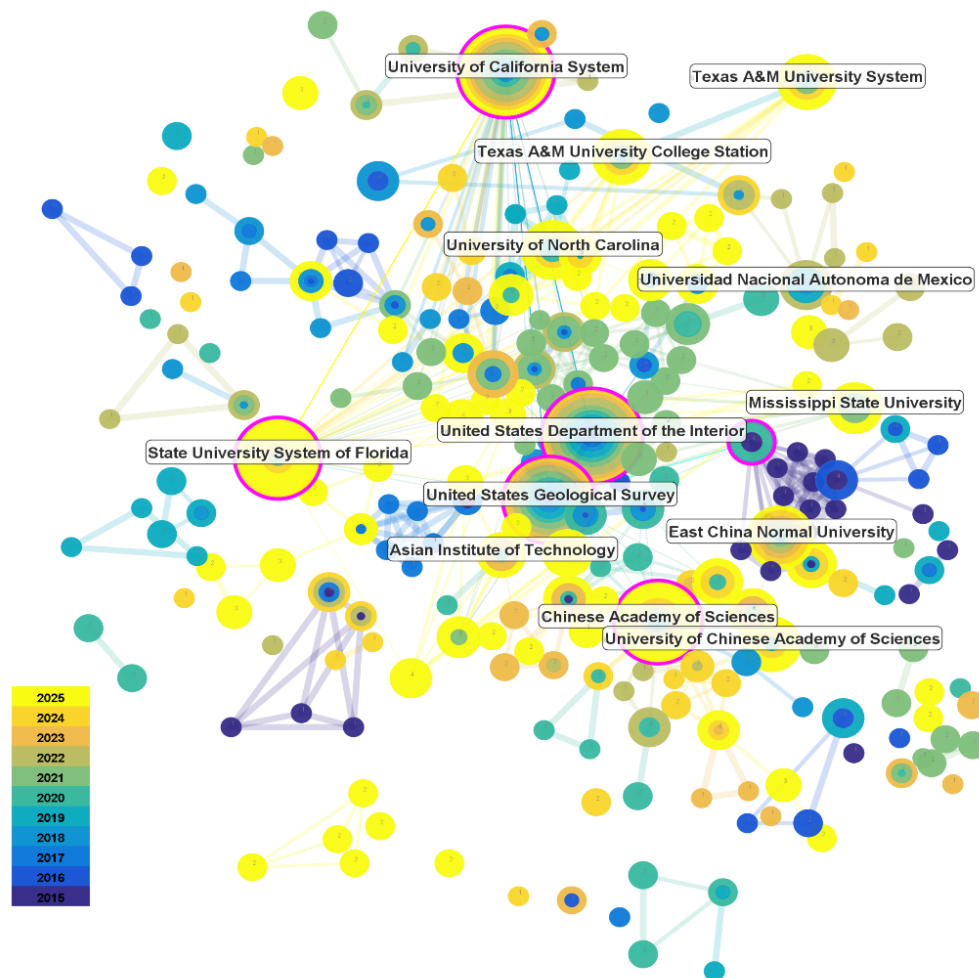


Figure 4. The cooperation network among research institutions. The number of connecting lines between nodes indicates the number of joint publications by various research institutions.

3.2. Analysis of Research Themes and Frontiers

3.2.1. Research Themes Analysis

The time-zone visualization of co-occurring keywords delineates the progression of knowledge within a specified temporal range. It helps provide a chronological examination of the research landscape and shifts in key focus areas. The analysis arranges nodes from left to right by publication year. Using the timing view function in CiteSpace, the distribution of keywords, calculated by frequency per year, is shown (Figure 5). The increasing appearance of keywords after 2020 indicates the emergence of research areas in the field that urgently require attention. The eight parallel axes represent 8 different clusters; the position represents the year of the first appearance of the keyword, and the arc-shaped connecting line represents the co-occurrence relationship of the keyword. The weighted mean silhouette (S) and modularity (Q) obtained from the cluster analysis were 0.7483 and 0.5702, respectively, indicating a significant cluster structure and reasonable results.

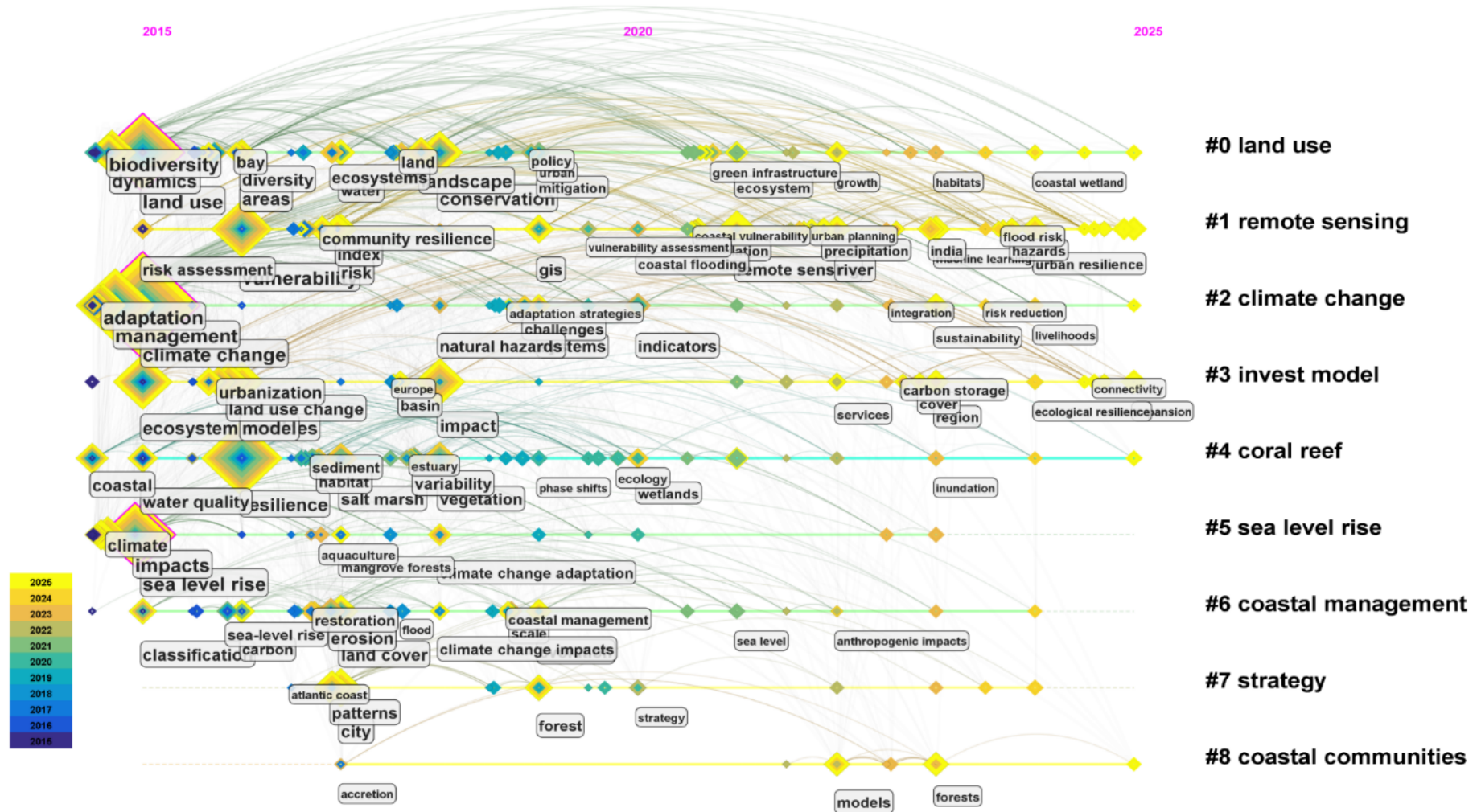


Figure 5. Keyword co-occurrence clustering timeline map of references. # represent the cluster. Nodes and lines represent keywords and their interconnections, respectively. Larger nodes signify a higher frequency of occurrence, while longer colored line segments denote an extended duration of a keyword’s presence.

Next, the cluster focuses primarily on models and methods, including methodological advances and perspectives on climate-driven risk modeling. These clusters, to some extent, reflect the rapid development of analytical methods and climate-risk-oriented research, marking a shift toward spatially explicit, high-resolution, data-intensive approaches. For instance, Cluster #1 (remote sensing) forms the primary methodological backbone of the field, with keywords such as GIS, remote sensing, land cover classification, machine learning, and deep learning becoming increasingly prominent over time. These methods are widely used to monitor coastal flooding, land subsidence, and ecosystem degradation, enabling fine-scale assessments of dynamic coastal processes. Complementing these perspectives on social and economic considerations, Cluster #3 (investment model) highlights the growing use of decision-support and evaluation tools, including the analytic hierarchy process, allocation models, and cost-related assessments, to inform adaptation planning and infrastructure investment. In particular, when operationalizing ecosystem service frameworks, the InVEST model is widely considered the most mature valuation tool. However, despite its recognition as a mature valuation tool, applying the InVEST in dynamic coastal environments has inherent limitations. Specifically, its heavy dependence on static spatial data limits its analytical capacity to capture temporal dynamics and non-linear threshold effects, such as ecological tipping points. This methodological limitation highlights a significant research gap in accurately modeling the complex, feedback-driven realities of coastal resilience. In parallel, Cluster #2 (climate change) focuses on climate-induced hazards and vulnerabilities, including sea-level rise, extreme events, flood risk, and coastal vulnerability. The timeline shows a gradual transition within this cluster from impact-centered analyses to adaptation-oriented research, with increasing attention to risk reduction, resilience, and community adaptation.

The remaining clusters show an increasing emphasis on management practices, strategic planning, and the social and cultural aspects of coastal systems, indicating a broadening of research themes beyond biophysical and technical analyses. For example, Cluster #6 (coastal management) emphasizes applied governance and policy implementation, with keywords such as adaptive management, disaster resilience, and risk governance, highlighting efforts to turn scientific insights into operational practice frameworks. At a more integrative level, Cluster #7 (strategy) emphasizes long-term, cross-sectoral planning that links sustainability, adaptation pathways, and system-level coordination. Cluster #8 (coastal communities) is a relatively recent, increasingly prominent theme that highlights livelihoods, cultural heritage, and community resilience. Overall, these clusters show that methodological innovation and climate risk assessment have become tightly intertwined in contemporary coastal research. The temporal evolution of keywords indicates a significant paradigm shift in the field, which serves as an empirical indicator of conceptual restructuring. For practice, it has advanced from static descriptive terms to proactive interventionist tech, reflecting a move beyond quantifying LUCC degradation to actively engineering recovery pathways.

3.2.2. Research Frontiers Analysis

Keyword bursts can indicate clear temporal shifts in research frontiers and thematic priorities. We applied keyword-burst analysis to identify keywords while excluding case-study regions, data-analysis methods, and single-word ambiguities. Figure 6 shows the top 17 keywords with significant burst strengths (Figure 6). The detected bursts exhibit distinct stage-wise patterns, reflecting the evolution of coastal research from early integrative ecological assessments toward risk-oriented, data-driven machine-learning models and regionally grounded sustainability studies. Before 2020, system-level ecological perspectives and environmental quality were predominant. Terms like social-ecological systems, water quality, future simulation, and resilience showed significant early relevance. These concepts underscore the integration of human-environment interactions and scenario-based simulations for predicting coastal dynamics. Concurrently, the rise in nitrogen levels indicates increased focus on nutrient loading and biogeochemical processes, while sea-level rise highlights the recognition of many climate change stressors. Overall, this phase underscores a fundamental emphasis on ecological integrity, system resilience, and the environmental influences on coastal transformation.

After 2019, the period marks a transition toward more analytical and management-oriented research frontiers. Keywords such as variability (3.21, 2018–2020) and mitigation (3.05, 2019–2021) indicate increasing recognition of uncertainty and dynamic processes, as well as the need for intervention strategies. Meanwhile, the appearance of risk analysis (2.24, 2022–2023) further underscores a growing orientation toward decision-relevant science, linking hazard assessment with planning and management needs. In the most recent phase, research frontiers have shifted markedly toward data-intensive approaches, sustainability discourses, and region-specific challenges. Keywords such as machine learning (3.01, 2023–2025) highlight the rapid integration of advanced computational techniques for modeling, prediction, and pattern recognition in coastal systems. Concurrently, sustainability (2.76) and inundation (2.34, primarily referring to territorial land inundation and coastal inundation) reflect heightened attention to long-term adaptive capacity and the tangible impacts of climate extremes. The burst analysis reveals

a distinct trajectory of research frontiers, beginning with early socio-ecological conceptualizations and environmental quality, advancing through variability-aware mitigation strategies and indicator-based evaluations, and culminating in contemporary data-driven, sustainability-oriented, and regionally contextualized coastal research. This temporal progression highlights the domain's increasing complexity and interdisciplinarity, thereby laying a foundation for future exploration of emerging research frontiers.

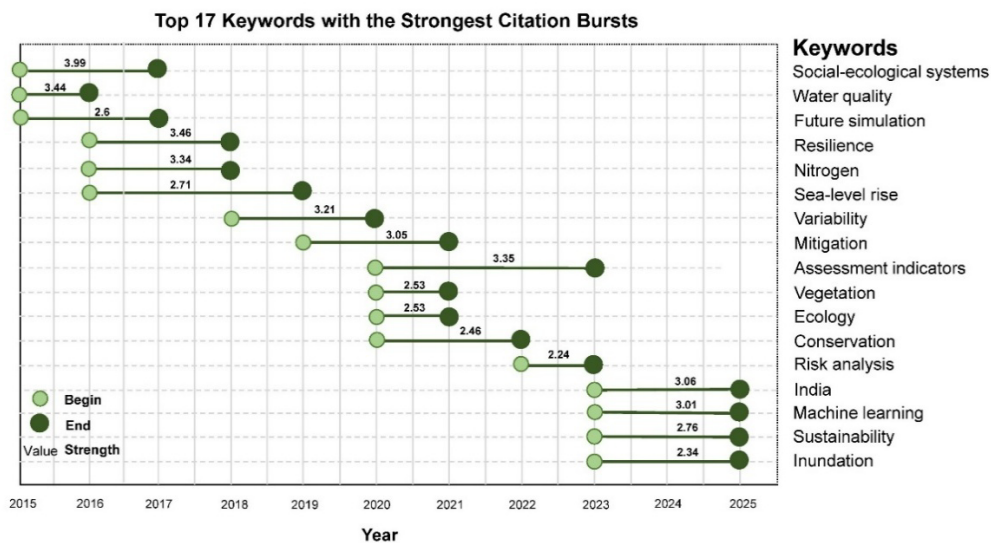


Figure 6. Keywords with intense frequency bursts. Begin represents the time when the emergent growth trend of the keyword first appeared, End indicates the year in which the emergent growth of the keyword ended, the line between the circles indicates the duration of the emergent continuation, and the value of that represents the strength of the emergent words.

3.3. Synthesizes Ecological Outcomes and Resilience Mechanisms

While the above bibliometric metadata outlines the field's structural evolution, a deep thematic synthesis of the literature reveals the substantive ecological outcomes of coastal LULC changes. Moving beyond surface-level land conversions, the literature highlights how different anthropogenic drivers trigger various cascading impacts and destroy specific resilience mechanisms across heterogeneous geographic regions (Table 1). We highlight four primary drivers: rapid urbanization, aquaculture and agricultural expansion, land reclamation and hydromodification, and tourism development and informal settlements, as they significantly characterize major coastal regions globally. For instance, East Asia (e.g., China), North America, and Western Europe predominantly experience rapid coastal urbanization, population concentration, and economic growth, while agricultural and fisheries development is mainly concentrated in East and Southeast Asia, reflecting the associated ecological consequences. Moreover, LUCC impacts vary with scale. At the micro-scale, changes like reclamation or aquaculture) drive benthic biodiversity collapse and the loss of critical habitats for critical species (e.g., migratory bird stopovers). At the meso-scale, these activities cause significant habitat fragmentation and coastal squeeze. Ultimately, at the landscape scale, they result in widespread spatial changes, including the rigidification of the urban-coastal mosaic, disruption of landscape connectivity, and homogenization of socio-ecological boundaries.

Furthermore, multi-scale and cross-scale ecological consequences may interact and trade off, potentially causing cascading effects and shifting resilience mechanisms. For example, the proliferation of impermeable hard infrastructure hinders the landward movement of wetlands. With sea-level rise (SLR), this spatial constraint causes ecosystems to submerge, irrevocably surpassing ecological thresholds. Likewise, aquaculture expansion increases nutrient loading, resulting in hypoxia and disruption of trophic food webs. Additionally, we briefly summarize a process that undermines resilience from the perspective of resilience components (e.g., resistance, recovery, redundancy, adaptivity), such as how hard infrastructure and reclamation mainly decrease the ecosystem's resistance (e.g., physical wave energy attenuation) and Adaptive capacity (e.g., spatial migration). In contrast, agricultural and informal expansion frequently compromise the system's recovery (e.g., biogeochemical self-purification) and socio-ecological redundancy, making marginalized coastal communities more vulnerable to increasing extreme events. Thus, the synthesized results suggest that resilience loss is context-specific and characterized by cascading failures influenced by regional land-use and land-cover.

Table 1. Synthesis of ecological cascading impacts and resilience mechanisms driven by major coastal LULC transformations across different geographic hotspots.

| LUCC Driver (Primary) | Multi-Scale Ecological Outcomes (Species/Habitat/Ecosystem/Landscape) | Cascading Impacts (Up > Down) | Compromised Resilience Regime | Geographic Hotspots (Key Area) |
|--|--|---|--|--|
| Rapid urbanization and hard infrastructure | Loss of breeding and foraging grounds. Coastal squeeze, habitat fragmentation. Disruption of tidal connectivity. Altered landscape connectivity, urban-coastal mosaic fragmentation. | Impermeable surfaces restrict landward migration > Habitats drown under incremental SLR > Irreversible loss of coastal buffering zones. | (1) Resistance: Weakened wave attenuation. (2) Adaptive capacity: Loss of spatial migration corridors and structural plasticity. | East Asia (e.g., China), North America, Western Europe |
| Aquaculture and agricultural expansion | Benthic biodiversity collapse. Massive clearance of mangroves/salt marshes Eutrophication and depletion of blue carbon sinks Expansion of non-point source pollution networks across the coastal landscape. | Excessive nutrient loading > Hypoxia, and algal blooms > Collapse of the trophic cascade and aquatic food webs. | (1) Recovery: Impaired biogeochemical cycling and self-purification. (2) Robustness: Simplified food webs lower the threshold for ecological regime shifts. | South/Southeast Asia (e.g., Bangladesh, Vietnam), Latin America |
| Land reclamation and hydromodification | Eradication of migratory bird stopovers. Burial of intertidal mudflats. Severe sediment starvation. Morpho-dynamic regime shifts and disruption of alongshore continuity. | Altered wave energy dissipation > Accelerated erosion in adjacent natural coasts > Systemic sediment budget imbalance. | (1) Dynamic stability: Loss of self-healing morpho-dynamics. (2) Resistance: Rigidification increases vulnerability to pulse disturbances (e.g., storm surges). | East Asia (e.g., Japan, South Korea), Middle East (e.g., Persian Gulf) |
| Tourism sprawl and informal settlements | Endemic species disturbance Sand dune flattening, groundwater depletion Freshwater lens salinization Socio-ecological spatial decoupling and landscape homogenization. | Over-extraction of resources > saltwater intrusion > coastal vegetation die-off > Dune destabilization and accelerated coastal erosion. | (1) Socio-ecological redundancy: Marginalized communities lose natural defense buffers. (2) Adaptive capacity: Amplified socioeconomic inequalities during disasters. | Mediterranean Coast, Small Island Developing States (SIDS) |

Notes: (1) > denotes the sequential propagation and top-down directional flow of cascading impacts across socio-ecological dimensions. (2) In the Multi-scale ecological outcomes column, elements are structurally ordered from top to bottom to reflect a hierarchical spatial progression from micro to macro scales. (3) The compromised resilience components column evaluates resilience not as a monolithic state, but deconstructs it into specific procedural and functional components (e.g., resistance, recovery, dynamic stability, adaptive capacity) to elucidate the precise mechanisms of ecosystem resilience.

4. Discussions and Prospects

4.1. Temporal Shifts in Research Frontiers: LUCC Patterns, Drivers, and Focus Transitions

The temporal and spatial distribution of keyword bursts indicates the evolution of coastal research frontiers. During the earlier period (Figures 1 and 5), research frontiers were primarily oriented toward understanding the impacts of coastal land-use and land-cover change on ecosystem structure and functions, and toward identifying underlying environmental pressures [49,50]. For instance, the prominence of burst terms such as water quality, nitrogen, vegetation, and soil biogenic elements reflects a phase in which scholars sought to conceptualize coastal regions as integrated systems while simultaneously diagnosing key stressors affecting their stability [51,52]. With growing global attention to climate change impacts following the IPCC Fifth and Sixth Assessment Reports and increasing awareness of cumulative and diffuse pressures on coastal ecosystems, more studies have focused on establishing causal associations, improving conceptual clarity, and developing scenario-based simulations to explore future trajectories across different climate and development pathways [53,54]. In this context, the interplay between climate change and land-use dynamics is now a focal point, driving significant research on coastal vulnerability, resilience under multiple stressors, and regional sustainability [55]. As research themes and frontiers (Figure 5 and 6), this trend reflects a shift from monitoring environmental state variables to understanding the holistic adaptive capacity of coastal social-ecological systems.

Importantly, the emergence of terms related to variability and uncertainty indicates a shift away from static or equilibrium-based views toward a more dynamic understanding of coastal processes [56]. Rather than treating environmental change as gradual and predictable, studies increasingly highlight interannual variability, nonlinear responses, and combined effects [57,58]. This focus marks a crucial turning point in which coastal research moved beyond simple descriptive characterizations toward explicit recognition of LUCC-driven pattern drivers and related physical mechanisms, as well as climate risks. However, study responses remained largely analytical, with limited emphasis on practical intervention or policy governance [59]. In this sense, the early frontier phase (Clusters #1 and #3) can be characterized as a problem-diagnosis stage, in which the primary objective was to understand what LUCC and resilience were changing, why they were changing, and how vulnerable coastal systems might be under future conditions.

Recently, particularly after 2019 (Figure 6), burst keywords such as mitigation, assessment indicators, risk analysis, inundation, and sustainability indicate that research attention has increasingly shifted from identifying risks to evaluating practical responses and supporting decision-making. This reflects broader societal and institutional demands for actionable knowledge, particularly amid accelerating climate impacts, more frequent extreme events, and heightened policy attention to adaptation and resilience [60]. The growing set of assessment indicators reflects an effort to translate complex system dynamics into measurable, comparable, and policy-relevant metrics that inform spatial planning, prioritization, and governance at various scales [61,62].

On the one hand, recent bursts in machine learning and region-specific terms, such as India, which represents the global south, further deepen this action-oriented shift (Figure 6). Advances in data availability and computational capacity have enabled more detailed modeling of inundation risks, exposure patterns [63], and adaptive capacity [64], while also facilitating applications in data-scarce and rapidly changing regions. On the other hand, the geographical concentration of recent bursts points to an expanding research focus on highly vulnerable coastal areas in the Global South (India, Figure 5), where urbanization, demographic change, and climate risks intersect most acutely [65]. In summary, the evolution of keyword bursts, network analysis, and, to some extent, the establishment of theoretical groundwork for understanding system dynamics, along with the operationalization and recognition of resilience, define the current frontier. Significantly, most studies are moving beyond descriptive analysis to generate actionable knowledge by leveraging data-driven models to inform spatial planning and risk mitigation.

4.2. Coastal Coupled Socio-Ecological System Perspective

The thematic structure revealed by the keyword clustering and timeline analysis suggests that coastal land use studies have undergone a fundamental transformation from an environmental impact-oriented knowledge base toward an increasingly integrated socio-ecological research paradigm. Here, we acknowledge that quantitative bibliometric metrics (e.g., keyword co-occurrence algorithms and node centrality) empirically reflect structural connectivity and thematic prominence within the dataset, but they do not inherently demonstrate conceptual restructuring. Therefore, the paradigm shift proposed in this study represents an interpretive extrapolation. Early studies focused on distinct themes, such as land-use patterns, intensity, and their impacts on ecosystem processes, water quality, and wetland ecosystems, often in isolation and within specific contexts [16,49]. However, the sustained prevalence of topics related to LUCC, climate change, and ecosystem dynamics suggests a gradual

convergence among these areas rather than independent development, such as climate change amplifying the multiple impacts of land use [52].

It is potentially due to growing recognition that coastal systems are inherently complex, characterized by strong feedbacks among physical processes, ecological structures, and human interventions. As land-use change intensifies under urbanization and development pressures, and as climate-driven stressors such as sea-level rise and extreme events become more pronounced [57], single-factor or sector-specific approaches have proven insufficient to explain observed patterns or to support effective decision-making. Coastal research, therefore, has moved beyond compartmentalized ecological or engineering analyses toward frameworks that explicitly recognize cross-scale linkages and coupled human-natural processes [66]. This perspective lays the conceptual groundwork for understanding coastal regions as socio-ecological systems in which environmental change, spatial planning, and most human activities are inseparable components of a single, evolving system [27,40].

Further, building on the integration of thematic structure, a second, equally significant transformation is the gradual shift from ecosystem-centered analyses to people-centered socio-ecological resilience frameworks [27]. While early coastal studies emphasized biophysical conditions, such as habitat degradation, nutrient loading, and shoreline change [18], the emergence and growing prominence of themes related to resilience, risk, and coastal communities indicate an expanding focus on the social dimensions of coastal systems [67]. This shift reflects growing recognition that ecological and social vulnerabilities are deeply intertwined, particularly in densely populated, rapidly urbanizing coastal regions [68,69].

Meanwhile, coastal communities (Cluster #6 and #8) not only experience the impacts of environmental change but also actively shape exposure, sensitivity, and adaptive capacity through land-use decisions, governance structures, and livelihood strategies [70,71]. As a result, resilience has evolved from a primarily ecological concept into a multidimensional framework encompassing social, institutional, and economic dimensions alongside environmental processes [72]. Additionally, rather than prioritizing ecological optimization alone, recent studies increasingly emphasize equity, livelihoods, cultural heritage, and local adaptive practices as integral components of sustainable coastal futures [68,73]. In other words, most is increasingly aligning with a people-centered perception of resilience that acknowledges trade-offs, power dynamics, and heterogeneous impacts across social groups [74,75]. Ultimately, these developments suggest that isolated environmental impact themes no longer define contemporary research, but rather a complex systems perspective that seeks to understand and manage coastal regions as coupled socio-ecological systems facing compound, interconnected challenges.

4.3. Structural Biases in Methods, Data Availability, Scale, and Geographic Representation

Methodologically, the growing prominence of remote sensing, geospatial analysis, and machine learning reflects a broader transformation toward data-intensive, computationally driven science [76]. For example, advances in satellite imagery, sensor networks, and cloud-based processing platforms have enabled unprecedented temporal and spatial coverage of coastal processes [77,78], facilitating detailed assessments of land-use change, inundation dynamics, vegetation patterns, and hazard exposure. Furthermore, with higher-resolution datasets, coastal research has increasingly shifted from localized case studies to large-scale comparative analyses and scenario-based modeling, yielding more generalizable insights across regions and systems [79].

Regarding models and functions learning, the integration of machine learning and related algorithms has shifted the emphasis from descriptive and explanatory models toward predictive and pattern-recognition approaches (Clusters #1 and #3, Figure 5). These methods have proven particularly effective in handling high-dimensional datasets and capturing nonlinear or causal relationships [71,80]. However, this methodological development made concepts such as inundation risk, land-cover change, and exposure indices/indexes readily amenable to computational analysis. In contrast, social processes such as governance effectiveness, institutional capacity, and cultural adaptation remain more difficult to quantify [81]. Actually, technological advances simultaneously generate both positive and negative implications for knowledge production. As analytical techniques become more sophisticated, research agendas always increasingly prioritize phenomena that are measurable, mappable, and algorithmically tractable.

Beyond methodological considerations, data availability, spatial scale, and regional representation also contributed to structural biases. First, the growing reliance on earth observation platforms (e.g., Landsat, Sentinel) and global datasets has enabled cross-regional comparisons and longitudinal analyses [77]. Yet it has also reinforced a tendency to prioritize regions with dense, consistent, and easily accessible data, particularly in North America, Western Europe, and coastal China [17]. This dynamic contributes to uneven geographic representation, with coastal hotspots experiencing rapid urbanization, such as the Pearl River Delta, the Yangtze River Delta, and the New York metropolitan area, receiving disproportionate scholarly attention because their landscape changes

are particularly visible. Conversely, data-scarce regions in parts of Africa and Small Island Developing States (SIDS) often remain understudied despite their high climate vulnerability. In addition, the recent emergence of region-specific bursts, such as those associated with India (e.g., the Sundarbans or coastal megacities like Mumbai), reflects a shifting frontier driven by both growing risk exposure and improved open-access data. This convergence of urgency and data readiness often dictates research priorities.

Additionally, we think contemporary discourse on coastal land use and resilience is witnessing a notable epistemic turn, one that increasingly valorizes Indigenous and Local Knowledge (ILK) and their governance practices [82]. Theoretically, coastal resilience is conceptualized as a multidimensional construct spanning engineering (recovery time), ecological (absorptive capacity), social, and economic domains [83]. Coastal land-use dynamics profoundly reshape these dimensions through complex biophysical and socio-economic coupling mechanisms [25]. Recognizing this systemic complexity, recent studies argue that local experiences are indispensable for navigating the specific interactions between human activities and environmental processes. However, indicator-based assessments and machine-learning-driven models often require simplification and standardization, which can inadvertently marginalize qualitative knowledge, Traditional Ecological Knowledge (TEK), and informal governance mechanisms unique to local communities [84]. As a result, coastal studies underrepresent place-based insights essential for understanding lived vulnerability. Recognizing these biases does not reduce the importance of recent methodological advances; instead, it highlights the need for critical reflection on how tools and data influence research priorities.

4.4. Limitations and Future Implications for Coastal Sustainability

While this study provides a comprehensive synthesis of the cascading impacts between coastal LUCC transformations and ecosystem resilience, several limitations must be acknowledged to contextualize these findings. First, regarding data sourcing, the bibliometric analysis relied exclusively on the Web of Science Core Collection (WoSCC). Although this ensures the inclusion of high-impact peer-reviewed literature, it may inadvertently exclude relevant studies indexed in other databases (e.g., Scopus, CNKI), non-English regional publications, and valuable grey literature, such as local government reports on coastal adaptation. Second, from a methodological perspective, while CiteSpace effectively maps macrostructural trends, its reliance on metadata (titles, abstracts, and keywords) inherently simplifies complex, localized ecological narratives. Although we mitigated this limitation through our in-depth qualitative synthesis (Section 3.3), certain highly context-specific nonlinear mechanisms may remain underrepresented. Finally, the multi-scale resilience frameworks and paradigm shifts proposed in this review represent interpretive extrapolation derived from literature synthesis. Consequently, future empirical research is urgently needed to quantitatively validate these theoretical pathways across diverse geographic and socio-ecological narratives.

Although substantial progress has been made in understanding land-use dynamics, climate impacts, ecosystem responses, and social vulnerability, these components are still often examined in insufficient detail. Future work should deepen the integration of biophysical and social sciences to address these gaps. Specifically, four key frontiers require urgent attention:

- (1) **Process-Based Modeling:** Future research must move beyond correlation to model feedback loops and trade-offs in coupled systems. Studies need to shift from treating environmental and social variables separately toward explicitly process-based modeling of interactions across coupled socio-ecological systems [25]. This involves integrating land-use change, hazard exposure, ecological processes, and human decision-making into unified analytical frameworks that capture nonlinearity, path dependence, and effects across different scales [85].
- (2) **Multi-Scale Approaches:** It is essential to bridge the gap between localized case studies and global assessments to understand how local actions contribute to system-level outcomes. Currently, many studies operate either at broad regional scales or highly localized levels with limited conceptual connection. Advancing coastal sustainability requires methods that connect fine-scale processes, such as neighborhood-level exposure, ecosystem fragmentation, and community adaptation strategies, to broader regional and global forces, including climate forcing and economic integration [86]. This integration enables robust exploration of how global pressures are mediated by coastal spatial planning and governance structures [87].
- (3) **Social Equity & Justice:** Researchers need to explicitly assess the social distributional impacts of resilience strategies to prevent climate gentrification and ensure just transitions. The aspect of social equity remains insufficiently explored within the land-use resilience relationship. As strategies like managed retreat and resilient urban design alter coastal landscapes, future research should examine whether policies focused on increasing physical resilience unintentionally displace vulnerable populations or exacerbate socio-spatial

inequalities. This emphasizes the importance of advancing theories that combine quantitative modeling with qualitative insights into governance, behavior, and institutional change [88,89].

- (4) Nature-Based Solutions (NbS): There is a critical need to thoroughly measure the long-term effectiveness and adaptation limits of NbS under changing land-use pressures [90,91]. Future research should assess how ecosystems like mangroves and wetlands perform under the combined impacts of coastal squeeze from urbanization and rising sea levels, and identify the specific thresholds where hybrid or natural infrastructure might fail or succeed.

Ultimately, the future focus and priority of coastal research should strive to harmonize the engineering of safe landscapes with the stewardship of just and inclusive societies. By embracing reflexivity alongside methodological innovation, coastal sustainability research can evolve toward a more balanced and comprehensive science that advances technical capabilities while deepening the understanding of the complex, evolving relationships between human societies and coastal environments.

5. Conclusions

This study provides a comprehensive, bibliometric review of global coastal LUCC and ecosystem resilience studies. By integrating keyword co-occurrence, thematic clustering, and burst detection in CiteSpace, this review visualizes the field's significant knowledge evolution from 2005 to 2025. Results showed that core themes related to land-use dynamics, climate change, ecosystem processes, and management practices form the structural foundation. Fundamentally, the paradigm has shifted from isolated, static environmental monitoring to highly integrated, dynamic socio-ecological resilience modeling. Emerging frontiers increasingly emphasize community-scale resilience, nature-based solutions (NbS), and data-driven sustainability models, reflecting a critical broadening of the research scope. Temporally, early studies prioritized system comprehension and environmental assessment, focusing on theoretical frameworks and biophysical pressures, including water quality, nutrient influx, and sea-level rise. In contrast, contemporary research has shifted towards pragmatic, solution-focused investigations, marked by an increase in evaluative metrics, risk assessment and mitigation approaches, and sophisticated computational techniques, including machine learning and high-resolution remote sensing. However, while this growing reliance on large-scale datasets and predictive algorithms has unprecedentedly expanded our analytical capacity, we argue that the increasing reliance on multi-model datasets is widening the gap between the Global North and South.

Therefore, addressing these structural biases and methodological limitations provides clear guidance for future research. Moving forward, the scientific community must actively bridge the geographic and data disparities identified in this review. Future studies should prioritize downscaling global computational models by coupling them with localized, high-fidelity empirical data and participatory, ground-based, and local community observations. Furthermore, to move beyond theoretical resilience, future interdisciplinary research must deeply integrate environmental justice and socio-economic equity into Integrated Coastal Zone Management (ICZM) frameworks. Ultimately, by situating thematic trajectories, frontier dynamics, and methodological shifts within a unified analytical framework, this study provides a robust, evidence-based foundation for advancing actionable, equitable climate adaptation strategies in coastal socio-ecological systems amid accelerating global transformation.

Author Contributions

C.L.: Resources, data curation, methodology, software, visualization, writing—original draft preparation; S.F.: Conceptualization, supervision, validation, writing—reviewing and editing. Both authors have read and agreed to the published version of the manuscript.

Funding

This research is funded by the National Key R&D Program of China (2017YFC0506002), Shanghai Science and Technology Innovation Action Plan Promising Star Project, Yangfan Plan (Grant No. 24YF2730800), and Pudong New Area Innovation Practice Base Enterprise Postdoctoral Research Project.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

During the revision of this work, the authors used ChatGPT 4o to edit language. After using this service, the authors reviewed and edited the content as needed and took full responsibility for the content of the published article.

References

1. Ward, N.D.; Megonigal, J.P.; Bond-Lamberty, B.; et al. Representing the Function and Sensitivity of Coastal Interfaces in Earth System Models. *Nat. Commun.* **2020**, *11*, 2458.
2. Cohen, J.E.; Small, C.; Mellinger, A.; et al. Estimates of Coastal Populations. *Science* **1997**, *278*, 1209–1213.
3. Varis, O.; Taka, M.; Kummu, M. Mapping World's Coastal Population Facing Water-Related Risks. *Geogr. Sustain.* **2026**, *7*, 100411.
4. Cosby, A.G.; Lebakula, V.; Smith, C.N.; et al. Accelerating Growth of Human Coastal Populations at the Global and Continent Levels: 2000–2018. *Sci. Rep.* **2024**, *14*, 22489.
5. Wang, Y.; Liao, J.; Ye, Y.; et al. Long-Term Human Expansion and the Environmental Impacts on the Coastal Zone of China. *Front. Mar. Sci.* **2022**, *9*, 1033466.
6. Tanwari, K.; Terefenko, P.; Shi, X.; et al. Coastal Zones Vulnerability Evaluation in the Southern Baltic Sea: Shoreline Dynamics and Land Use/Land Cover Changes over Five Decades. *Sci. Total Environ.* **2025**, *976*, 179345.
7. Liu, Y.; Zeng, H. Coastal Squeeze and Multi-Scenario Risk Assessment in China, 1985–2024. *Environ. Impact Assess. Rev.* **2026**, *118*, 108248.
8. Durkin, C.J.; Seenath, A.; Knaapen, M.A.F. A Critical Review of Closure Depth Theories and Uncertainties: Implications for Shoreline Modelling and Coastal Management. *Ocean Coast. Manag.* **2025**, *267*, 107732.
9. Vousdoukas, M.I.; Paprotny, D.; Mentaschi, L.; et al. Coastal Flood Impacts and Lost Ecosystem Services along Europe's Outermost Regions and Overseas Countries and Territories. *Nat. Commun.* **2026**, *17*, 188.
10. Borzi, L.; Marino, M.; Stagnitti, M.; et al. Impact of Coastal Land Use on Long-Term Shoreline Change. *Ocean Coast. Manag.* **2025**, *262*, 107583.
11. Pricope, N.G.; Halls, J.N.; Dalton, E.G.; et al. Precision Mapping of Coastal Wetlands: An Integrated Remote Sensing Approach Using Unoccupied Aerial Systems Light Detection and Ranging and Multispectral Data. *J. Remote Sens.* **2024**, *4*, 0169.
12. Dong, Y.Q.; Zhou, Y.; Zhang, L.; et al. Intensive Land-Use Is Associated with Development Status in Port Cities of Southeast Asia. *Environ. Res. Lett.* **2023**, *18*, 044006.
13. Taylor, C.M.; Klein, C.; Parker, D.J.; et al. "Late-Stage" Deforestation Enhances Storm Trends in Coastal West Africa. *Proc. Natl. Acad. Sci. USA* **2022**, *119*, e2109285119.
14. Wolff, C.; Bonatz, H.; Vafeidis, A.T. Setback Zones Can Effectively Reduce Exposure to Sea-Level Rise in Europe. *Sci. Rep.* **2023**, *13*, 5515.
15. Tay, C.; Lindsey, E.O.; Chin, S.T.; et al. Sea-Level Rise from Land Subsidence in Major Coastal Cities. *Nat. Sustain.* **2022**, *5*, 1049–1057.
16. Yang, D.; Luan, W.; Li, Y.; et al. Multi-Scenario Simulation of Land Use and Land Cover Based on Shared Socioeconomic Pathways: The Case of Coastal Special Economic Zones in China. *J. Environ. Manag.* **2023**, *335*, 117536.
17. Elyasi, A.H.; Ledari, D.G.; Nasser, M.; et al. Assessing the Impacts of Anthropogenic-Induced Land Use/Land Cover Changes in Wetlands Using Remotely Sensed Information: A Systematic State-of-the-Art Review and Future Directions. *Anthropocene* **2025**, *52*, 100496.
18. Jamilah, M.; Becker, A.; Lee, S.L.; et al. Socioeconomic Impacts Linked to Land Use and Land Use Changes Affecting Blue Carbon Ecosystems in Southeast Asia: A Systematic Map. *Ocean Coast. Manag.* **2025**, *267*, 107643.
19. Wang, Y.; Ye, Y.; Nicholls, R.J.; et al. Managing Development Choices Is Essential to Reduce Coastal Flood Risk in China. *Nat. Clim. Chang.* **2025**, *15*, 1033–1034.
20. Lansu, E.M.; Reijers, V.C.; Hofer, S.; et al. A Global Analysis of How Human Infrastructure Squeezes Sandy Coasts. *Nat. Commun.* **2024**, *15*, 432.

21. Hagger, V.; Waltham, N.J.; Lovelock, C.E. Opportunities for Coastal Wetland Restoration for Blue Carbon with Co-Benefits for Biodiversity, Coastal Fisheries, and Water Quality. *Ecosyst. Serv.* **2022**, *55*, 101423.
22. Guimond, J.A. The Overlooked Role of Terrestrial Groundwater in Coastal Wetland Resilience. *Nat. Water* **2025**, *3*, 364–366.
23. Richardson, C.M.; Peucker-Ehrenbrink, B.; Wyatt, S.; et al. Effects of Climate Change on River and Groundwater Nutrient Inputs to the Coastal Ocean. *Commun. Earth Environ.* **2025**, *6*, 761.
24. Richardson, C.M.; Davis, K.L.; Ruiz-González, C.; et al. The Impacts of Climate Change on Coastal Groundwater. *Nat. Rev. Earth Environ.* **2024**, *5*, 100–119.
25. Siddik, M.A.; Islam, A.R.M.T. Review of Coastal Land Transformation: Factors, Impacts, Adaptation Strategies, and Future Scopes. *Geogr. Sustain.* **2024**, *5*, 167–178.
26. Aerts, J.C.J.H.; Botzen, W.J.W.; Emanuel, K.; et al. Evaluating Flood Resilience Strategies for Coastal Megacities. *Science* **2014**, *344*, 473–475.
27. He, Q.; Li, Z.A.; Daleo, P.; et al. Coastal Wetland Resilience through Local, Regional, and Global Conservation. *Nat. Rev. Biodivers.* **2025**, *1*, 50–67.
28. Campbell, A.D.; Fatoyinbo, L.; Goldberg, L.; et al. Global Hotspots of Salt Marsh Change and Carbon Emissions. *Nature* **2022**, *612*, 701–706.
29. Ghosh, M.; Mondal, K.C.; Roy, A. Recognition of the Co-Existence Pattern of Salt Marshes and Mangroves for Littoral Forest Restoration. *Ecol. Inform.* **2022**, *71*, 101769.
30. Thyrring, J.; Archambault, P.; Burrows, M.; et al. A Horizon Scan for Arctic Coastal Biodiversity Research: Understanding Changes Requires International Collaboration. *Trends Ecol. Evol.* **2025**, *40*, 460–467.
31. Huang, A.; Zhou, W.; Han, W.; et al. Nutrient Thresholds Drive Nonlinear Shifts in Estuarine Macrobenthic Functional Traits: Implications for Eutrophication Monitoring and Ecological Resilience. *J. Environ. Manag.* **2025**, *394*, 127519.
32. Zhou, T.; Li, Y.; Zheng, L.; et al. Capturing Land Use System Thresholds through Regime Shifts of Coastal Sustainability in China. *Environ. Impact Assess. Rev.* **2026**, *116*, 108127.
33. Martínez, M.L.; Silva, R.; Pérez-Maqueo, O.; et al. The Dilemma of Coastal Management: Exploitation or Conservation? *Camb. Prism. Coast. Futures* **2024**, *2*, e10.
34. Pichler, E.; Connell, S.D.; McAfee, D. Improving Human Well-Being through Community-Led Coastal Restoration. *Biol. Conserv.* **2025**, *301*, 110892.
35. Reguero, B.G.; Gaido, C.; Storlazzi, C.D.; et al. Where to Restore and Conserve? A Regional Benefit Cost Analysis of Coral Reef Protection and Restoration for Coastal Flood Resilience. *J. Environ. Manag.* **2026**, *397*, 128166.
36. Chen, M.H.; Chen, F.; Tang, C.J.; et al. Integration of DPSIR Framework and TOPSIS Model Reveals Insight into the Coastal Zone Ecosystem Health. *Ocean Coast. Manag.* **2022**, *226*, 106285.
37. Fan, Y.; Wei, G. Assessment of Ecological Resilience and Its Response Mechanism to Land Spatial Structure Conflicts in China's Southeast Coastal Areas. *Ecol. Indic.* **2025**, *170*, 112980.
38. Mishra, M.; Bhattacharyya, D.; Mondal, B.; et al. Forecasting Shoreline Dynamics and Land Use/Land Cover Changes in Balukhand-Konark Wildlife Sanctuary (India) Using Geospatial Techniques and Machine Learning. *Sci. Total Environ.* **2025**, *975*, 179207.
39. Yu, L.; Du, Z.; Li, X.; et al. FROM-GLC Plus 3.0: Multimodal Land Change Mapping with SAM and Dense Surface Observations. *J. Remote Sens.* **2025**, *5*, 0728.
40. Bevacqua, A.; Yu, D.; Zhang, Y. Coastal Vulnerability: Evolving Concepts in Understanding Vulnerable People and Places. *Environ. Sci. Policy* **2018**, *82*, 19–29.
41. Li, S.-H.; Lin, W. A Hybrid Landscape Metric-Enhanced Cellular Automata Model (LE-CA) for Land Use/Land Cover Change Simulation: An Application to Coastal Wetlands. *Ecol. Modell.* **2025**, *508*, 111209.
42. Zhou, J.; Xu, H.; Jim, C.Y.; et al. Spatiotemporal Dynamics of Land Use and Landscape in Coastal Zhejiang Using Multiple Methods. *iScience* **2025**, *28*, 112898.
43. Hood, W.W.; Wilson, C.S. The Literature of Bibliometrics, Scientometrics, and Informetrics. *Scientometrics* **2001**, *52*, 291–314.
44. Chen, C. Searching for Intellectual Turning Points: Progressive Knowledge Domain Visualization. *Proc. Natl. Acad. Sci. USA* **2004**, *101*, 5303–5310.
45. Chen, C. CiteSpace II: Detecting and Visualizing Emerging Trends and Transient Patterns in Scientific Literature. *J. Am. Soc. Inf. Sci. Technol.* **2006**, *57*, 359–377.
46. Segaran, T.C.; Azra, M.N.; Mohd Noor, M.I.; et al. Knowledge Mapping Analysis of the Global Seaweed Research Using CiteSpace. *Heliyon* **2024**, *10*, e28418.
47. Laino, E.; Iglesias, G. Scientometric Review of Climate-Change Extreme Impacts on Coastal Cities. *Ocean Coast. Manag.* **2023**, *242*, 106709.
48. Synnæstvedt, M.B.; Chen, C.; Holmes, J.H. CiteSpace II: Visualization and Knowledge Discovery in Bibliographic Databases. *AMIA Annu. Symp. Proc.* **2005**, *2005*, 724–728.

49. Chuai, X.; Huang, X.; Wu, C.; et al. Land Use and Ecosystem Services Value Changes and Ecological Land Management in Coastal Jiangsu, China. *Habitat Int.* **2016**, *57*, 164–174.
50. Sarfo, I.; Qiao, J.; Yeboah, E.; et al. Meta-Analysis of Land Use Systems Development in Africa: Trajectories, Implications, Adaptive Capacity, and Future Dynamics. *Land Use Policy* **2024**, *144*, 107261.
51. Albarico, F.P.J.B.; Chen, C.W.; Dong, C.D. Multifactorial Environmental and Ecological Gradients from Hydrology and Land-Use Reflect Coordinated Plankton–Organic Pollutant Spatial Dynamics in Coastal Ecosystems. *Water Res.* **2026**, *288*, 124727.
52. Meng, C.; Wu, C.; Wu, J.; et al. Spatiotemporal Changes of Coastal Land Use Land Cover and Its Drivers in Shanghai, China between 1989 and 2015. *Ocean Coast. Manag.* **2023**, *244*, 106802.
53. IPCC. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Edenhofer, O., Pichs-Madruga, R., Sokona, Y., et al., Eds.; Cambridge University Press: Cambridge, UK/New York, NY, USA, 2014.
54. IPCC. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., et al., Eds.; Cambridge University Press: Cambridge, UK/New York, NY, USA, 2022. <https://doi.org/10.1017/9781009325844>.
55. Cinner, J.E.; McClanahan, T.R.; Graham, N.A.J.; et al. Vulnerability of Coastal Communities to Key Impacts of Climate Change on Coral Reef Fisheries. *Global Environ. Chang.* **2012**, *22*, 12–20.
56. Xu, W.; He, M.; Meng, W.; et al. Temporal-Spatial Change of China’s Coastal Ecosystems Health and Driving Factors Analysis. *Sci. Total Environ.* **2022**, *845*, 157319.
57. Leijnse, T.; van Ormondt, M.; Nederhoff, K.; et al. Modeling Compound Flooding in Coastal Systems Using a Computationally Efficient Reduced-Physics Solver: Including Fluvial, Pluvial, Tidal, Wind- and Wave-Driven Processes. *Coast. Eng.* **2021**, *163*, 103796.
58. Zhou, S.; Geng, X.; Jia, W.; et al. Towards Climate-Adaptive Equality in Coastal Megacities: Assessing Urban Flooding Risk Disparities and Nonlinear Effect of Multidimensional Indicators through an Interpretable LightGBM-SHAP Framework. *Sustain. Cities Soc.* **2025**, *132*, 106809.
59. Capano, G.; Lepori, B. Designing Policies That Could Work: Understanding the Interaction between Policy Design Spaces and Organizational Responses in the Public Sector. *Policy Sci.* **2024**, *57*, 53–82.
60. Amorim-Maia, A.T.; Olazabal, M. Beyond Adjustment: A New Paradigm for Climate Change Adaptation in a Complex World. *Global Environ. Chang.* **2025**, *93*, 103027.
61. Babacan, H. From Crisis to Policy Action: Tackling Climate Change through SDG 13. *Int. J. Community Soc. Dev.* **2025**, *7*, 205–221.
62. Goonesekera, S.M.; Olazabal, M. Climate Adaptation Indicators and Metrics: State of Local Policy Practice. *Ecol. Indic.* **2022**, *145*, 109657.
63. Anik, M.; An, C.; Li, S.S. Evolution from the Physical Process-Based Approaches to Machine Learning Approaches to Predicting Urban Floods: A Literature Review. *Environ. Syst. Res.* **2025**, *14*, 15.
64. Ghosh, S.; Saha, S.; Bera, B. Flood Susceptibility Zonation Using Advanced Ensemble Machine-Learning Models in the Himalayan Foreland Basin. *Nat. Hazards Res.* **2022**, *2*, 363–374.
65. Shaw, R.; Luo, Y.; Cheong, T.S.; et al. Asia. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., et al., Eds.; Cambridge University Press: Cambridge, UK/New York, NY, USA, 2022; pp. 1457–1579.
66. Patrick, C.J.; Kominoski, J.S.; McDowell, W.H.; et al. A General Pattern of Trade-Offs between Ecosystem Resistance and Resilience to Tropical Cyclones. *Sci. Adv.* **2022**, *8*, eabl9155.
67. Wu, W.; Gao, Y.; Chen, C. CLSER: A New Indicator for the Social-Ecological Resilience of Coastal Systems and Sustainable Management. *J. Clean. Prod.* **2024**, *435*, 140564.
68. Elrick-Barr, C.E.; Thomsen, D.C.; Smith, T.F. Governance Innovations in the Coastal Zone: Towards Social-Ecological Resilience. *Environ. Sci. Policy* **2024**, *153*, 103687.
69. Mabon, L.; Kawabe, M. Social Media within Digitalisation for Coastal Resilience: The Case of Coastal Fisheries in Minamisoma, Fukushima Prefecture, Japan. *Ocean Coast. Manag.* **2023**, *232*, 106440.
70. Muis, S. Early Action for Coastal Communities. *Nat. Geosci.* **2026**, *19*, 239–240.
71. Pichler, M.; Hartig, F. Machine Learning and Deep Learning—A Review for Ecologists. *Methods Ecol. Evol.* **2023**, *14*, 994–1016.
72. Teng, M.; Zhang, F.; Gong, Z.; et al. Evaluating Climate Adaptation Strategies for Coastal Resilience Using a Multi-Criteria Decision-Making Framework. *Mar. Pollut. Bull.* **2025**, *217*, 118060.
73. Lawless, S.; Cohen, P.J.; McDougall, C.; et al. Tinker, Tailor or Transform: Gender Equality amidst Social-Ecological Change. *Global Environ. Chang.* **2022**, *72*, 102434.
74. Seenath, A.; Romeo Mahadeo, S.M.; Catterson, J. Public Perceptions of Nature-Based Coastal Solutions in the UK. *J. Environ. Manag.* **2025**, *373*, 123413.

75. Wang, W.; Wu, C.; Fang, Q.; et al. Cultural Ecosystem Services Evaluation in a Coastal City of China Using Social Media Data. *Ocean Coast. Manag.* **2023**, *242*, 106693.
76. Zhong, W.; Chu, T.; Tissot, P.; et al. Integrated Coastal Subsidence Analysis Using InSAR, LiDAR, and Land Cover Data. *Remote Sens. Environ.* **2022**, *282*, 113297.
77. Agate, J.; Ballinger, R.; Ward, R.D. Satellite Remote Sensing Can Provide Semi-Automated Monitoring to Aid Coastal Decision-Making. *Estuar. Coast. Shelf Sci.* **2024**, *298*, 108639.
78. Zhang, X.; Xiao, X.; Qiu, S.; et al. Quantifying Latitudinal Variation in Land Surface Phenology of *Spartina alterniflora* Saltmarshes across Coastal Wetlands in China by Landsat 7/8 and Sentinel-2 Images. *Remote Sens. Environ.* **2022**, *269*, 112810.
79. Fringer, O.B.; Dawson, C.N.; He, R.; et al. The Future of Coastal and Estuarine Modeling: Findings from a Workshop. *Ocean Modell.* **2019**, *143*, 101458.
80. Leist, A.K.; Klee, M.; Kim, J.H.; et al. Mapping of Machine Learning Approaches for Description, Prediction, and Causal Inference in the Social and Health Sciences. *Sci. Adv.* **2022**, *8*, eabk1942.
81. Martínez, M.L.; Intralawan, A.; Vázquez, G.; et al. The Coasts of Our World: Ecological, Economic and Social Importance. *Ecol. Econ.* **2007**, *63*, 254–272.
82. Hill, R.; Adem, Ç.; Alangui, W.V.; et al. Working with Indigenous, Local, and Scientific Knowledge in Assessments of Nature and Nature's Linkages with People. *Curr. Opin. Environ. Sustain.* **2020**, *43*, 8–20.
83. Lloyd, M.G.; Peel, D.; Duck, R.W. Towards a Social-Ecological Resilience Framework for Coastal Planning. *Land Use Policy* **2013**, *30*, 925–933.
84. Martin, J.F.; Roy, E.D.; Diemont, S.A.W.; et al. Traditional Ecological Knowledge (TEK): Ideas, Inspiration, and Designs for Ecological Engineering. *Ecol. Eng.* **2010**, *36*, 839–849.
85. Kankam, S.; Koo, H.; Inkoom, J.N.; et al. Modeling Coastal Land Use Scenario Impacts on Ecosystem Services Restoration in Southwest Ghana, West Africa. *NPJ Ocean Sustain.* **2025**, *4*, 13.
86. Babapoorkamani, A.; Ricci, L. Decision-Making Strategies for Climate Change Adaptation in Coastal Regions of Africa. *Environ. Dev.* **2025**, *55*, 101196.
87. Allen, C.; Malekpour, S.; Mintrom, M. Cross-Scale, Cross-Level and Multi-Actor Governance of Transformations toward the Sustainable Development Goals: A Review of Common Challenges and Solutions. *Sustain. Dev.* **2023**, *31*, 1250–1267.
88. Lawless, S.; Ogier, E.M.; Streit, R.; et al. Promoting Socially Responsible Governance of New Marine Climate Intervention. *Cell Rep. Sustain.* **2025**, *2*, 100366.
89. Marzio, S.; Tosi, J.; Poggi, F.; et al. Nature-Based Solutions for Urban Waterfront Regeneration: A Systematic Review of Frameworks, Strategies and Applications. *City Environ. Interact.* **2026**, *29*, 100281.
90. Haddad, N.M.; Brudvig, L.A.; Clobert, J.; et al. Habitat Fragmentation and Its Lasting Impact on Earth's Ecosystems. *Sci. Adv.* **2015**, *1*, e1500052.
91. Storlazzi, C.D.; Reguero, B.G.; Alkins, K.C.; et al. Hybrid Coral Reef Restoration Can Be a Cost-Effective Nature-Based Solution to Provide Protection to Vulnerable Coastal Populations. *Sci. Adv.* **2025**, *11*, eadn4004.