Sustainable Development
ISSN Print: 3104-4174
ISSN Online: 3104-4182
CD ISSN: 3104-4190
https://doi.org/10.63313/SD.9010

Research Progress and Hotspot Analysis of Ecosystem Service Value in China Based on CiteSpace

Xinyue Liu. Junfeng Zeng
Yangtze University, College of Horticulture and Gardening, Jingzhou 434000, China

How to cite this paper: Liu, X., & Zeng, J. (2026). Research Progress and Hotspot Analysis of Ecosystem Service Value in China Based on CiteSpace. Sustainable Development, 1(3), 1–13. ISSN Print: 3104-4174; ISSN Online: 3104-4182.
https://doi.org/10.63313/SD.9010
Published: 2026-07-23

Copyright © 2026 by author(s) and Erytis Publishing Limited.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
CC BY 4.0

Abstract

This study employs CiteSpace software to analyze 892 domestic articles related to ecosystem service value indexed in the China National Knowledge Infrastructure (CNKI) from 2021 to 2025. By examining publication trends, keyword co-occurrence and clustering, keyword burst detection, and keyword timeline mapping, this paper identifies research hotspots and evolutionary trends in the field of ecosystem service value in China. The results show that: 1) The number of publications on ecosystem service value in China has remained stable over the past five years, with an average annual output of 178 articles. 2) Collaboration among domestic institutions and authors exhibits a pattern of "small clusters, large dispersion." 3) "Land use" and "spatiotemporal evolution" are keywords that persist throughout the entire research period, while terms such as "driving factors" and "trade-off synergy" represent emerging frontiers and hotspots in the field.

Keywords

Ecosystem service value; CiteSpace; Research hotspots; Bibliometrics

1. Introduction

Ecosystem services refer to the material goods and spiritual benefits provided by ecosystems that contribute to human well-being[1]. Ecosystem service value (ESV) is the quantitative assessment of these services, measuring the contribution of ecosystems to human society in monetary or other terms[2]. Research on ESV helps deepen theoretical understanding of the complex interrelationship between ecosystems and human society, revealing the intrinsic value and functions of ecosystems and enriching the theoretical frameworks of ecology, economics, and other disciplines. In practice, findings from ESV research provide scientific support for ecological policy formulation, guide rational resource allocation, promote sustainable ecosystem management, and safeguard long-term human well-being.

Therefore, studying ESV holds great significance.

Research on ESV has undergone gradual development. In the early stages, studies focused primarily on identifying and describing types of ecosystem services, establishing a basic conceptual framework. As research progressed, value assessment methods became a central focus. Scholars have applied various methods to quantify ESV, evolving from simple market valuation approaches to model-based assessments that integrate ecological processes[3], thereby improving the accuracy and scientific rigor of evaluations. In recent years, research has placed greater emphasis on practical applications, highlighting the coupling and coordination between ESV and socio-economic systems and aiming for win-win outcomes in ecological conservation and economic development.

Visualization analysis of literature helps identify research hotspots, frontier trends, and developmental trajectories in a given field. CiteSpace is widely used for visual bibliometric analysis across disciplines due to its readability, aesthetic output, and integration of multiple analytical methods. Based on the CNKI database, this paper employs CiteSpace and bibliometric methods to summarize the state of domestic research over the past five years, aiming to identify future hotspots and directions in ESV research.

2. Data Sources and Research Methods

2.1. Data Sources

This study uses CNKI as the primary data retrieval platform, conducting a precise search using the topic "ecosystem service value." The time range is strictly limited to January 1, 2021, to December 31, 2025. After careful filtering and sorting, a total of 892 relevant articles were obtained. These articles were exported in Refworks format[4] as the data foundation for subsequent analysis using CiteSpace.

2.2. Research Methods

2.2.1. CiteSpace Software Settings

CiteSpace version 6.3.R1 was used for bibliometric analysis. Parameter settings were as follows: time span from 2021 to 2025, time slice = 1 year, and node types including author, institution, and keyword.

2.2.2. Analytical Methods

Publication volume analysis: The number of articles per year was precisely counted, and a trend graph was plotted to visually present the development trajectory of domestic ESV research over the past five years[5], revealing changes in research popularity over time.

Analysis of publishing institutions and authors: Cooperation network analyses of research institutions and authors were conducted based on CNKI retrieval results, identifying major contributors and collaborative relationships in the ESV field.

Keyword co-occurrence analysis: A keyword co-occurrence map was generated, where node size reflects keyword frequency (larger nodes indicate higher frequency), and line thickness indicates co-occurrence strength[6] (thicker lines denote stronger co-occurrence).

Keyword clustering analysis: Clustering operations were performed on keywords, yielding multiple clusters, each representing a relatively independent research theme, thereby revealing the distribution of research hotspots across thematic areas.

Keyword burst detection: Burst detection was conducted to identify keywords that experienced a sudden increase in frequency within specific time periods, indicating emerging hotspots and frontier trends.

3. Research Results

3.1. Publication Volume Analysis

The annual publication volume of domestic ESV research over the past five years shows a stable trend (Figure 1). The number of articles was 186 in 2021, decreased to 172 in 2022, rose to 192 in 2023, then to 188 in 2024, and fell to 154 in 2025. The average annual publication volume is approximately 178 articles. This trend clearly indicates that the field has received sustained attention in China over the past five years. It not only reflects the academic importance of ESV research but also demonstrates increased research investment and growing research capacity under the context of ecological protection and sustainable development strategies[7].

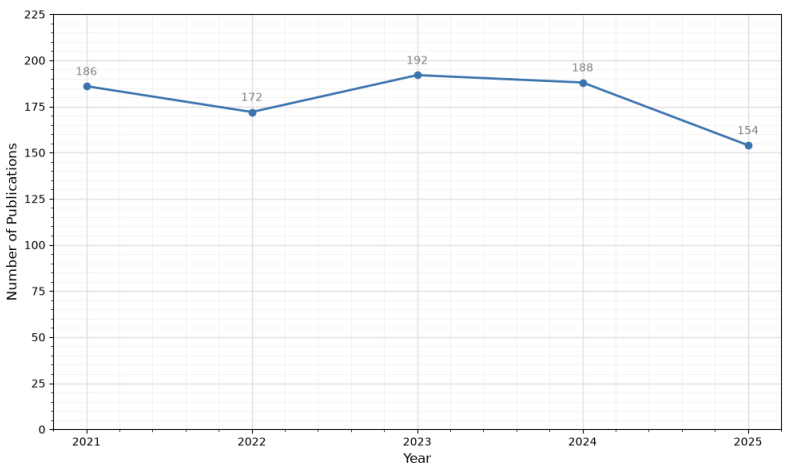


Figure 1. Annual Trend of Literature Publication Volume.

3.2. Analysis of Publishing Institutions

Analysis from CNKI reveals that collaboration among domestic publishing institutions exhibits a pattern of "small clusters, large dispersion"[8]. Institutions such as the University of Chinese Academy of Sciences, China University of

Geosciences (Beijing), the Institute of Geographic Sciences and Natural Resources Research (CAS), and the School of Geography and Tourism at Anhui Normal University have published more articles in this field (Table 1). In terms of collaborative networks, close partnerships exist between the University of Chinese Academy of Sciences and the Northwest Institute of Eco-Environment and Resources (CAS), among others. Judging by the proportion of publications, the University of Chinese Academy of Sciences (39 articles) and the Institute of Geographic Sciences and Natural Resources Research (11 articles) account for the largest share in CNKI, indicating the significant contribution of the Chinese Academy of Sciences to research on ecosystem service value in forests and beyond.

Table 1. Top 6 Institutions by Publication Volume

Rank	Institution	Number of Articles
1	University of Chinese Academy of Sciences	39
2	Institute of Geographic Sciences and Natural Resources Research, CAS	11
3	School of Land Science and Technology, China University of Geosciences (Beijing)	11
4	School of Geography and Tourism, Anhui Normal University	8
5	State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, CAS	6
6	School of Public Administration, China University of Geosciences (Wuhan)	6

3.3. Keyword Co-occurrence Analysis

3.3.1. Interpretation of the Keyword Co-occurrence Network

The keyword co-occurrence network generated by CiteSpace (Figure 2) visually displays complex co-occurrence relationships among keywords. In the network, "land use" unquestionably serves as the core keyword, occupying the central position with the largest node, indicating its dominant role as a primary research focus[9]. Keywords such as "spatiotemporal evolution," "value assessment," "landscape pattern," and "service value" also have relatively large nodes and are closely connected to "land use," constituting important research directions related to ESV.

"Land use" has the highest frequency (117 occurrences). This high frequency is because land use critically influences ecosystem structure and function, making it integral to ESV research. Next are "spatiotemporal evolution," "spatial-temporal change," "value assessment," and "service value." Since ESV research ultimately aims to inform ecosystem service management and decision-making[10], "spatiotemporal evolution" ranks second in frequency. The high frequency of "value assessment" and "service value" indicates that valuation is a research hotspot. In terms of centrality, ten keywords have centrality greater than 0.1. The highest centrality values are for "land use," "value assessment," and "spatiotemporal evolution," all exceeding 0.3. The high centrality of "land use" reflects that land use types cover virtually all ecosystem types, and different land use patterns determine the types and magnitudes of ecosystem service values[11]. Higher keyword centrality indicates

that the term is a hotspot and core of the research field.

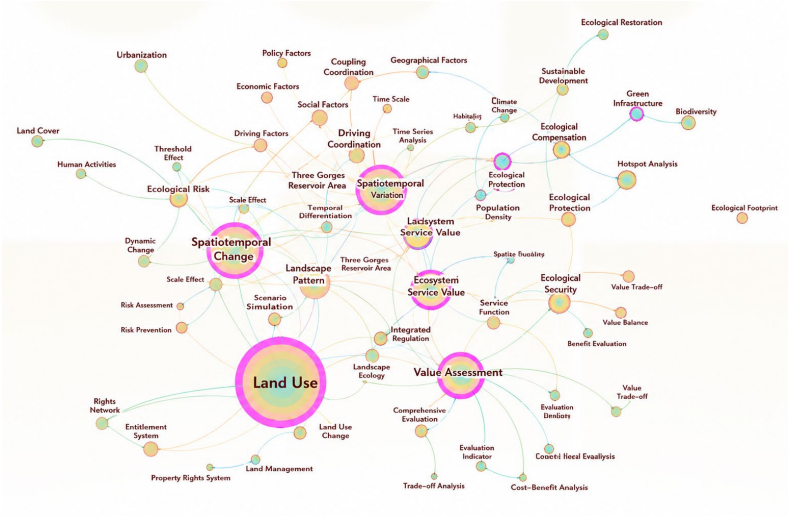


Figure 2. Keyword Co-occurrence Network Map.

3.3.2. Keyword Clustering Analysis

After clustering keywords, several clusters were obtained (Figure 3), each representing a relatively independent research theme[12]. These clusters illustrate the distribution of research hotspots in the ESV field from different angles.

Cluster 0 (spatiotemporal evolution) focuses on the patterns of ESV changes over time and space. Temporally, studies examine dynamic trends in ESV over time, such as how ecological succession and long-term climate change affect ESV. Spatially, research investigates the distribution characteristics of ESV across different geographic regions[13], including differences in service values among various ecosystem types (e.g., forest, grassland, wetland) in different areas (e.g., mountains, plains, coastal zones) and the causes of these differences. In-depth study of ESV spatiotemporal evolution helps understand the formation mechanisms and influencing factors of ESV.

Cluster 2 (land use) focuses on the impact mechanisms of land use change on ESV and corresponding strategies. Against the backdrop of accelerated urbanization and intensified agricultural activities, land use change has become a key factor affecting ESV. Research includes the impact of urban construction land expansion on surrounding ESV; the effects of agricultural land use transformation (e.g., from traditional to modern or ecological agriculture) on ESV. Based on understanding these mechanisms, scholars actively explore strategies, including strengthening land use planning and management, formulating rational land use policies (e.g., strictly controlling construction land expansion, delineating ecological redlines, land consolidation and reclamation)[14], and promoting eco-friendly land use methods such as ecological agriculture and ecotourism, to achieve sustainable land use and

thereby maintain and enhance ESV.

Cluster 4 (value accounting) focuses on the calculation methods and model construction for ESV. Scholars strive to develop more accurate and comprehensive valuation methods, considering multiple ecosystem services (e.g., climate regulation, water conservation, soil retention, biodiversity maintenance) and the interrelationships among different ecosystem services[15]. Various methods, such as the equivalent factor method, emergy analysis, and market valuation, are employed and compared through case studies. By continuously optimizing valuation methods and models, the accuracy and scientific basis of ESV assessment are improved, enabling results to more truthfully reflect the contribution of ecosystems to human society.

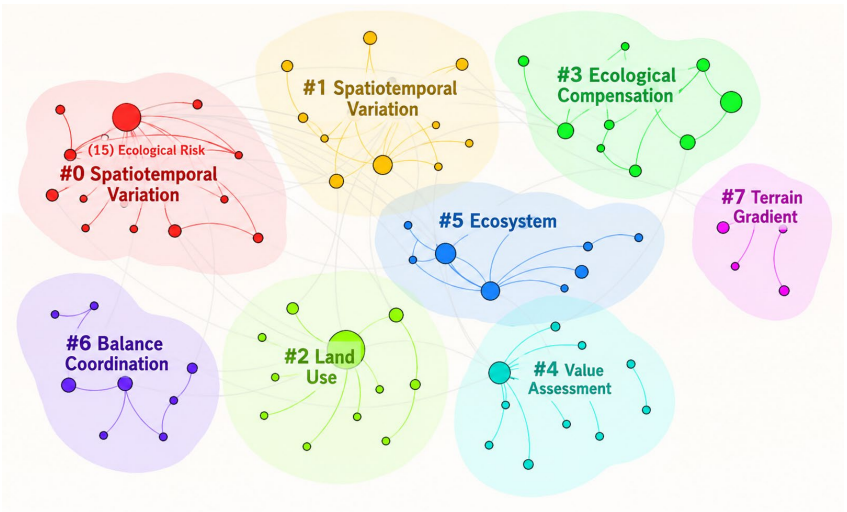


Figure 3. Keyword Clustering Map.

3.4. Keyword Burst Analysis

In 2021, "Three Gorges Reservoir area" exhibited a high burst intensity (Table 2). This is primarily due to the profound and extensive impact of the ongoing operation of the Three Gorges Project on the reservoir area's ecological environment. As a globally significant large-scale water conservancy project, while providing immense benefits in flood control, power generation, and navigation, it has inevitably altered the structure and function of the reservoir's ecosystem. Therefore, scholars focused research on the ESV of the Three Gorges Reservoir area, aiming to comprehensively assess changes in service values (e.g., water supply, climate regulation, soil conservation) following the project's construction and operation[16]. Through extensive field monitoring, model simulations, and data analysis, they explored trends, influencing factors, and potential ecological risks.

In the same year, "ecological security" also showed a burst. This indicates that scholars attached great importance to the close relationship between ESV and

ecological security[17]. Maintaining and enhancing ESV is regarded as a fundamental basis for ensuring regional ecological security. Research focused on how to prevent ecological risks and ensure ecosystem health and stability through scientific monitoring, assessment, and effective management of ESV, thereby safeguarding human ecological security. Scholars examined the interaction mechanisms between ESV and ecological security from perspectives of structural integrity, functional stability, and service sustainability[18], constructing ecological security evaluation indices to inform regional ecological security management.

In 2022, "urbanization" became a burst keyword. This change is closely related to the accelerated process of urbanization in China. Rapid urbanization, including urban expansion and population concentration[19], has significantly impacted ESV, making it a research hotspot. Scholars investigated how activities such as increasing urban construction land and infrastructure development alter the structure and function of urban and peri-urban ecosystems, thereby affecting the supply and demand of ESV. Concurrently, keywords such as "production-living-ecological space" (PLE space) and "ecological land" also burst in 2021[20]. This indicates that under urbanization, scholars began to emphasize research on rational planning and management of ecological space, ensuring the quantity and quality of ecological land to maintain ESV. How to scientifically delineate production, living, and ecological spaces to achieve coordinated development became an important research topic.

From 2023 to 2025, "coupling coordination" exhibited a burst. This keyword reflects the field's deepening exploration of the interrelationship between ecosystems and socio-economic systems[21]. ESV does not exist in isolation; it has complex interactions with regional economic development and social well-being. Scholars seek to reveal the mechanisms of coupling coordination, studying how to achieve positive interactions between ecological protection and economic development, thereby enhancing the contribution of ESV to regional sustainable development. "Ecological restoration" also continuously burst during this period. As environmental problems become increasingly prominent, the importance of ecological restoration in enhancing ESV is widely recognized[22]. Ecological restoration covers areas such as mine rehabilitation, wetland restoration, and forest tending. Research includes innovations in restoration techniques, evaluation of implementation effects, and the role of restoration in recovering and enhancing ESV. Studies on different types of ecological restoration projects provide scientific bases and practical experience for restoring damaged ecosystems and improving ESV.

Table 2. Keyword Burst Detection.

Keyword	Year	Strength	Begin	End	2021—2025
Three Gorges Reservoir area	2021	2.53	2021	2022	
Ecological security	2021	1.57	2021	2022	
Assessment	2021	1.53	2021	2021	
Spatial pattern	2021	1.53	2021	2021	
Transfer matrix	2021	1.53	2021	2021	
Urbanization	2022	1.57	2022	2023	
PLE space	2022	1.5	2022	2022	
Ecological land	2022	1.5	2022	2022	
Xiong'an New Area	2022	1.5	2022	2022	
Terrain gradient	2022	1.5	2022	2022	
Coupling coordination	2023	1.7	2023	2025	
Landscape architecture	2023	1.68	2023	2025	
Ecological restoration	2023	1.53	2023	2023	
Benefit transfer	2023	1.53	2023	2023	
Influencing factors	2024	2.16	2024	2025	
Driving factors	2024	2.14	2024	2025	
Service function	2024	1.87	2024	2025	

3.5. Keyword Timeline Analysis

The keyword timeline map generated by CiteSpace (Figure 4) shows the evolution of different keywords from 2021 to 2025. From an overall structure, the timeline progresses from left to right. Keywords are distributed along different timelines; colors and sizes may represent clusters and frequencies, respectively. Lines between nodes indicate co-occurrence relationships, with thickness reflecting association strength.

Regarding major keywords, "spatiotemporal evolution" persists throughout 2021-2025 and is associated with "ecological risk," "urban agglomeration," and "spatiotemporal differentiation," indicating its core status and integration with

multiple research aspects. "Spatial-temporal change" is linked to "driving factors" and "Yellow River Basin," suggesting research attention to drivers and the Yellow River Basin as an important study area. "Land use" is a key node, connected to "urbanization" and "landscape architecture"[23], highlighting its importance and relationship with urbanization and landscape planning. "Ecological compensation" is associated with "ecological benefit" and "ecological footprint," indicating its connection to benefit assessment and footprint analysis. "Value assessment" links to "wetland" and "value accounting," showing assessment as a key step and wetlands as important objects. "Ecosystem" connects to "scenario simulation," indicating the latter as an important method for studying ecosystems. "Trade-off synergy" links to "hotspot analysis," indicating an emerging research direction and analytical tool.

In terms of research trends, early hotspots likely centered on fundamental research such as "spatiotemporal evolution" and "landscape pattern"[24].In the mid-term, "land use" and "ecological compensation" became more prominent, shifting focus toward land use impacts and compensation mechanisms. Recently, "value assessment" and "trade-off synergy" have become hotspots, emphasizing precise valuation and trade-off/synergy among services.

Potential future directions include interdisciplinary research, as the field involves multiple disciplines; regional and watershed studies, as evidenced by the appearance of the Yellow River Basin; and application of new technologies, such as remote sensing (RS) and GIS, which may be increasingly used for monitoring and analysis.

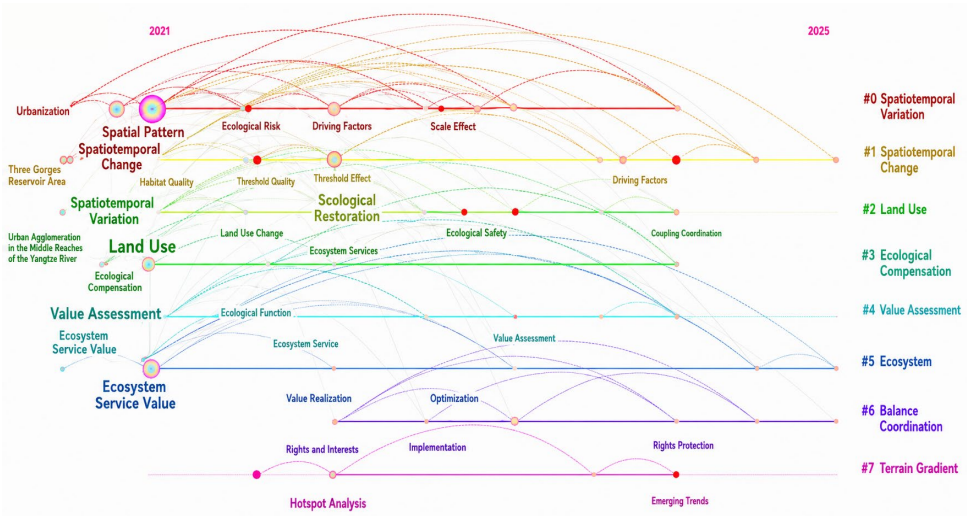


Figure 4. Keyword Timeline Map.

4. Conclusion

Research on ESV has been ongoing for several decades, yielding substantial results in both theoretical and applied research. This paper used the bibliometric tool

CiteSpace to conduct a knowledge graph analysis of ESV-related literature and draws the following conclusions:

1) The number of domestic ESV publications over the past five years has been stable, averaging about 178 articles per year, highlighting the field's prominence under the framework of ecological protection and sustainable development strategies, with sustained research investment and growing capacity. Domestic publishing institutions and authors exhibit a pattern of "small clusters, large dispersion." Some institutions, such as the University of Chinese Academy of Sciences and the Institute of Geographic Sciences and Natural Resources Research (CAS), perform remarkably well, with varying degrees of collaboration; the Chinese Academy of Sciences has made outstanding contributions.
2) Keyword analysis yields rich findings. Co-occurrence analysis shows that "land use" is the core, profoundly influencing ecosystem structure and function, and is closely intertwined with "spatiotemporal evolution," "value assessment," and others, forming key research directions. Notably, "value assessment" receives much attention, as evidenced by its high frequency and centrality. Clustering analysis identifies several thematic areas: "spatiotemporal evolution" focuses on spatiotemporal patterns and influencing factors[25]; "land use" explores the impacts of land use change and coping strategies; "value accounting" concentrates on methods and model construction to improve assessment accuracy and scientific rigor.

   Burst detection reveals distinct burst keywords across years. In 2021, "Three Gorges Reservoir area" became a focus due to the project's impact, and "ecological security" highlighted the link between value and security. In 2022, "urbanization" gained attention due to its accelerated pace, with "PLE space" and "ecological land" emerging. From 2023 to 2025, "coupling coordination" reflects exploration of ecosystem-socioeconomic relationships, and "ecological restoration" underscores its significance for value enhancement. These dynamic changes align with societal development needs. Timeline analysis indicates that "spatiotemporal evolution" remains central and linked to various aspects; "land use" is associated with urbanization, etc.; research hotspots have shifted over time, from early fundamental research, to mid-term emphasis on land use and ecological compensation, to recent focus on value assessment and trade-off synergies.
3) Trade-offs and synergies among ecosystem service functions have become an emerging and important research hotspot. As understanding of ecosystem complexity deepens, scholars gradually recognize that different service functions are not isolated but exhibit mutually constraining and mutually reinforcing relationships. Investigating the mechanisms of trade-offs and synergies under different ecosystem types, regions, and land use scenarios

provides a more scientific and comprehensive theoretical basis and practical guidance for optimizing ecosystem management and sustainable development. This also reflects the trend toward multi-dimensional expansion and refined exploration in the field.

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your journal for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper.

5. Outlook

Deep integration across disciplines will become an inevitable trend. Future research will break down disciplinary boundaries, promoting deep collaboration among ecology, economics, geography, sociology, and other fields. When analyzing the impact of ESV on social welfare, ecology will precisely analyze ecosystem functions, sociology will gain deep insights into human perceptions and needs, and economics will provide quantitative assessment and decision-making models, thereby constructing a comprehensive research framework for scientifically sound and socially relevant ecosystem management strategies.

Regional and watershed-specific research will continue to deepen and expand. Beyond the already studied Yellow River Basin, regions with unique ecological and socio-economic characteristics such as the Yangtze River Basin and Pearl River Basin will become key targets. In-depth exploration of ESV differences, evolution mechanisms, and interactions with regional development will provide targeted bases for delineating ecological redlines, resource development planning, and constructing precise ecological compensation mechanisms, promoting coordinated regional ecological and economic development.

The application of new technologies is imperative. Advanced technologies such as remote sensing (RS), geographic information systems (GIS), big data analytics, and artificial intelligence (AI) will play significant roles in this field. RS can monitor land use and vegetation cover changes in real time; GIS integrates multi-source data and performs spatial analysis to reveal value distribution; big data helps uncover data correlations and patterns; AI excels in complex model construction and scenario simulation, greatly improving research efficiency and precision, and enabling refined and intelligent ecosystem management.

References

[1] Xie G D, Lu C X, Cheng S K. Progress in global ecosystem service value assessment [J]. Resources Science, 2001(6): 5--9.

[2] Burkhard B, Kroll F, Nedkov S, et al. Mapping ecosystem service supply, demand and budgets [J]. Ecological Indicators, 2012, 21: 17--29.

[3] Villamagna A M, Angermeier P L, Bennett E M. Capacity, pressure, demand, and flow: A

conceptual framework for analyzing ecosystem service provision and delivery [J]. Ecological Complexity, 2013, 15(5): 114--121.

[4] Yan Y, Zhu J Y, Wu G, et al. Research progress on ecosystem service demand, supply and consumption [J]. Acta Ecologica Sinica, 2017, 37(8): 2489--2496.

[5] Liu L C, Liu C F, Wang C, et al. Supply-demand matching of ecosystem services in loess hilly region: A case study of Lanzhou [J]. Acta Geographica Sinica, 2019, 74(9): 1921--1937.

[6] Xiao Y, Xie G D, Lu C X, et al. Research progress on spatial flow of ecosystem services based on supply-demand relationships [J]. Acta Ecologica Sinica, 2016, 36(10): 3096--3102.

[7] Liu C F, Wang W T, Liu L C, et al. Supply-demand matching of ecosystem services in county scale of Northwest China: A case study of Gulang County, Gansu Province [J]. Journal of Natural Resources, 2020, 35(9): 2177--2190.

[8] Li F, Sun R H, Yang L R, et al. Assessment of water ecosystem service function in Beijing based on supply-demand balance [J]. Chinese Journal of Applied Ecology, 2010, 21(5): 1146--1152.

[9] Zhao Q J, Wen Z M, Zhang M X. Identifying supply and demand of forest ecosystem services: From the perspective of ecosystem service flow [J]. Forestry Economics, 2014, 36(10): 3--7.

[10] Qin J, Qin C, Zhou H J, et al. Study on cultivated land ecological compensation in Guangxi based on ecological carrying capacity supply-demand and ecological service value [J]. Acta Agriculturae Jiangxi, 2016, 28(3): 77--81.

[11] Zhang P T, Liu S J, Zhou Z, et al. Measurement and spatiotemporal evolution of ecosystem service supply and demand in the Beijing-Tianjin-Hebei region [J]. Acta Ecologica Sinica, 2021, 41(9): 1--14.

[12] Chen Y, Chen C M, Liu Z Y, et al. The methodology function of CiteSpace mapping knowledge domains [J]. Studies in Science of Science, 2015, 33(2): 242--253.

[13] Wang T, Ren Y Y. Research focus and frontier analysis of green infrastructure based on CiteSpace bibliometric analysis [J]. Journal of Beijing Forestry University (Social Sciences), 2020, 19(4): 24--36.

[14] Ma L, Liu H, Peng J, et al. A review of ecosystem services supply and demand [J]. Acta Geographica Sinica, 2017, 72(7): 1277--1289.

[15] Hou P, Wang Q, Shen W M, et al. Progress in integrated ecosystem assessment: Connotation, framework and challenges [J]. Geographical Research, 2015, 34(10): 1809--1823.

[16] Chhetri N B. Water-demand management: Assessing impacts of climate and other changes on water usage in Central Arizona [J]. Journal of Water and Climate Change, 2015, 2(4): 288--312.

[17] Pitcher T J. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future [J]. Ecological Applications, 2001, 11(2): 601--617.

[18] Sandhu H S, Wratten S D, Cullen R. Organic agriculture and ecosystem services [J]. Environmental Science & Policy, 2010, 13(1): 1--7.

[19] Tirado M C, Cohen M J, Aberman N, et al. Addressing the challenges of climate change and biofuel production for food and nutrition security [J]. Food Research International, 2010, 43(7): 1729--1744.

[20] Yan W T, Huang X, Wang Y C. Research progress on supply and demand measurement of flood regulation service of green infrastructure [J]. Acta Ecologica Sinica, 2019, 39(4): 1165--1177.

[21] Wang Y C, Shen J K, Peng Z W, et al. Optimization of green infrastructure ecosystem services for urban growth adaptation [J]. Chinese Landscape Architecture, 2018, 34(10): 45--49.

[22] Wang M M, Wang Y C. Construction of a resilience measurement system for urban park

green space guided by ecological wisdom [J]. Chinese Landscape Architecture, 2020, 36(6): 23--27.

[23] Rong Y J, Yan Y, Wang C X, et al. Construction and optimization of ecological network in Xiong'an New Area based on ecosystem service supply and demand [J]. Acta Ecologica Sinica, 2020, 40(20): 7197--7206.

[24] Li X J, Gao Y, Li S C. A basic supply service model of the Beijing-Tianjin-Hebei urban agglomeration based on the LUCC-ESs matrix [J]. Acta Scientiarum Naturalium Universitatis Pekinensis, 2020, 56(5): 950--958.

[25] Liu Z M. Urban resilience from a socio-ecological perspective [D]. Changchun: Northeast Normal University, 2019.