

ECOLOGICAL SUSTAINABILITY AND REGIONAL GREEN ECONOMY DEVELOPMENT: KNOWLEDGE MAPPING AND RESEARCH FRONTIERS

Hu Ying

PHD Student, "Silk Road" International University of Tourism and Cultural Heritage, Samarkand City, Republic of Uzbekistan, 140104, 17, University Boulevard.

Lecturer at the Three Gorges Tourism Polytechnic College, Hanyu Road, Yiling District, Yichang City, 443001, Hubei Province, China.

Email: huyingtravel@163.com

Tel: +86 15572738919

DOI: 10.61587/mmit.tiue.uz.v1i1.362

Abstract. Ecological sustainability and regional green economic development are important global issues, but the knowledge structure and research frontiers at their intersection have not been fully explored. This study retrieved 306 peer-reviewed articles from the Web of Science Core Collection (2000-2026) and used CiteSpace to construct a comprehensive knowledge graph, drawing maps of keyword co-occurrence, clustering, timeline visualization, and outbreak detection to reveal the knowledge structure, evolutionary trajectory, and emerging frontiers in this field. The results identified six core theme clusters: fiscal decentralization, energy consumption, green growth, sustainability, regional development, and lake rejuvenation. These clusters form a multidimensional and coherent research pattern. It systematically elucidates the structural positioning and interrelationship mechanisms of "institutional environment", "development paradigm", and "regional practice" in this field. Analysis shows that research direction has shifted from a value-based understanding of "whether green development should be pursued" to exploring "how to achieve green development", and further analyzing the mechanisms of "how to drive green transformation through institutional and technological innovation", pointing out certain directions for policymaking and future research.

Keywords: *ecological sustainability; regional green economy; knowledge mapping; research frontiers; CiteSpace.*

1 INTRODUCTION

Ecological sustainability is one of the most pressing issues of this century, facing numerous challenges. Economic development is a crucial aspect of people's well-being, but the utilization of ecological resources during economic development sometimes inevitably impacts the natural ecosystem. A green economy is a key measure to coordinate economic development with the limited carrying capacity of natural systems, and regions are crucial spaces for implementing sustainable development commitments and translating them into tangible economic restructuring and optimization. However, different regions possess varying natural resource endowments, administrative capacities, and development paths. Against this diverse backdrop, systematically elucidating the interaction between ecological sustainability and regional green economic development is essential, possessing both theoretical and policy significance. To clarify the knowledge framework in this field, identify existing research gaps, and determine future research priorities, this study comprehensively reviews the academic literature at the intersection of these two fields, exploring various connections between them through bibliometric methods.

Numerous examples illustrate the conflict between economic development and ecological sustainability. For instance, the Ganges-Brahmaputra-Meghna Delta in Bangladesh is one of the world's most vulnerable to climate change, yet rare earth mining and traditional industrial activities are severely damaging mangrove ecosystems and the coastal communities they depend on, creating a fundamental conflict between resource-centric growth models and ecological protection. Furthermore, global aquaculture exacerbates overnutrition and antibiotic resistance, damaging aquatic environments, and its cost-effectiveness is difficult to reconcile

with environmental restoration goals. Currently, the internal environments of many regional economies are deteriorating, and regional green economic development is the result of a game between economic needs, ecological constraints, and institutional path dependencies within a specific context; existing research has not yet fully explored the full complexity of this game.

To clarify the relationship between ecological sustainability and regional green economy development, this study focuses on the following questions: What is the knowledge structure, historical evolution, and current research frontier of academic research related to ecological sustainability and regional green economy development? What key knowledge gaps need to be filled and integrated in future work? To answer these questions, this study employed a systematic search strategy, retrieving 306 relevant core articles from the Web of Science database and conducting in-depth analysis using the CiteSpace bibliometric tool. Through keyword co-occurrence analysis, cluster analysis, timeline visualization, and citation burst detection, the study diagnosed the current research status in this field, tracked the formation and evolution of research clusters, and identified emerging research directions. This scientific mapping method reveals potential thematic connections within currently fragmented research areas and allows for the analysis of future research trends based on the temporal evolution of existing research hotspots. This research scientifically maps the overall knowledge map of this field, providing valuable insights for guiding future academic research and proposing regional sustainable development governance agendas.

2 LITERATURE REVIEW AND METHODS

2.1 Literature Review

In recent years, the number of studies at the intersection of ecological sustainability and regional green economic development has gradually increased. Some scholars have reviewed and summarized the research results in this field, and have drawn some meaningful findings. Ferraz et al. (2021), through an analysis of literature from 1988 to 2020, found that research on the correlation between economic complexity, diversification, and sustainable development is insufficient, and that research on economic complexity rarely involves continuous critical examination of theory and policy. Qudrat-Ullah (2023) focused on green energy and environmental policy research in South Asia, finding that the region is heavily reliant on fossil fuels, and that it is difficult to balance the increasing energy demand with emission reduction targets. Kouskoura et al. (2024) extracted ten core factors for measuring regional competitiveness, including economy, labor market, poverty, healthcare, education, environmental conditions, transportation infrastructure, science and technology, high-tech industries, and innovation. Mishra and Pandey (2025) found that most of the published research is from developed economies, and research on emerging regions such as Southeast Asia, Latin America, and Africa is also increasing, but there are still shortcomings in areas such as environmental, social, and governance (ESG) standardization, implementation in emerging market environments, and integration of technological innovation. Ding et al. (2026) focused on the peer effect mechanism of digitalization on corporate green innovation, finding that increased digitalization under significant external competitive pressure can significantly promote green innovation. Li et al. (2026) proposed a comprehensive global strategy for sustainable development of aquaculture, combining regionally differentiated policy design with cross-jurisdictional cooperation arrangements, and pointed out that regional context should be placed at the core of the analysis rather than on the periphery. Baghel et al. (2025) argued that policy innovation, strengthening cross-jurisdictional coordination mechanisms, and establishing global knowledge exchange platforms can effectively promote the development of local energy markets, and called for comprehensive regional green economy governance arrangements at the macro level. O'Gilvie et al. (2026) assessed the development path of renewable methanol in the Gladstone Industrial Centre of Australia, pointing out that

integrating renewable resources can reduce greenhouse gas emissions by up to 90%, but such integration has geographical limitations and requires further exploration. These findings demonstrate the breadth of this field in terms of themes, regions, and methodologies.

Most existing reviews employ narrative or thematic literature analysis methods, making it difficult to reveal potential structural connections between different research groups and accurately grasp research trends. Furthermore, existing research often treats "ecological sustainability" and "environmental sustainability" as synonyms, diminishing the unique analytical value of ecological sustainability as a systemic concept. Theoretical discussions on how regional conditions regulate the relationship between ecological sustainability and the green economy are also severely lacking, with numerous descriptive statements lacking explanatory frameworks, and their effectiveness in guiding regional sustainable development and governance is very limited. These studies have not used bibliometric methods to dynamically track their development, resulting in a lack of clear understanding of the research frontier and making it difficult for researchers and policymakers to grasp the key areas and directions for future knowledge production and policy adjustments. This study urgently needs to conduct quantitative analysis of knowledge graphs to fully grasp the research scope, reveal the potential knowledge structure, accurately identify research hotspots and trends, and conduct a more scientific review and summary of existing research in this field, thereby clarifying future research directions.

2.2 Methods

On May 1, 2026, this study used the search query TS = ("Regional Green Economy" OR "Regional Green Development" OR "Green Regional Growth") AND ("Ecological Sustainability" OR "Environmental Sustainability" OR "Ecological Sustainability") to retrieve high-quality research literature on the intersection of ecological sustainability and regional green economy from the Web of Science (WoS) Core Collection, obtaining a total of 376 records. Articles, reviews, and conference papers were selected, and documents with irrelevant themes or missing bibliographic information were manually removed. Combined with CiteSpace's deduplication function, 306 valid documents were ultimately retained as the final analysis dataset for CiteSpace analysis (Chen, 2004 & 2006) to create a corresponding knowledge graph to elucidate the research landscape in this field.

This study first statistically analyzed the number of annual publications, creating a graph showing the number of research findings published in the field over time. Then, it used CiteSpace software to create a keyword co-occurrence network graph to reveal the conceptual architecture of the field. Next, it used cluster analysis to divide thematic research clusters and used timeline visualization to track the temporal evolution of the identified clusters. Finally, it used burst detection to locate emerging research frontiers with rapidly increasing citations, thereby identifying mature paradigms and emerging research directions, providing an empirical basis for subsequent discussions.

3 RESULTS

3.1 Annual Publication Trends

To better understand the overall state of existing research, I conducted statistical analysis and created charts on the number of publications in relevant fields each year, generating an "Annual Publication Quantity Trend Chart." This chart shows a significant growth trend in research at the intersection of ecological sustainability and regional green economic development (Fig.1). Between 2000 and 2020, research in this field essentially stagnated, with annual output fluctuating between 0 and 7 papers, averaging less than 2 papers

per year. This indicates that the integration of regional economic analysis and ecological sustainability has not yet attracted widespread attention from the academic community.

Fourteen papers were published in 2021, and research output in this field has shown a significant upward trend since then. This increased to 23 papers in 2022, further to 39 papers in 2023, and peaked at 105 papers in 2025, marking the rapid development and integration of the field and indicating a significant increase in academic attention to core issues. As of May 1, 2026, 40 papers have already been published in 2026. Based on past trends and the number of publications in the first four months, it is reasonable to predict that the high productivity of 2025 will continue in 2026. Thus, it is evident that research on the relationship between ecological sustainability and regional green economy development, once a marginal field, has gradually developed into a mainstream research frontier over the past five years.

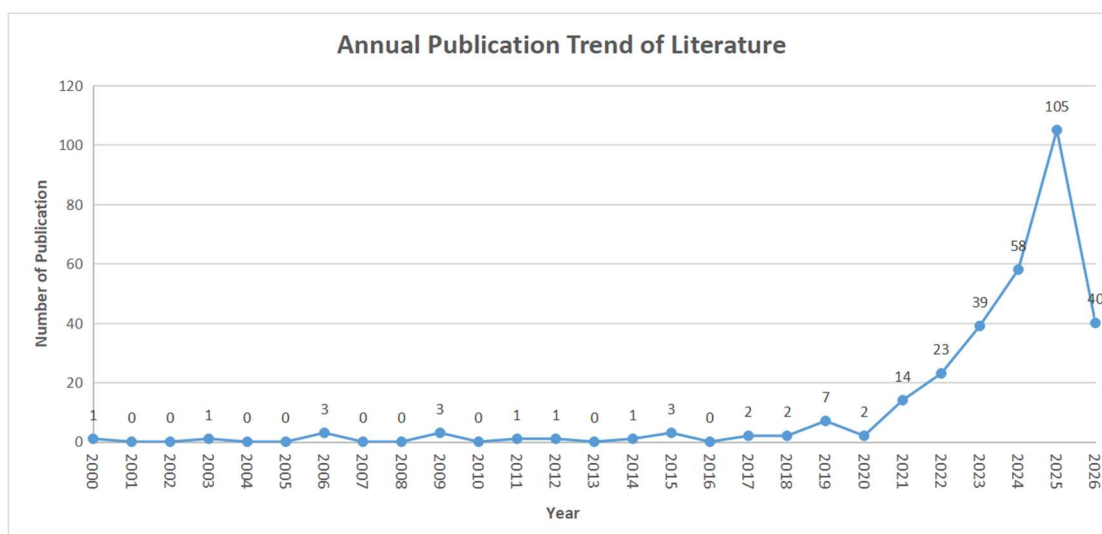


Fig.1 Trend in the Annual Number of Publications

3.2 Intellectual Structure and Thematic Communities

Based on the keywords and clustering diagrams generated by CiteSpace (Figures 2 and 3), this study systematically analyzed the knowledge structure of this field. First, the diagram contains 754 nodes and 2941 connections, with a network density of 0.0104, indicating that a considerable amount of literature has been accumulated in this research field. However, the connections between different research topics are not yet strong, presenting a relatively dispersed research pattern. From another perspective, this also suggests that the research perspectives in this field are relatively diverse, and future research can achieve theoretical integration and breakthroughs by connecting different issues. Further clustering was conducted based on keyword co-occurrence to rationally divide research topics. The modularity $Q=0.8254$, the average silhouette coefficient $S=0.9174$, and the harmonic mean $(Q,S)=0.869$ in the clustering diagram indicate that the cluster structure is closely connected internally, and the boundaries between clusters are clear. The clustering results are highly statistically significant, and the keyword members within each cluster exhibit strong consistency and homogeneity. Clusters labeled #0 "Fiscal Decentralization," #2 "Green Growth," and #5 "Lake Revitalization" collectively outline the core knowledge framework of this field. The likelihood of keywords being misassigned to adjacent clusters is extremely low. Overall, this clustering achieves a good balance between structural discriminative power and internal consistency.

Cluster #0, "Fiscal Decentralization," represents the largest research theme. Its core focus is on the impact mechanism of intergovernmental fiscal relations on green economic development. Key high-frequency keywords include "green financial," "technology innovation," and "renewable energy consumption," indicating that fiscal decentralization is not

an isolated research topic but is closely intertwined with specific practical paths such as green finance, technological innovation, and renewable energy consumption. In the keyword co-occurrence network in Fig.2, the three nodes of "green financial," "technology innovation," and "renewable energy consumption" play a crucial role in connecting government governance and industrial technology dimensions. Their existence enables the macro-level institutional variable "fiscal decentralization" to establish a link with micro-level behaviors, thus forming a complete transmission chain from policy allocation to green economic growth.

Cluster #2, "green growth," points to a theoretical paradigm of synergistic optimization between economic growth and the ecological environment. The map shows a significant overlap between "green growth" and "renewable energy consumption." Renewable energy consumption is not only a technological variable but also a key mediating variable for decoupling economic growth from the environment. The co-occurrence map reveals that renewable energy consumption connects the concept of green growth with specific emission reduction actions (such as CO₂ emissions). Green consumption energy further expands the connotation of green growth, extending the research perspective from the production side to the consumption side. The shift from supply-oriented to demand-oriented approaches in this field is quite evident.

Cluster #5 "lake rejuvenation" focuses on regional-level ecological restoration and sustainable development practices. Its core topics include pollution, water, and constructed wetlands, demonstrating that ecological sustainability research does not merely remain at the level of macro policies or abstract theories, but truly focuses on the restoration and governance performance of specific geographical units (such as lake ecosystems).

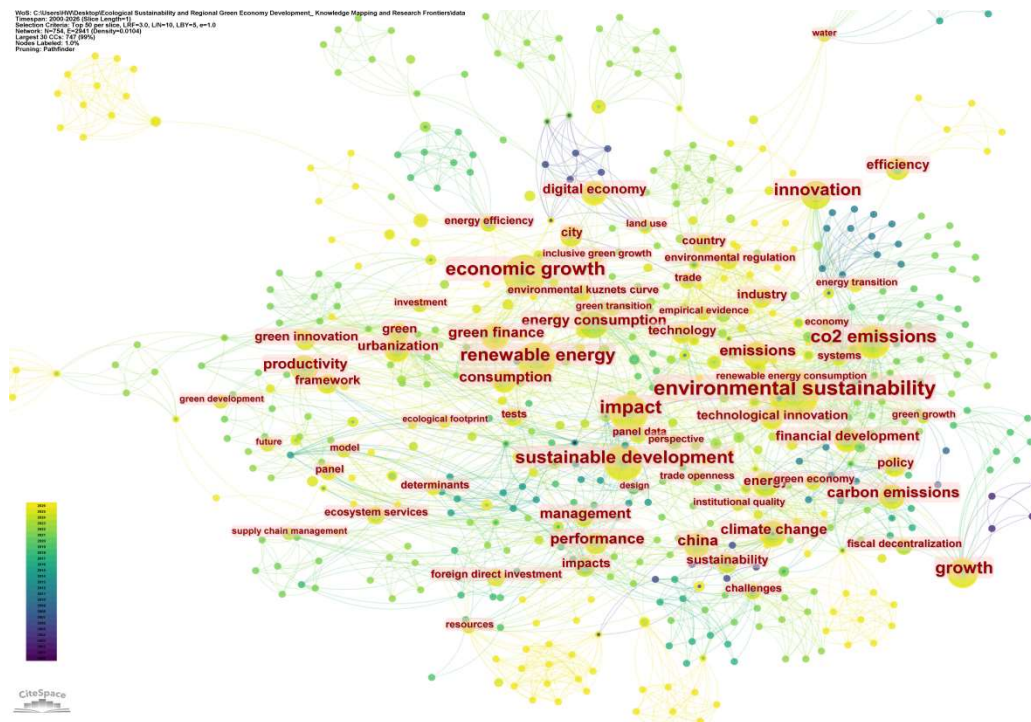


Fig.2 Keyword co-occurrence network

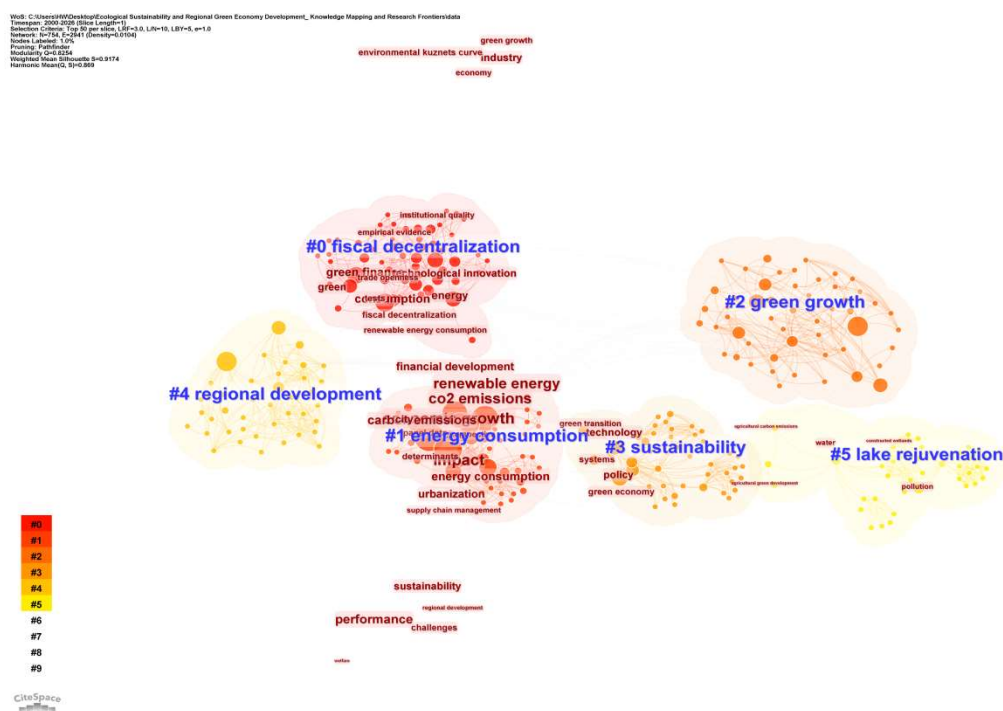


Fig.3 Cluster Map of Keywords (Top Six Clusters)

3.3 Temporal Evolution and Emerging Frontiers

Based on the keyword timeline and the strongest Citation Bursts generated by CiteSpace (Fig.4 and Fig.5), this study systematically analyzes the evolution and cutting-edge trends of research topics in this field from 2000 to 2026. From a macro-temporal evolution perspective, the entire research period is divided into three stages. The period from 2000 to 2010 was the basic exploration stage, with research topics relatively dispersed. Keyword nodes were sparsely distributed in the left area of the graph, centered around the word "city." Concepts surrounding this included "growth," "policy," "green growth," "land use," and "governance," forming the starting point of research in this field and reflecting the initial path scholars took in exploring the fundamental relationship between urban development and environmental protection. The period from 2010 to 2020 was the rapid development stage, with a high-density clustering of key terms in the central area. Terms such as "CO2 emissions," "performance," "economic growth," and "impact" appeared frequently and were intertwined, indicating that the research focus during this period shifted from basic understanding to multi-dimensional, interdisciplinary theoretical construction and empirical testing. The period from 2020 to 2026 is a period of deepening and differentiation. The timelines of the major clusters have been further extended and developed in different directions. The "#2 Green Growth" cluster saw a significant increase in node density in the late 2020s, while clusters such as "#0 Fiscal Decentralization" and "#5 Lake Revitalization" also showed independent development trajectories, indicating that this research field is developing towards specialization and refinement.

Emerging terms analysis provides a clear direction for identifying research frontiers. From a phased perspective, early emerging terms are represented by "design" (intensity 2.35, active period 2014-2019) and "impacts" (intensity 2.28, active period 2015-2021), reflecting the research focus on methodological exploration and impact assessment during this stage. However, entering the 2020s, emerging terms exhibit a completely new landscape. "Renewable energy" and "energy consumption" began to surge in 2023 (intensity 3.94) and 2022 (intensity 3.64), respectively. This phenomenon closely matches the dense growth of the #2 green growth cluster in the timeline of Fig. 4, indicating that energy structure transformation driven by global

carbon neutrality policies has become the core path for regional green growth research. Of particular note are the top four emerging terms in terms of intensity: "economic growth" (intensity 5.59, active period 2023-2026), "innovation" (intensity 4.18, active period 2024-2026), "environmental sustainability" (intensity 4.09, active period 2024-2026), and "renewable energy" (intensity 3.94, active period 2023-2026). These high-intensity emerging terms are all currently active and will continue until 2026, constituting core evidence for judging recent research frontiers.

Based on the emergence map to identify cutting-edge trends, "innovation", with an intensity of 4.18 and a red duration spanning from 2024 to 2026, is undoubtedly one of the most promising emerging themes. This trend corresponds to the nodal status of "green financial" and "technological innovation" as constituent elements of cluster #0, fiscal decentralization, in the timeline map, indicating that "innovation" is becoming a core driving force for research in this field. Also noteworthy are emerging terms such as "environmental sustainability" (intensity 4.09, 2024-2026) and "digital economy" (intensity 2.58, 2024-2026). The former, as a global goal, is associated with all clusters, while the latter represents the penetration trend of digital governance tools and research methods. "China" as a sudden term in 2023-2024 (intensity 3.1) reflects China's prominent position as a key research case region, eventhough its red block lasted for a relatively short period. "Fiscal decentralization" emerged in 2022-2024 which indicates that institutional issues have more long-term academic vitality than specific regional cases.

The aforementioned analysis reveals a clear evolutionary logic in this research field, from classic to emerging themes. Initially, a deepening understanding of the contradictory relationship between economic growth and environmental sustainability gave rise to early core concepts such as sustainable development. Subsequently, the surge in the concepts of "economic growth" and "environmental sustainability" directly reflects how external policy pressures and shifts in research paradigms have, in turn, prompted the exploration of pathways to achieve green development, such as "innovation" and "green financial technology." The research focus has shifted from "whether green development should be pursued" to "how to achieve green development." Meanwhile, the digital economy, as one of the latest research hotspots, indicates that digital technology is becoming a key variable in bridging the theoretical gap between fiscal decentralization, green innovation, and regional development performance.

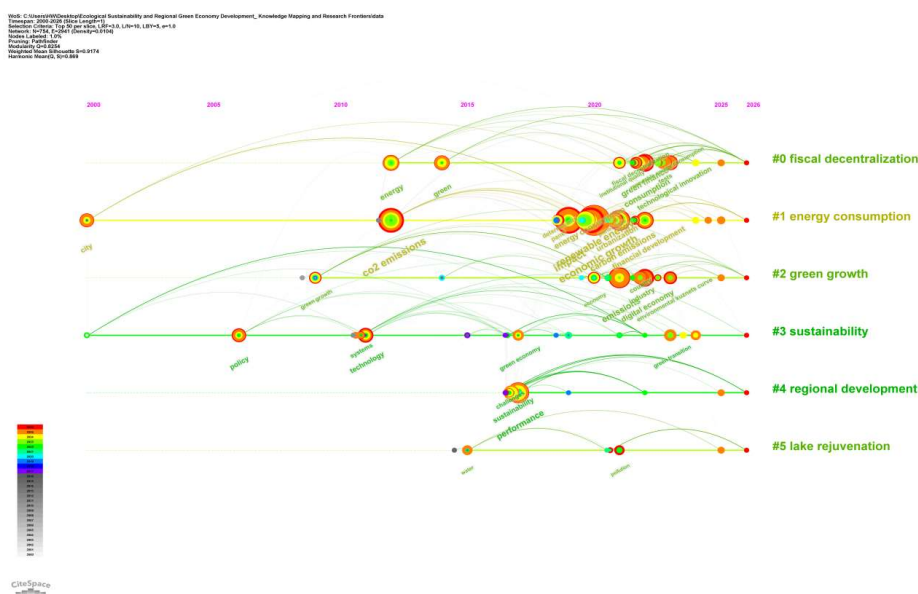


Fig.4 Timeline View of Keyword Clusters

Top 13 Keywords with the Strongest Citation Bursts



Fig.5 Top 13 Keywords with the Strongest Citation Bursts

4 CONCLUSION AND DISCUSSION

Research in the field of ecological sustainability and regional green economy development began with the conceptual foundations laid between 2000 and 2010, underwent rapid theoretical development between 2010 and 2020, and finally entered a phase of deepening and differentiation after 2020. Due to the guidance and shaping of academic research directions by external policy agendas, especially the advancement of carbon neutrality goals and the shift in research paradigms, research literature has grown rapidly since 2021. This study, based on a knowledge graph generated by CiteSpace, visually reveals the knowledge structure and research evolution patterns in this field, identifying three parallel and interacting core research paths: an institutional driving mechanism centered on fiscal arrangements; a technology growth synergy paradigm supported by green technologies and renewable energy consumption; and regional governance practices focusing on the restoration and performance evaluation of specific geographical units. These are interconnected through nodes such as "green finance," "technological innovation," and "renewable energy consumption," forming a complete logical chain from macro-level institutional design to micro-level technology adoption, and finally to the governance of specific ecological regions. The research focus shifted from a value-based understanding of "whether green development should be pursued" to exploring "how to achieve green development," and then to analyzing "how to drive green transformation through institutional and technological innovation," forming a logically complete and progressive development model.

By constructing a clustering structure with high statistical significance and internal consistency, this study systematically elucidates for the first time the structural positioning and interrelationship mechanisms of "institutional environment (fiscal decentralization)," "development paradigm (green growth)," and "regional practice (lake revitalization)" within the interdisciplinary field, thus building a systematic framework for the knowledge architecture of this field. Simultaneously, this study confirms that "innovation" and "digital economy" are important emerging research frontiers, expanding the focus of academic attention from traditional environmental economic issues to transformational paths driven by technological and institutional innovation. Furthermore, this study demonstrates the application paradigm of the CiteSpace bibliometric tool in systematically tracing the evolution of knowledge in the field of ecological economics, providing a clear analytical framework and directional guidance for subsequent researchers in this field.

The network density of the keyword co-occurrence map is 0.0104, indicating that although the total amount of research literature in this field is considerable, the theoretical integration between different research methods is still insufficient. This article recommends that policymakers and funding agencies give priority to stimulating interdisciplinary research projects, combining fiscal system design with green technology innovation, and linking macro governance structures with micro consumption behavior. In addition, given the strong growth momentum of "innovation" since 2024, it is recommended that the development of green financial instruments and support for the application of clean technologies be regarded as an important part of the regional green development strategy. At the same time, "digital economy" is one of the latest research frontiers. When countries plan regional green economic transformation paths, this article recommends using digital technology to improve fiscal efficiency and standardize green financial markets, and incorporate digital governance capabilities into their strategic frameworks.

The limitations of this study are mainly as follows: all analyzed data came from the Web of Science Core Collection, and the insufficient representativeness of non-English literature and regional journals may lead to bias. Although a composite search query was constructed, literature using other terminology variations may still be missed, thus limiting the comprehensiveness of the search sample. CiteSpace's clustering and burst detection procedures based on co-occurrence frequency may prioritize established, highly cited topics, easily overlooking emerging but less cited research directions. Furthermore, while bibliometric methods can effectively reveal the evolution of research topics and changes in academic attention, their analysis is limited to keywords and citation relationships in the literature, making it difficult to directly assess the scientific quality of research conclusions and the effectiveness of policy and recommendation implementation. Therefore, this paper suggests that future research could appropriately expand the sources of data analysis and adopt more diverse research methods, especially in practical research in emerging research fields. Simultaneously, methods such as structural equation modeling can be used to further explore the interaction of causal mechanisms between clusters, such as examining the transmission chain between fiscal decentralization, green technology innovation, and renewable energy consumption, thereby promoting the exploration of causal explanations based on correlation descriptions. In addition, emerging paradigms such as digital technology development and artificial intelligence applications can be combined to explore the revision and reconstruction of green economic development theories.

References

1. Chen, C. M. (2004). Searching for intellectual turning points: Progressive knowledge domain visualization. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Supplement 1), 5303-5310. <https://doi.org/10.1073/pnas.0307513100>.
2. Chen, C. M., Chen, Y., Hou, J. H., & Liang, Y. X. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology*, 57(3), 359-377. <https://doi.org/10.1002/asi.20317>.
3. Ferraz, D., Falguera, F. P. S., Mariano, E. B., & Hartmann, D. (2021). Linking economic complexity, diversification, and industrial policy with sustainable development: A structured literature review. *Sustainability*, 13(3), Article 1265. <https://doi.org/10.3390/su13031265>.
4. Qudrat-Ullah, H. (2023). A review and analysis of green energy and the environmental policies in South Asia. *Energies*, 16(22), Article 7486. <https://doi.org/10.3390/en16227486>.
5. Kouskoura, A., Kalliontzi, E., Skalkos, D., & Bakouros, I. (2024). Assessing the key factors measuring regional competitiveness. *Sustainability*, 16(6), Article 2574. <https://doi.org/10.3390/su16062574>.

6. Mishra, P., & Pandey, V. K. (2025). Triple bottom line and environmental sustainability: Evolution of global ESG research—a bibliometric analysis. *Environmental Sciences Europe*, 37(1), Article 136. <https://doi.org/10.1186/s12302-025-01184-9>.
7. Ding, Q., Huang, J., Yan, Y., & Chen, J. (2026). Digitalization, peer effects, and corporate green innovation. *Emerging Markets Finance and Trade*. Advance online publication. <https://doi.org/10.1080/1540496X.2026.2615000>.
8. Li, Z., Deng, Y., Zheng, M., Yang, L., He, C., Yang, C., Li, C., Wang, J., Zhang, X., Zhao, Y., & Liu, B. (2026). A review of global aquaculture wastewater treatment and management: Sustainable pathways through technological innovations and policy coordination. *Journal of Hazardous Materials*, 503, Article 141235. <https://doi.org/10.1016/j.jhazmat.2026.141235>.
9. Baghel, N., Kumar, A., Manjunath, K., & Prakash, O. (2025). Advancing local energy markets in India: Policy framework, regulatory barriers, and sustainable energy transition. *Wiley Interdisciplinary Reviews: Energy and Environment*, 14(3), Article e70013. <https://doi.org/10.1002/wene.70013>.
10. O'Gilvie, H., Rasul, M. G., Mandal, N. K., Nabi, M. N., & Naiker, M. (2026). Renewable methanol resources to achieve energy transition goals and environmental sustainability in the Gladstone (Australia) industrial hub—A review. *Biomass and Bioenergy*, 209, Article 108968. <https://doi.org/10.1016/j.biombioe.2026.108968>.