Geojournal of Tourism and Geosites
ISSN 2065-0817, E-ISSN 2065-1198

Year XIX, vol. 65, no. 2, 2026, p.1212-1224
DOI 10.30892/gtg.65254-1759

BIBLIOMETRIC ANALYSIS OF THE RESEARCH LANDSCAPE AND EVOLUTIONARY TRENDS OF CLIMATE CHANGE IMPACTS ON ECOTOURISM DESTINATIONS: USING VOSVIEWER & CITESPACE

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Citation: Safarov, B., Hu, Y., Zou, T., Mahmoud, H.M.E., & Salem, A.E. (2026). Bibliometric analysis of the research landscape and evolutionary trends of climate change impacts on ecotourism destinations: Using vosviewer & citespace. *Geojournal of Tourism and Geosites*, 65(2), 1212–1224. https://doi.org/10.30892/gtg.65254-1759

Abstract: Research on the impacts of climate change on ecotourism destinations is mostly dominated by qualitative descriptions and single-region empirical analyses, suffering from fragmentation and lack of cross-regional analysis, which makes it difficult to grasp the global knowledge landscape and evolutionary trends of this field. This study takes 178 relevant literatures from the Web of Science Core Collection between 2002 and 2025 as samples, employs VOSviewer and CiteSpace for bibliometric analysis, and explores four core issues—research hotspots, distribution of research forces, thematic evolution trends, and research gaps—through methods such as keyword co-occurrence, bibliographic coupling, burst detection, combined with clustering and multi-tool cross-validation. The results show that research in this field has experienced three stages: embryonic, development, and expansion, with an average annual growth rate of 14.6% after 2018. Three core clusters have been formed: Ecosystem Services–Biodiversity, Nature Conservation–Protected Areas, and Online Interaction–Post-Pandemic Recovery. The research themes have gone through three stages: impact documentation, adaptation exploration, and governance optimization. The global research force is characterized by European and American dominance and regional agglomeration, with weak cross-regional cooperation and research gaps in Small Island Developing States (SIDS). Meanwhile, three key research gaps are identified: insufficient research on stakeholders' micro-behavioral mechanisms, limited cross-regional comparisons of homogeneous destinations, and inadequate exploration of climate adaptation policy linkage mechanisms. This study clarifies the progressive research logic of "vulnerability assessment → adaptation strategy → sustainable governance" in the field, addresses the fragmentation defect of traditional research, and provides a global knowledge landscape for research in this area. Based on this, the study proposes directions including strengthening micro-oriented empirical research, promoting cross-regional comparisons and international cooperation, and advancing technology-enabled research on policy linkage mechanisms. It also suggests expanding data sources and conducting targeted case studies to provide scientific guidance for academic research and practical management of climate adaptation in ecotourism destinations.

Keywords: climate change, ecotourism destination, bibliometric analysis, climate adaptation, governance, VOSviewer, citespace, tourist resources

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INTRODUCTION

Climate change affects and threatens the ecological sustainability, operational sustainability, and social-community sustainability of ecotourism in various aspects. Rising average temperatures, abnormal precipitation, and frequent extreme weather events have impacted the biodiversity of sensitive habitats such as mangroves, desert Gobi, and alpine meadows, directly damaging the tourism value of ecotourism destinations.

Climate change makes the tourism sector highly vulnerable to its detrimental impacts, while the tourism industry also significantly worsens the climate crisis through its carbon footprint (Fuster-Uguet, 2026).

Abnormal precipitation patterns caused by climate fluctuations have disrupted seasonal tourism cycles—for example, shortening alpine skiing seasons, increasing operational risks from heatwaves and wildfires, and raising infrastructure renovation costs for coastal destinations—threatening the economic viability of small businesses.

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Some tourists also consider the impacts of climate change when making travel decisions, making it a key factor influencing tourists' perceptions and changes in tourism demand (Gössling et al., 2012). Meanwhile, climate change poses challenges to the adaptive capacity of tourism systems. For instance, Jordan's Dana Biosphere Reserve only exhibits a moderate level of perceived resilience to climate change-related threats in the environmental dimension, while resilience in the social, economic, and governance dimensions is still underdeveloped. The stable development of its ecotourism social-ecological system faces direct challenges due to climate change threats (Jamaliah & Powell, 2019).

Despite the urgency of these challenges, research on the impacts of climate change on ecotourism destinations remains predominantly qualitative descriptions and single-region empirical analyses. While contributing to contextual depth, such studies fail to capture cross-regional knowledge flows, collaborative networks, or long-term thematic evolutions—areas where bibliometric methods excel in systematic and global comprehensive analysis. This study utilizes two validated knowledge structure mapping tools in tourism research, VOSviewer (van Eck & Waltman, 2010) and CiteSpace (Chen, 2006), to analyze 178 peer-reviewed articles from the Web of Science Core Collection spanning 2002-2025. By employing methods such as keyword co-occurrence, bibliographic coupling, burst detection, combined with clustering and multi-tool cross-validation, it explores four core research questions: (1) What are the main research hotspots and thematic clusters in the field? (2) How are core research forces distributed, and what patterns characterize their collaborative networks? (3) How have research themes and priorities evolved over time, and what emerging trends have emerged? (4) What key research gaps exist, and which directions merit future attention? Based on this, optimized directions for research and practice are proposed.

LITERATURE REVIEW

Climate change poses a significant challenge to the long-term sustainable development of global tourism destinations. Due to its inherent reliance on intact ecosystems and low-impact operational models, ecotourism exhibits unique climate vulnerability and has become a key subfield of tourism climate research. Existing studies have formed a multi-dimensional exploration system around this theme, with the core thread extending from risk identification to response practices, covering the key dimensions of climate impacts on ecotourism destinations and their adaptation pathways.

The assessment of climate change vulnerability and risks of ecotourism destinations is the foundational starting point of relevant research, and related explorations have expanded from single regions to various types of ecosystems and stakeholder groups. Jamaliah & Powell (2019) conducted the first comprehensive vulnerability assessment of the ecotourism system in Jordan’s Dana Biosphere Reserve through semi-structured interviews, finding that high climate exposure caused by reduced precipitation and intensified droughts has manifested in environmental degradation, tourism season shifts, and changes in community livelihoods. Kathirvelpandian et al. (2024) extended the research perspective from terrestrial protected areas to coastal ecosystems, constructing a multi-scale vulnerability index for India’s Pichavaram Mangroves, which revealed the dual vulnerability (as resource users and affected individuals) faced by mangrove fishermen, with higher risks in coastal areas than in marine areas. Salpage et al. (2020) took Sri Lanka’s Rekawa Coastal Wetland as the research object, quantifying demand-side vulnerability for the first time, and concluded that climate change would lead to a 43%-53% decline in ecotourism visits to the region, with foreign tourists being less sensitive than local tourists. Baytelieva et al. (2023) verified the high vulnerability of natural resources caused by droughts and temperature fluctuations among nomadic pastoralists in the Zhetysu region of Kazakhstan through the Livelihood Vulnerability Index (LVI), while establishing a link between diversified ecotourism operations and the mitigation of livelihood vulnerability. These studies, based on the core framework of "exposure-sensitivity-adaptive capacity," confirm that resource dependence, climate exposure, and management and policy support capacity are the key factors affecting vulnerability. Although the research scope has covered various typical destinations in Asia, Africa, and Europe, there are still obvious deficiencies in the assessment of special regions such as polar and high-altitude areas, dynamic simulations under future climate scenarios, and cross-regional comparative analyses.

The impacts of climate on ecotourism destinations are not limited to the risk level; its direct damage to ecosystems has become an undeniable core issue. LaVal (2004) first revealed the synergistic effect of global warming and ecotourism development in his study of the Monteverde Cloud Forest in Costa Rica. Simic et al. (2022) expanded the research object to river basin ecosystems, finding that 80% of the area of Serbia’s Great Morava River Basin has fallen into an ecologically unsustainable state due to the combined effects of climate and human pressures, resulting in a significant decline in ecological service functions such as leisure and ecotourism. Relevant research on marine ecosystems has also made breakthroughs: Diaz-Carballido et al. (2022) used the MaxEnt model to predict the future distribution of 25 species of carcharhinid sharks in Mexico, linking changes in the habitats of top marine predators to the economic value of ecotourism for the first time, and confirming that habitat reduction caused by climate change will directly damage the value of related tourism resources. Suresh et al. (2025) proposed the core viewpoint of "two-way interaction between climate change-ecological degradation-tourism" in blue carbon ecosystems through a systematic review, pointing out that unsustainable tourism practices exacerbate the degradation of mangroves and seagrass beds, while acknowledging the positive value of ecotourism in enhancing conservation awareness and promoting ecological restoration. Padhy et al. (2022) focused on the mangrove-agricultural composite ecosystem in India’s Sundarbans, supplementing freshwater scarcity and salinization as climate impact factors, and revealing their destructive mechanisms on ecosystem structure and the service functions of tourism and fisheries. Overall, these studies collectively confirm that climate change directly impacts the resource base of ecotourism by altering biodiversity, ecosystem structure and functions, and the synergistic effect of human tourism activities and climate factors often amplifies this destructive effect.

The impacts of climate on ecosystems are further transmitted to the socio-economic level, reshaping the development pattern and community status of ecotourism destinations. Ramaano (2024) verified the dual value of sustainable

ecotourism in rural areas of South Africa's Limpopo Province for the first time, alleviating the negative impacts of climate change on livelihoods and achieving a win-win situation between environmental protection and economic development. Dayour et al. (2025) found that community-based ecotourism can enhance women's climate resilience in semi-arid regions of Ghana, where women mitigate climate pressures through livelihood diversification while promoting environmental protection. Salpage et al. (2020) and Dushani et al. (2023) took Sri Lanka's Rekawa Wetland as a continuous research carrier, forming a complete research context of "climate impact-demand decline-economic compensation," and confirming that tourists' willingness to pay for ecological restoration can be an effective path to mitigate the economic impact of wetland tourism. Makian et al. (2023) shifted the research perspective to less developed regions, pointing out that climate change is a key environmental factor affecting the development of nature-based tourism destinations in Ardabil Province, Iran, and that sustainable management and climate response capacity are the core to enhancing their economic competitiveness. Although research on the socio-cultural dimension is relatively scattered, it has shown unique value: Silva (2015) took whale-watching tourism in the Azores as an example, discovering for the first time that the combined effect of changes in whale habitats caused by climate change and the development of whale-watching tourism has promoted the community's cultural perception of whales from "hunting" to "protection," revealing the phenomenon of community cultural reconstruction driven by the interaction between climate and tourism. Currently, diversified ecotourism operations have been proven to be an effective path to mitigate the socio-economic impacts of climate change, and research from segmented perspectives such as gender and indigenous peoples is gradually becoming an emerging hotspot in this field. Li et al. (2026) found that gender inequality is substantially aggravated by climate change vulnerability, with striking cross-country variations.

Faced with the multiple challenges brought by climate change, academic and practical circles have carried out a large number of explorations on adaptation strategies and supporting mechanisms, forming a research pattern of diversified development. Nature-based Solutions (NbS) is an important direction among them: Chen et al. (2023) took multiple climate-vulnerable regions in Taiwan, China as examples, repeatedly verifying the climate adaptation value of agri-ecotourism, and providing key quantitative evidence for the implementation of NbS through quantitative methods to verify its economic feasibility; Agaton & Collera (2022) used the real options model to evaluate the ecotourism and carbon sequestration value of mangrove restoration in the Philippines, confirming that it exceeds the investment cost, and providing a quantitative decision-making framework for NbS in coastal ecosystems. Jawabreh et al. (2025) conducted a case study of the Wadi Rum Protected Area to examine ecosystem restoration as a nature-based solution (NbS), and confirmed that the integrated implementation of passive and active restoration measures effectively enhances ecological resilience, providing scalable lessons for arid and semi-arid regions worldwide.

Resilience building and management system construction have also attracted much attention: Domenici & Seebacher (2020) approached from a biomechanical perspective, first revealing the intrinsic mechanism by which climate change reduces ecosystem resilience by affecting animal biomechanics, leading to population decline and habitat destruction; Jones et al. (2024) expanded the research to the post-pandemic era, constructing a sustainable development framework for wildlife tourism destinations, and proposing that ecotourism can enhance the resilience of destinations to cope with the dual impacts of climate and pandemic; Sharma & Pradhan (2025) supplemented the role of Civil Society Organizations (CSOs), confirming that their professional capabilities and collaborative capabilities can enhance community climate resilience through ecotourism protection projects; Mudzengi et al. (2021) provided the first systematic climate adaptation management framework for community-based ecotourism projects in Africa, covering key measures such as community cohesion building, diversified income, and climate-smart ecotourism. Innovations in quantitative models and technological applications have enriched the research methodology system: the Ecotourism Sustainability Maximization (ESM) model constructed by Ashok et al. (2022), the climate scenario simulation model by Weststrate et al. (2025), and the GIS and RS spatial analysis technologies applied by Kathirvelpandian et al. (2024) and Roshani et al. (2024) provide support for accurate assessment and prediction; while qualitative methods such as semi-structured interviews and focus group discussions adopted by Dayour et al. (2025) and Bawi (2025), as well as mixed methods by Ni & Say (2023) and Zeng et al. (2023), have jointly achieved complementary research perspectives. At the policy and governance level, Saidmamatov et al. (2020) pointed out the policy barriers such as infrastructure, microfinance support, and international networks faced by ecotourism development in the Aral Sea region of Uzbekistan, while Wondirad et al. (2024) proposed a post-pandemic tourism governance model for East Africa, emphasizing the integration of indigenous knowledge and sustainable practices, which has promoted the deepening of regional climate governance research.

Comprehensive analysis of existing studies shows that the exploration of climate change impacts on ecotourism destinations has formed an interconnected and complete system, presenting an inherent logic of "impact assessment-adaptation response-support guarantee." The academic community generally recognizes that climate change is a core challenge to the development of ecotourism destinations; it is transmitted to the socio-economic level by damaging the resource base of ecotourism, further exacerbating the vulnerability of destinations.

However, sustainable ecotourism is not merely a passive recipient of impacts, but can serve as an effective path to address climate change, achieving a win-win situation between ecological protection and community development through livelihood diversification, nature-based solutions, and resilience building. It is worth noting that community participation, stakeholder collaboration, and localized strategies have become the core principles jointly followed in research and practice in this field, providing important guidance for subsequent explorations.

Despite the significant progress made in existing research, there are still some gaps that need to be filled, highlighting the necessity of conducting systematic and global analyses. From the perspective of research structure, the

problem of uneven regional distribution is prominent, making it difficult to fully cover the climate adaptation needs of global ecotourism destinations. From the perspective of research perspective and depth, most existing achievements focus on static analysis of single themes and single dimensions, lacking cross-theme integrated research and dynamic prediction of future scenarios. From the perspective of research methods, excessive reliance on single-site case studies hinders the extraction of cross-ecosystem comparisons and transferable adaptation experiences, making it difficult to form a theoretical and practical framework with universal guiding significance. These limitations indicate that existing research is still in a fragmented state, and there is an urgent need for integration and sorting through systematic bibliometric analysis to provide a global knowledge landscape and scientific guidance for the in-depth development of this field.

MATERIALS AND METHODS

This study selects the Web of Science Core Collection as the sole data source. This database includes high-quality peer-reviewed journals, featuring interdisciplinary content coverage and standardized literature metadata, encompassing both social and natural science research outcomes. It is highly consistent with the interdisciplinary research nature of this study, which intersects climate change and ecotourism. Based on the research theme, a precise retrieval was conducted in the database using the "Topic" field to cover titles, abstracts, and keywords. The retrieval formula is: TS = ("climate change" OR "climate variability" OR "global warming" OR "sea level rise" OR "extreme weather") AND TS = ("ecotourism destination" OR "ecotourism site" OR "protected area tourism" OR "biosphere reserve tourism" OR "nature-based tourism destination"), using the "Topic" field to cover titles/abstracts/keywords. During retrieval, strict screening of literature types was performed, retaining only "Article," "Review," and "Article; Early Access." This composition not only reflects the core status of empirical research in the field but also reflects the diverse channels for academic achievement dissemination. The retrieval time span was set from 2002 to 2025, ultimately yielding 178 valid literature samples. After deduplication verification via CiteSpace, no duplicate or invalid records were found, ensuring the uniqueness and validity of the research samples. The 178 papers are scattered across 121 journals, covering multiple disciplinary categories such as tourism science, ecology, and climatology, confirming the interdisciplinary nature of cross-research on climate change and ecotourism, and indicating that the field has formed a stable knowledge inheritance system and a continuous academic dialogue atmosphere.

This study employs two academically validated bibliometric analysis tools, VOSviewer and CiteSpace (van Eck & Waltman, 2010; Chen, 2006). VOSviewer focuses on the mining and visualization of static knowledge networks, while CiteSpace concentrates on the analysis of dynamic evolutionary trends in research fields. The two complement each other to form a complete quantitative analysis system. The analysis dimensions of VOSviewer include co-author networks at three levels (country, institution, author), keyword co-occurrence networks, multi-level citation networks, bibliographic coupling networks, and co-citation networks. To ensure the scientificity and intuitiveness of knowledge graphs, appropriate parameter standards were set for different analysis dimensions, and the Leiden algorithm was used to complete network clustering analysis. For CiteSpace analysis, a 1-year time slice was set, with country, keyword, and author selected as core node types. The top 50 nodes were extracted for each time slice, and network pruning was performed through the pathfinder algorithm. Burst detection algorithm was used to identify keywords with sudden changes in research popularity, and core nodes in the research field were screened based on betweenness centrality indicators to achieve accurate capture of research dynamics.To ensure the reliability and robustness of the research results, this study conducted consistency verification of research conclusions through cross-validation of results from VOSviewer and CiteSpace. Through mutual confirmation of results from multiple tools, algorithmic biases of a single analysis tool were effectively avoided, and the scientificity of the research conclusions was ensured.

RESULTS AND DISCUSSION

To ensure the reliability and robustness of the bibliometric results in this study, cross-validation was conducted from two dimensions—tool consistency and alignment with highly cited literature—thereby guaranteeing the scientificity and field adaptability of the analytical conclusions.

1. Basic Characteristics of Literature

The annual publication volume distribution of the literature clearly reflects the phased evolutionary characteristics of the research scale in this field (Figure 1). The period from 2002 to 2008 was the embryonic stage of research, with basically 1 relevant paper published each year during these seven years, indicating that academic attention to this interdisciplinary topic was relatively limited at that time. 2010 became the first key turning point in research development, with the annual publication volume rising to 4, achieving the first significant growth in research output. This change is closely related to the deepening global understanding of the impacts of climate change in the late 2000s.

During the same period, international research programs focusing on "climate change and sustainable development" were successively promoted, directly driving preliminary explorations in the interdisciplinary field of climate change and ecotourism. After a short-term fluctuation, the field entered a critical stage of sustained expansion in 2018.

The annual publication volume steadily increased from 10 in 2018 to 26 in 2025, with an average annual growth rate of approximately 14.6%. The rapid development of this stage is mainly due to the deepening implementation of the Paris Agreement, which has consolidated the global consensus on climate action and prompted more scholars to focus on climate response research in the ecotourism industry. At the same time, practical problems such as ecological degradation and tourism resource loss caused by climate change have become increasingly prominent, further highlighting the practical value and academic urgency of research in this field.

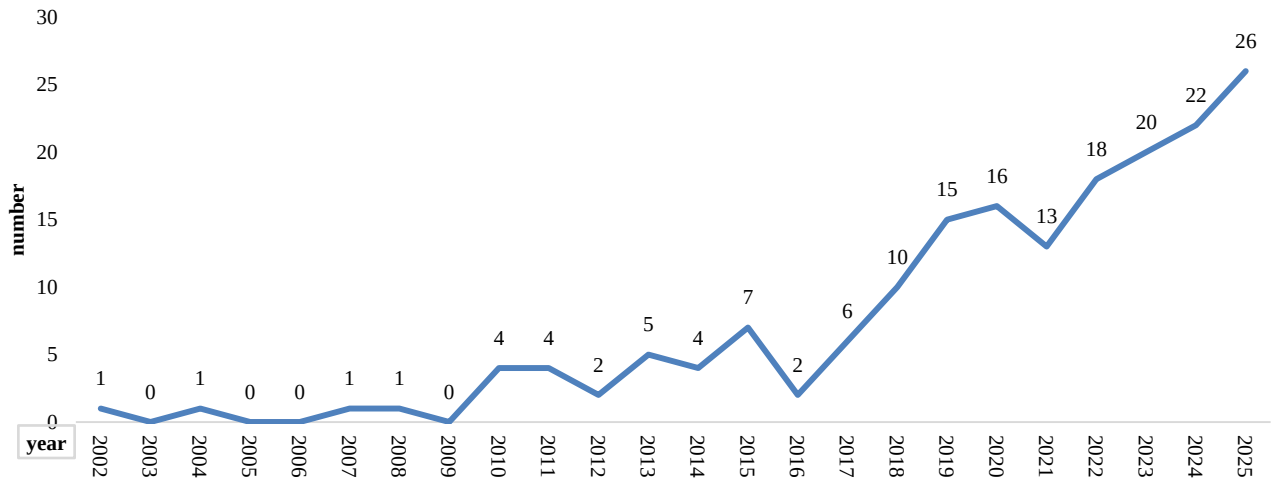

Figure 1. Annual Publication Trend of Literature on Climate Change Impacts on Ecotourism Destinations (2002-2025) (Data source: Web of Science Core Collection)

2. VOSviewer Visualization Results

(1) Keyword Co-occurrence and Clustering

The results of keyword co-occurrence analysis (Figure 2, Figure 3) clearly depict the thematic core and knowledge structure of this research field. Among the high-frequency keywords, climate change (n=89), ecotourism (n=67), resilience (n=42), adaptation (n=38), and biodiversity conservation (n=35) form the core nodes, and their co-occurrence relationships are highly consistent with the dual thematic focus of this study. The strong correlation between climate change and adaptation intuitively presents the core research tension between environmental pressure and response strategies.

Jamaliah et al. (2019)'s study taking Jordan's Dana Biosphere Reserve as a case provides empirical support for this, which analyzes the destination vulnerability caused by drought and points out that funding shortage is a key barrier restricting the implementation of adaptation. The high-frequency co-occurrence of ecotourism and protected areas (n=31) confirms that protected area-based ecotourism is the core research scenario in this field, a feature that echoes the research conclusions of Kathirvelpandian et al. (2024) on Pichavaram Mangrove. This study adopts the Leiden algorithm for clustering the keyword co-occurrence network, identifying 10 thematic clusters with clear boundaries. The calculated modularity Q=0.72 indicates that the cluster structure has good robustness and differentiation. Three core clusters dominate the thematic pattern of the field: Cluster #0 (Ecosystem Services–Biodiversity) is marked by ecosystem services (n=21) and carbon sink (n=12) as the core, focusing on the ecosystem foundation of ecotourism development. The Ecotourism Sustainability Maximization (ESM) model constructed by Ashok et al. (2022) in the Indian Himalayas serves as a typical practice of the research orientation of this cluster. Cluster #4 (Nature Conservation–Protected Areas) aggregates around protected areas and Dana Biosphere Reserve (n=9), and the series of studies on ecotourism resilience in arid regions by the Jamaliah team have laid the core theoretical foundation for this cluster. Cluster #3 (Online Interaction–Post-Pandemic Recovery) includes keywords such as COVID-19 (n=13) and online interaction (n=7), accurately capturing the shift of research topics after 2020. The analytical framework for the sustainability of wildlife tourism destinations in the post-pandemic era proposed by Jones et al. (2024) is a representative research achievement under this theme.

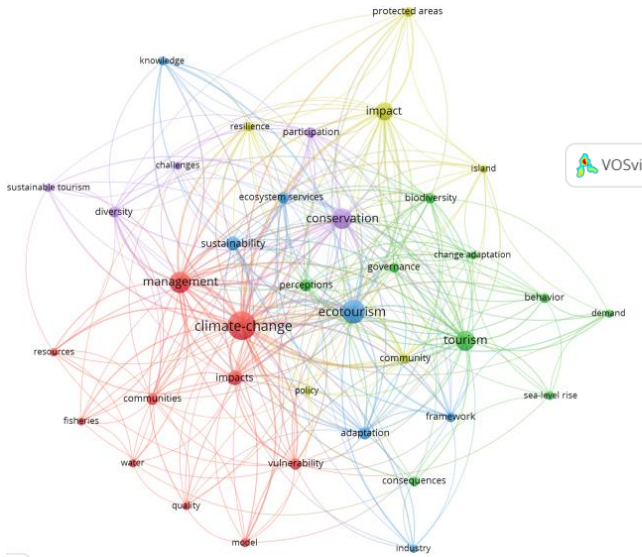

Figure 2. Keyword Co-occurrence Network (Keywords Plus)

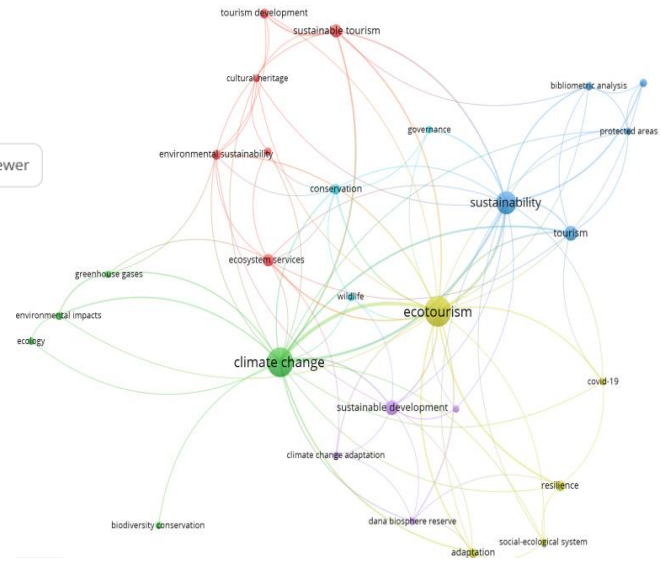

Figure 3. Keyword Co-occurrence Network (Author Keywords)

(2) Author and Institution Cooperation Networks

Bibliographic coupling analysis (Figure 4, Figure 5) identifies core researchers and key institutions based on the similarity of shared references, clearly presenting the distribution pattern of academic forces and the differentiated characteristics of research expertise. The core author group with a coupling strength ≥10 has formed clear thematic research directions. Jamaliah, Malek M. has a bibliographic coupling strength of 28, serving as the core leader in research on ecotourism in arid-region protected areas. Her series of studies on the Dana Biosphere Reserve have laid an important empirical foundation for the construction of the vulnerability assessment system in this field (Jamaliah & Powell, 2019). Ramaano, Azwindini Isaac, with a coupling strength of 24, focuses on rural ecotourism and livelihood resilience. His 2024 study on South Africa's Limpopo Province empirically reveals the correlation mechanism between biodiversity loss and the decline in homestay income (Ramaano, 2024). The research team composed of Chen, Wan-Jiun and Jan, Jihn-Fa has a coupling strength of 22, specializing in East Asian agri-ecotourism. Chen et al. (2023)'s study on Northeastern Taiwan quantifies tourists' willingness to pay and verifies the practical value of agri-ecotourism as a climate adaptation tool (Chen et al., 2023).

Core research institutions with a coupling strength ≥8 exhibit significant geographical agglomeration characteristics, and institutions in different regions have formed differentiated research focuses. Represented by National Taiwan Normal University in East Asia, with a coupling strength of 15, its research direction focuses on island and water ecotourism. Ni et al. (2023)'s exploration on the sustainable development of peripheral island communities in Taiwan serves as a typical study in this direction. The National Institute of Technology Patna in South Asia has a coupling strength of 10, leading the research on ecotourism model construction in the Himalayan region. The University of Venda in South Africa has a coupling strength of 9, with its research core concentrated on community-based ecotourism. Dayour et al. (2025)'s study on women's livelihood diversification in Ghana's semi-arid region is a representative achievement of this institution. From the perspective of network structure, the cross-regional cooperation links between core institutions in various regions are relatively sparse, which directly reflects the obvious regionalization characteristics of the current research network in this field.

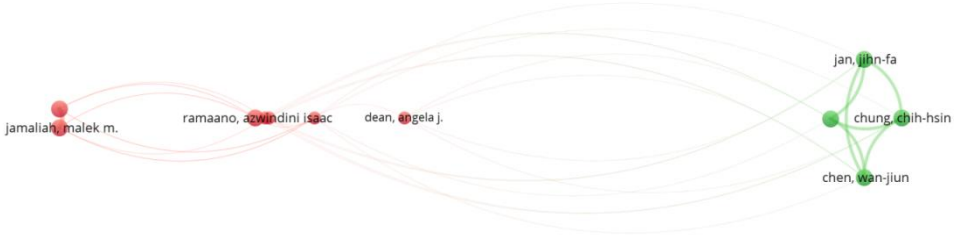

Figure 4. Bibliographic Coupling Network of Authors (Visualized by VOSviewer)

Figure 5. Bibliographic Coupling Network of Institutions (Visualized by VOSviewer)

(3) National/Regional Research Pattern

Analysis of national-level research patterns (Figure 6, Figure 7) clearly reveals the geographical differentiation characteristics of the field in terms of literature publication volume and thematic focus.

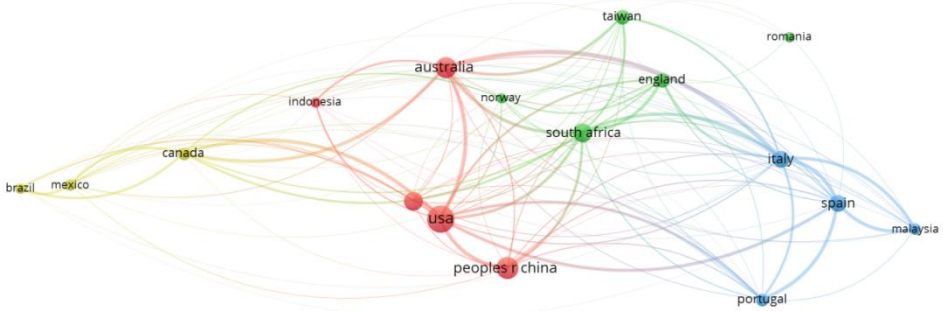

Figure 6. Bibliographic Coupling Network of Countries (Visualized by VOSviewer)

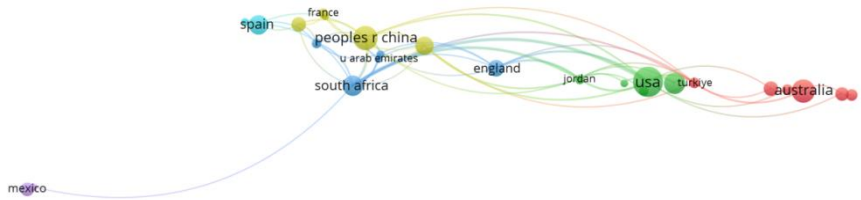

Figure 7. Citation Network of Countries (Visualized by VOSviewer)

The top Seven countries/regions in terms of publication volume are USA, China, Australia, India, South Africa, Spain, and Italy (Table 1). The differentiation in their research focuses constitutes the core geographical research pattern in the field. China's research strengths lie in climate adaptation and Nature-based Solutions (NbS). The USA dominates theoretical innovation. Both South Africa and Taiwan, China conduct empirical research based on local specific contexts: South Africa focuses on rural community-based ecotourism, while Taiwan, China specializes in two core directions—agri-ecotourism and island resilience. Indonesia's research core is focused on mangrove ecotourism, and so on. In terms of cooperation network characteristics, international cooperation in this field exhibits a significant regional agglomeration effect. Asian countries and regions such as China and Indonesia focus their collaborative research on coastal and island ecotourism issues; African countries including South Africa and Ghana have formed an intra-continental cooperation network, with research focusing on community-based tourism. The North-South imbalance in the research network remains prominent: high-income countries such as the USA and the UK hold absolute advantages in theoretical innovation and citation influence, while low- and middle-income countries like Indonesia and Mexico, despite contributing rich empirical cases, have relatively low cross-regional citation frequencies of their research outcomes. Notably, small island developing states (SIDS) such as the Maldives and Tuvalu are not among the top publishing countries, a phenomenon that directly exposes the key geographical gap in ecotourism adaptation research and indicates the insufficient academic voice of small island economies in this field.

Table 1. Data of Bibliographic coupling of Countries

Country	Documents	Citeations	Total Link Strength
USA	29	1134	1718
China	28	621	982
Australia	18	926	1466
India	15	167	234
South Africa	14	625	1221
Spain	12	336	1084
Italy	11	302	1467

3. CiteSpace Visualization Results

Using CiteSpace, this study focuses on three core dimensions—keyword clustering, temporal evolution, and burst detection—to systematically explore the dynamic evolutionary characteristics and knowledge base structure of the field of "climate change impacts on ecotourism destinations". All analytical conclusions are derived from the visual outputs of CiteSpace (Figure 8, Figure 9, Figure 10) and have been cross-validated against the content of empirical literature to ensure the scientific rigor and authenticity of the findings.

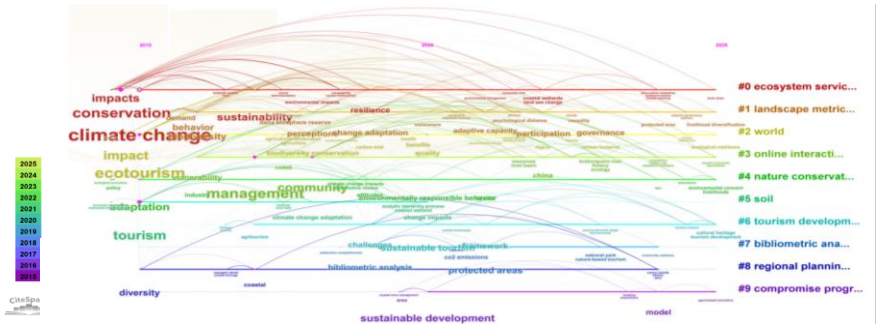

Figure 8. Timeline View of Keyword Clusters (2015-2025)

Keywords	Year	Strength	Begin	End	2015 - 2025
management	2017	1.68	2018	2019	
Dana biosphere reserve	2018	1.1	2018	2021	
sustainability	2017	2.14	2019	2020	
resilience	2019	2.13	2019	2021	
impacts	2015	1.57	2019	2020	
bibliometric review	2019	1.01	2019	2020	
consequences	2020	1.34	2020	2021	
change impacts	2020	1.15	2020	2022	
protected areas	2021	1.58	2021	2025	
impact	2015	1.42	2021	2022	
CO_2 emissions	2021	1.07	2021	2023	
vulnerability	2016	1.52	2022	2023	
perceptions	2018	1.26	2022	2023	
China	2022	1.23	2022	2025	
diversity	2015	1.66	2023	2025	
governance	2023	1.4	2023	2025	

Figure 9. Top 16 Keywords with the Strongest Citation Bursts (2015-2025) (visualized by citespace) (Source: Web of science core collection)

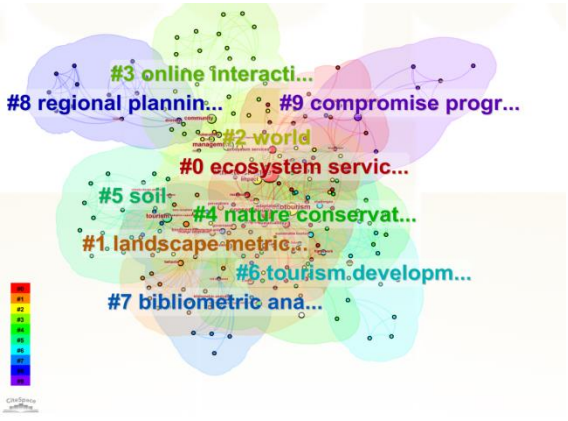

Figure 10. Keyword Clustering Network

Analysis of the keyword timeline view (2015–2025) (Figure 8) clearly delineates three distinct developmental phases in the field. The period 2015–2018 represents the impact documentation phase, dominated by Cluster #0 “Ecosystem Services” and Cluster #1 “Landscape Metrics”. Core keywords such as environmental impacts and protected area emerged as focal points, with the primary objective being to identify the ecological risks of climate change to ecotourism destinations. For instance, studies during this phase concentrated on documenting climate-related impacts such as coastal wetland degradation and beach erosion, laying an empirical foundation for subsequent adaptation research. The period 2019–2022 constitutes the transition stage, where research focus shifted to adaptation and resilience. The scope of Cluster #0 expanded to include themes such as carbon sink and adaptive capacity, while Cluster #3 “Online Interaction” emerged concomitantly with COVID-19 as a new keyword. This shift marked a transition from problem identification to solution-oriented research, focusing on enhancing the resilience of ecotourism destinations through pathways such as infrastructure adjustment and organizational management optimization. The period 2023–2025 represents the frontier stage, centered on the core theme of governance and diversification. Cluster #2 “World” and Cluster #9 “Compromise Program” underscore the growing importance of governance and diversity, reflecting the academic community’s deepening focus on inclusive institutional coordination and the construction of multi-functional ecotourism models.

The Strongest Citation Bursts map (Figure 9) identified 16 keywords with high burst intensity (burst strength ≥ 1.0). Among these, protected areas (2021–2025, strength = 1.58) exhibited the longest duration and the highest burst intensity, consistent with the sustained academic attention to protected areas observed in the timeline view, confirming its status as a long-term and stable research hotspot in the field. Governance (2023–2025, strength = 1.40), as the most recently emerged burst keyword, highlights the current research focus on institutional mechanisms for climate adaptation.

From a historical perspective, the strong burst characteristic of resilience (2019–2021, strength = 2.13) marked a critical turning point, signaling the field’s shift from problem identification to adaptation exploration. The bursts of CO_2 emissions (2021–2023, strength = 1.07) and China (2022–2025, strength = 1.23) respectively highlight low-carbon ecotourism as a distinctive research direction and China’s regional research advantage in this field. The keyword clustering map (Figure 8) further validates the rationality of the aforementioned thematic division, with each cluster corresponding to the core research directions in the timeline view, reflecting the internal consistency of the field’s knowledge structure.

4. Result Cross-validation

To ensure the reliability and robustness of the bibliometric results in this study, cross-validation was conducted from two dimensions: tool consistency and alignment with highly cited literature, thereby guaranteeing the scientificity and field adaptability of the analytical conclusions.

(1) Tool Consistency Test: Differences and Causes of Core Themes and Institutional Results

This test selected five core visual maps: VOSviewer’s Author Keyword Co-occurrence Map (Figure 3), Organizational Bibliographic Coupling Map (Figure 5), as well as CiteSpace’s Keyword Clustering Map (Figure 10), Keyword Timeline View (Figure 8), and Institutional Citation Map (Figure 11). It focused on two core indicators—"core theme overlap" and "institutional ranking consistency"—and explained result discrepancies by combining methodological differences between the tools.

Figure 11. Citation Network of Core Institutions

At the core theme level, the identification results of VOSviewer and CiteSpace showed high consistency, jointly locking in the three dominant knowledge axes of the field. First, ecosystem services and biodiversity conservation: VOSviewer Cluster #0 includes high-frequency keywords such as "ecosystem services" (n=21) and "biodiversity conservation" (n=35), while CiteSpace Cluster #0 covers the same theme synchronously. Its timeline view indicates that this direction extended to carbon sink research after 2019, echoing Ashok et al. (2022)’s research on the ecosystem service model in the Indian Himalayas. Second, protected area management: VOSviewer Cluster #4 centers on "protected areas" and "Dana Biosphere Reserve", while CiteSpace lists "protected area" as Cluster #1 and identifies it as a high-burst keyword (strength = 1.58)

during 2021-2025. This feature is highly consistent with Jamaliah et al. (2019)'s series of studies on Jordan's Dana Biosphere Reserve. Third, climate change adaptation and resilience: VOSviewer includes "adaptation" (n=38) and "resilience" (n=42) in the top five high-frequency keywords, and CiteSpace's burst detection confirms that "resilience" (2019-2021, strength = 2.13) is a key turning point theme in the field's development, consistent with the conclusions of Deason et al. (2022)'s research on community tourism resilience in Mexico. Minor differences at the theme level stem from the inherent analytical logic of the tools: VOSviewer focuses on static co-occurrence density and divides "post-pandemic recovery" (including COVID-19, n=13) into an independent sub-cluster; CiteSpace, based on the temporal continuity of 1-year time slices, classifies it as a sub-theme under Cluster #3 "online interaction". In addition, VOSviewer separately lists "bibliometric analysis" as Cluster #7 by enhancing network density; CiteSpace merges it into a larger cluster according to the top 10% pruning strategy, reflecting priority consideration for thematic dominance. At the core institutional level, the top five institutions identified by the two tools overlap highly, confirming the dominant position of these institutions in the field. National Taiwan Normal University ranks first in VOSviewer's bibliometric coupling analysis, and its research on island ecotourism (Ni et al., 2023) also ranks high in the institutional citation view; the Indian Institute of Technology Kharagpur specializes in Himalayan ecotourism modeling (Ashok et al., 2022); the University of Venda in South Africa is a leader in community-based ecotourism (Ramaano, 2024). A small number of ranking differences (e.g., the Chinese Academy of Sciences ranks 4th in VOSviewer and 6th in CiteSpace) are essentially due to methodological differences: VOSviewer focuses on "shared references", while CiteSpace emphasizes "direct citation centrality".

(2)Validation with Highly Cited Literature: Matching Degree Between Research Results and Field Research Focuses

Based on VOSviewer's Document Citation Map (Figure 12), CiteSpace's Author Citation Map (Figure 13), and high-impact studies in the field, this section examines the matching degree between the bibliometric results and core research focuses. The validation results show a high degree of alignment.

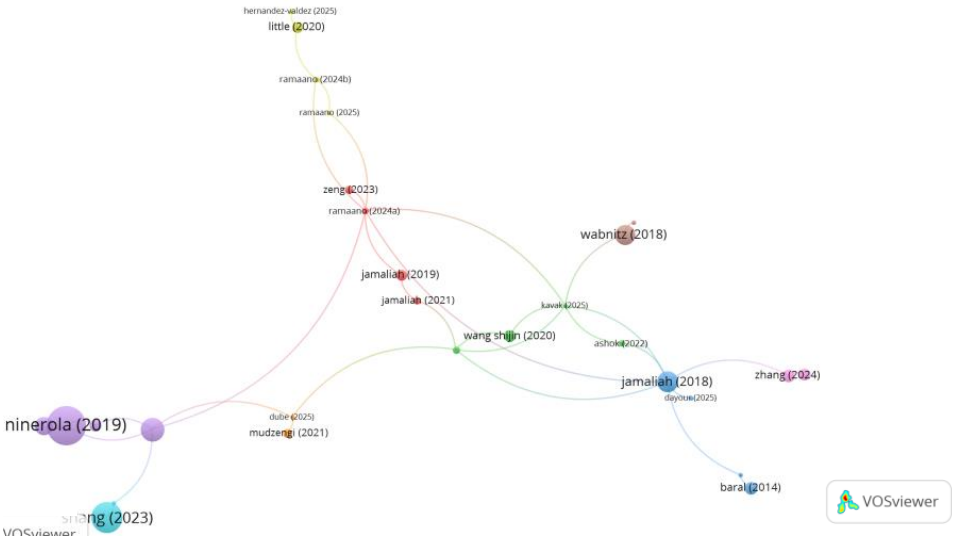

Figure 12. Citation Network of Documents

Figure 13. Citation Network of Core Authors

In terms of thematic matching, highly cited papers accurately correspond to the core themes identified by the two tools. Jamaliah, M. M. (2019)'s Integrated vulnerability assessment of ecotourism to climate change in Dana Biosphere Reserve, Jordan focuses on protected area vulnerability, which fully matches VOSviewer Cluster #4 and CiteSpace's burst keyword "protected areas". Its analysis of drought-driven adaptation barriers is also consistent with the core theme of "adaptation & resilience" in CiteSpace's timeline view after 2019. Ghosh et al. (2022)'s Falling "fortresses": Unlocking Governance Entanglements and Shifting Knowledge Paradigms to Counter Climate Change Threats in Biodiversity Conservation focuses on governance and cultural ecosystem services, directly corresponding to CiteSpace's latest burst keyword "governance" (2023-2025, strength = 1.40) and the thematic agglomeration feature of "governance" (n=22) in VOSviewer.

At the level of core research forces, highly cited papers are concentrated among the core authors and institutions identified by the two tools. Jamaliah, M. M. and Ramaano, A. I., who have the highest citation counts in VOSviewer, are also the authors with the highest betweenness centrality in CiteSpace. Among them, Jamaliah's research on the Dana Biosphere Reserve is frequently cited in both tools, establishing her status as a core researcher in the field. The highly cited achievements of core institutions such as National Taiwan Normal University (Chen et al., 2023), the Indian Institute of Technology Kharagpur (Ashok et al., 2022), and the University of Venda (Ramaano, 2024) are highly consistent with the thematic specialization directions presented in the bibliometric results.

CONCLUSIONS

1. Interpretation of Core Research Findings

Based on VOSviewer and CiteSpace analyses, this study clarifies the global knowledge landscape of the field examining climate change impacts on ecotourism destinations. Research hotspots in this field form a progressive logical chain of "vulnerability assessment → adaptation strategy → sustainable governance," a conclusion dual-validated by VOSviewer's keyword clustering (modularity Q=0.72) and CiteSpace's timeline evolution results. Among these, vulnerability assessment realizes the quantitative expression of climate risks, adaptation strategy translates assessment results into actionable practical plans, and sustainable governance provides institutional guarantees for climate adaptation.

The global research force exhibits a spatial characteristic of "European and American dominance with weak cross-regional cooperation," and geographical differences are highly correlated with research directions.

Among the countries and regions with the highest number of publications, the United States dominates theoretical innovation and citation influence, jointly leading theoretical research in the field with the United Kingdom; China and South Africa focus on empirical analysis of local cases, Indonesia specializes in mangrove ecotourism research, while small island developing states (SIDS) such as the Maldives and Tuvalu are absent from the list of high-output countries, becoming key geographical gaps in research on this field. Meanwhile, cooperation among core research institutions shows obvious regional agglomeration characteristics: core institutions in East Asia, South Asia, and Africa focus on island and water area, Himalayan, and community ecotourism research respectively, but the cross-regional bibliographic coupling strength is low, reflecting the regionalization of research networks.

The research themes in this field have undergone a mature evolutionary process over time, from "problem identification" to "adaptation exploration" and then to "governance optimization," a phased feature confirmed by CiteSpace's burst detection results. The period 2015-2018 was the problem identification stage, with the core research focusing on documenting the actual impacts of climate change on ecotourism destinations; keywords such as beach erosion and environmental impacts appeared frequently, laying a factual foundation for subsequent research. The period 2019-2022 entered the adaptation exploration stage, where "resilience" emerged as the core burst keyword (burst strength = 2.13); research focus shifted from problem identification to solution exploration, and the frequency of terms related to quantitative methods such as models and frameworks increased significantly.

The period 2023-2025 has stepped into the governance optimization stage, with "governance" becoming the latest burst keyword; research focuses on inclusive institutional coordination and the construction of multi-functional ecotourism models, forming an effective echo with the United Nations Sustainable Development Goals. The bibliometric analysis of this study fills the gaps of fragmented focus and lack of comprehensive trend analysis in traditional research, captures the potential connections between themes and temporal evolution laws through map analysis, and provides empirical support from a global perspective for systematic research in this field.Compared with existing research, the combined analysis method of VOSviewer and CiteSpace adopted in this study ensures the objectivity of theme division through modularity Q values (VOSviewer=0.72, CiteSpace=0.68), avoiding subjective biases.

Meanwhile, the analysis with research samples from 42 countries achieves a global perspective, identifying issues overlooked by traditional reviews such as the underrepresentation of SIDS. Additionally, the timeline view reveals the thematic evolution sequence of "vulnerability → governance," making up for the deficiency of isolated theme analysis. Compared with existing quantitative research, this study further refines the subfield of ecotourism destinations, locates application clusters of different empirical models through bibliographic coupling analysis, and emphasizes destination-specific terms and regional sub-themes, reducing the application bias of bibliometric research on broad themes.

2. Research Limitations and Core Research Gaps

The objective limitations of this study stem from the settings of data selection, analysis tools, and research scope, which do not have a substantial impact on the core research conclusions but point out directions for improvement in subsequent research. Firstly, while the data source of this study ensures the quality and standardization of research samples, it excludes relevant studies from other databases such as Scopus and CNKI, non-English literature, and gray

literature. This results in insufficient representation of non-English research in Southeast Asia and relevant research in SIDS, as well as the loss of practical insights that could bridge the gap between academia and application.

Secondly, VOSviewer and CiteSpace excel at quantifying network relationships and dynamic evolution trends but cannot fully evaluate the theoretical depth and contextual details of literature.

Although they can identify gaps in micro-behavior research through keyword frequency, they struggle to systematically analyze the methodological rigor and theoretical frameworks of existing research. Moreover, the unique algorithmic biases of the tools lead to slight differences in cluster division, which, although alleviated through cross-validation, still affect the granularity of some theme analyses. Thirdly, this study synthesizes the global research pattern from a macro bibliometric perspective, lacking in-depth case verification of specific themes. Meanwhile, it analyzes ecotourism destinations as a whole, ignoring the differentiated characteristics of different sub-types of destinations such as alpine, coastal, and mangrove areas, which may obscure the unique adaptation challenges of specific ecosystems.

Based on the bibliometric results and research limitations, this study identifies three core research gaps in the field, which serve as key breakthrough directions for subsequent research. Firstly, research on the micro-behavioral mechanisms of stakeholders is seriously insufficient. Existing studies mostly rely on cross-sectional surveys to explore tourist intentions, failing to capture the dynamic changes in behaviors driven by climate events such as heatwaves and droughts, resulting in an obvious disconnect between macro adaptation strategies and micro stakeholders' actions. Secondly, cross-regional comparative research on homogeneous ecotourism destinations is limited.

The lack of systematic cross-regional comparisons makes it difficult to identify transferable adaptation experiences, restricting the promotion and application of adaptation strategies. Thirdly, the exploration of climate adaptation policy linkage mechanisms is inadequate. CiteSpace's burst detection did not identify keywords related to "policy coordination," and VOSviewer's analysis shows that the co-occurrence strength between "policy" and "adaptation" is only 0.12. Empirical and simulation research on policy synergy is still in a blank state.

3. Future Research Directions

Targeting the identified research limitations and core research gaps, combined with the research frontier of this field, three future academic research directions are proposed to complement and deepen the research. Firstly, adopt mixed methods to strengthen micro-oriented empirical research. On the basis of existing cross-sectional surveys, supplement 1-2 years of longitudinal tracking to analyze the dynamic impacts of climate events on tourists' revisit decisions and consumption behaviors (Yu et al., 2023; Caciora et al., 2023). Meanwhile, study the adaptive actions of stakeholders such as local residents and small-scale operators to establish a mapping framework of "macro strategy - micro behavior." Secondly, promote cross-regional comparison and international cooperation of homogeneous ecotourism destinations (Caciora et al., 2024a; Safarov et al., 2022). Rely on core research institutions to establish international research alliances, systematically compare the vulnerability drivers and adaptation effects of homogeneous destinations in different regions, extract transferable adaptation experiences, and solve the problem of regionalization of research networks (Caciora et al., 2024b). Thirdly, advance technology-enabled research on policy linkage mechanisms.

Utilize big data, natural language processing technology, and artificial intelligence technology to capture tourists' real-time perceptions of climate risks, establish system dynamics models, quantify the actual effects of policy linkage, and fill the gap in policy coordination research. Meanwhile, subsequent research should expand data sources, combine case studies to deepen the interpretation of macro bibliometric results, and conduct targeted analyses for different types of ecotourism destinations to improve the comprehensiveness and depth of research.

Future research and practical applications should focus on the core idea of "academic innovation - practical implementation - international collaboration." At the academic research level, continuously deepen research in the three directions of micro-behavior, cross-regional comparison, and policy linkage, and combine mixed methods with big data technology to improve the scientificity and accuracy of research (Ilieș et al., 2024; Safarov et al., 2024).

At the practical application level, promote the development of technology-enabled decision support tools, establish community-led multi-stakeholder participation mechanisms, and adapt and promote the successful experiences of typical cases such as Yuanshan Township in Taiwan and Mahenye in Zimbabwe to local contexts.

At the international collaboration level, build a global cooperation platform for climate adaptation in ecotourism, focusing on addressing the research and practical shortcomings of SIDS, promoting South-South cooperation and North-South mutual learning, and enhancing the climate adaptation capacity of global ecotourism destinations through knowledge sharing, technical support, and financial assistance, so as to realize the ecological, operational, and community sustainable development of ecotourism destinations.

Author Contributions: Conceptualization, Y.H.; methodology, Y.H.; software, Y.H.; validation, T.Z.; formal analysis, Y.H.; data collection, T.Z.; writing - original draft preparation, Y.H.; writing - review and editing, Y.H.; visualization, Y.H.; supervision, B.S.; paper review and revision, H.M.E.M., A.E.S.; project administration, B.S.; funding acquisition, B.S. Author have read and agreed to the published version of the manuscript

Funding: This study was conducted within the framework of the scientific project entitled "Development of Methodological Foundations for Organizing Inclusive Tourism (A Case Study of Khatirchi, Nurata, and Kyzyltepa Districts of the Navoi Region)". Innovative grant number: IL-9124093892. This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant No KFU 260909]. This work was supported by the Special Project for the Protection and Inheritance of Cultural

Heritage, National Social Science Fund of China [Grant No. 24VWB023]: Research on the Interpretation and Development of Historical and Cultural Values of National Cultural Parks (Sub-project 4: Reference on International Experience in the Protection and Utilization of National Cultural Parks: The United States, France, Italy, the United Kingdom, Spain, Iran, and Turkey). This work was supported by the Key Project of the National Social Science Fund of China [Grant No. 24AGL032]: Research on the Operation Mechanism of Tourism Flow Economy and Government Governance in the Omnimedia Era (2024–2027). This work was supported by the Major Project of the National Social Science Fund of China [Grant No. 25ZD115]: Research on the Collaborative Mechanism for the Protection and Revitalization of Urban Cultural Heritage (2025–2027) (Sub-project 5: Research on the Policy System and Institutional Guarantee for the Protection and Revitalization of Urban Cultural Heritage).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study may be obtained on request from the corresponding author. Methods for Optimizing Property Relations as a Key Aspect of Stimulating the Development of the Tourism Industry.

Acknowledgements: The research undertaken was made possible by the equal scientific involvement of all the authors concerned.

Conflicts of Interest: The authors declare no conflict of interest.

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Article history: Received: 20.12.2025 Revised: 15.02.2026 Accepted: 21.05.2026 Available online: 25.06.2026