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Bibliometric Insights into Ecosystem Services Research from 2000 to 2025

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ABSTRACT

Ecosystem services research has experienced significant growth over the past two decades as scholars increasingly seek to understand and quantify the contributions of ecosystems to human well-being and sustainable development. This study aims to map the intellectual structure, thematic evolution, and collaboration patterns of ecosystem services research published between 2000 and 2025 using a bibliometric approach. Bibliographic data were retrieved from the Scopus database and analyzed using VOSviewer to examine publication trends, co-authorship networks, institutional and country collaborations, keyword co-occurrence, and temporal dynamics. The results reveal a rapidly expanding and highly interdisciplinary field, with ecosystem services research strongly anchored in themes related to biodiversity, land use, climate change, and conservation, while progressively integrating urban sustainability, socio-economic dimensions, and advanced computational methods such as machine learning and artificial intelligence. The analysis also highlights the dominant role of a limited number of countries and institutions in shaping global research agendas, alongside increasing international collaboration. By providing a comprehensive synthesis of the field's development and emerging research fronts, this study contributes to a clearer understanding of ecosystem services scholarship and offers insights to support future research, policy formulation, and sustainability-oriented decision-making.

Keywords: *Bibliometric analysis; Biodiversity; Ecosystem services; Land use; Sustainability*

INTRODUCTION

Ecosystem services research has emerged as one of the most influential paradigms in environmental and sustainability science over the past two decades. The concept broadly refers to the benefits that humans derive from ecosystems, encompassing material outputs, life-support functions, cultural values, and ecological processes that sustain social and economic systems [1]. The formalization of this concept was significantly advanced in the early 2000s, particularly through the Millennium Ecosystem Assessment, which provided a widely adopted classification of ecosystem services into provisioning, regulating, cultural, and supporting services. This framework helped bridge ecological science with policy discourse by translating complex ecosystem functions into categories relevant for decision-making and human well-being [2], [3].

Following this foundational milestone, ecosystem services research expanded rapidly in both scale and scope. Scholars from ecology, economics, geography, environmental planning, and public policy increasingly adopted the ecosystem services lens to address pressing global challenges such as biodiversity loss, land-use change, climate change, and resource scarcity [4], [5]. The growing volume of publications reflects heightened awareness that ecosystem degradation directly undermines food security, climate regulation, disaster risk reduction, and cultural identity. Global scientific assessments have consistently emphasized that declines in ecosystem functions pose systemic risks to sustainable development, reinforcing the relevance of ecosystem services as a unifying analytical framework [6], [7].

A major driver of ecosystem services scholarship has been the need to make environmental values visible within economic and governance systems. Traditional development models often

overlook or undervalue ecological contributions, leading to policy decisions that prioritize short-term economic gains at the expense of long-term ecosystem resilience. In response, ecosystem services research has increasingly focused on valuation approaches (both monetary and non-monetary) to articulate the social, economic, and cultural importance of ecosystems. Initiatives such as The Economics of Ecosystems and Biodiversity have played a pivotal role in advancing valuation methodologies and highlighting the integration of ecosystem services into policy instruments, spatial planning, and sustainability accounting [8].

Beyond valuation, the field has progressively incorporated governance, equity, and social dimensions [9]. Recent studies emphasize that ecosystem services are not only biophysical phenomena but also socially constructed outcomes shaped by institutions, power relations, and cultural contexts. This shift has led to growing attention to issues such as benefit distribution, stakeholder participation, Indigenous and local knowledge systems, and trade-offs among ecosystem services across different social groups [10]. As a result, ecosystem services research has evolved from a predominantly ecological and economic focus toward a more interdisciplinary and transdisciplinary domain that aligns closely with sustainability science and socio-ecological systems thinking.

Despite its maturation, ecosystem services research remains conceptually and methodologically diverse. Scholars continue to debate definitions, classification systems, and measurement approaches, particularly regarding the distinction between ecosystem functions, services, and benefits. Differences in spatial scale, data availability, modeling techniques, and valuation assumptions further contribute to fragmentation across studies. While this diversity reflects the richness of the field, it also complicates cumulative knowledge building and limits comparability across regions and policy contexts. Understanding how these conceptual and methodological strands have evolved over time is therefore essential for consolidating the field and identifying future research directions.

Although ecosystem services research has generated a substantial body of literature since 2000, the rapid growth and interdisciplinary nature of the field have resulted in a fragmented knowledge structure. Existing studies are dispersed across journals, disciplines, and thematic orientations, making it difficult to systematically identify dominant research trends, influential contributions, collaboration patterns, and emerging topics. Moreover, the lack of a comprehensive longitudinal synthesis hampers efforts to understand how ecosystem services research has evolved in response to global environmental and policy challenges. Without an integrated bibliometric perspective, scholars and policymakers may struggle to recognize knowledge gaps, redundancies, and future research opportunities within this expansive field. The objective of this study is to provide a comprehensive bibliometric analysis of ecosystem services research published between 2000 and 2025.

METHOD

This study employed a bibliometric research design to systematically map and analyze the intellectual structure and evolution of ecosystem services research from 2000 to 2025. Bibliographic data were retrieved from the Scopus database due to its comprehensive coverage of peer-reviewed journals and its suitability for large-scale scientometric analysis. The search strategy used relevant keywords related to “ecosystem services” within article titles, abstracts, and keywords, and the dataset was refined by document type and publication year to ensure relevance and consistency. The retrieved records were exported in compatible formats and analyzed using VOSviewer software to construct and visualize bibliometric networks. The analysis included co-authorship analysis to examine collaboration patterns among authors and countries, co-occurrence analysis of keywords to identify major research themes and emerging topics, and citation and co-citation analyses to determine influential publications and knowledge clusters. Network visualization, overlay

visualization, and density visualization techniques were applied to capture temporal dynamics, thematic prominence, and research intensity within the field.

RESULT AND DISCUSSION

Co-Authorship Analysis

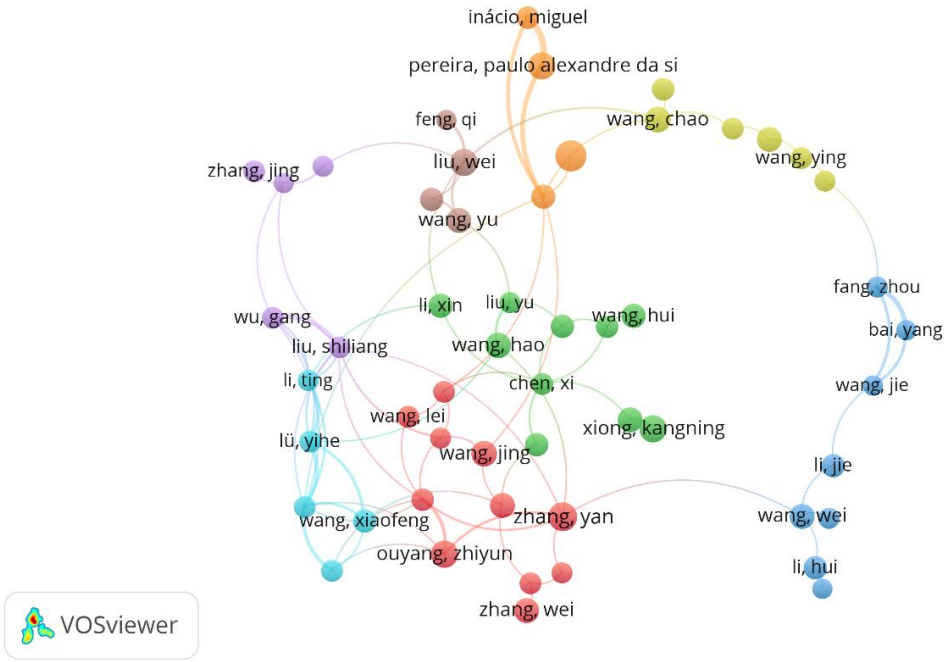

Figure 1. Author Visualization
Source: Data Analysis

Figure 1 reveals a moderately fragmented but interconnected structure within ecosystem services research, characterized by several distinct author clusters that reflect collaborative communities. Prominent clusters (indicated by different colors) suggest groups of researchers who frequently collaborate internally, often around shared thematic interests or regional research contexts. Central authors such as Wang Jing, Zhang Yan, Wang Hao, Liu Yu, and Chen Xi occupy strategically important positions, acting as bridges that connect multiple clusters and facilitate knowledge diffusion across the network. The density of links within clusters indicates strong intra-group collaboration, while the presence of thinner, cross-cluster links highlights emerging or less frequent inter-group cooperation. Notably, the dominance of authors with Chinese affiliations points to the significant contribution and leadership of Chinese scholars in ecosystem services research over the analyzed period.

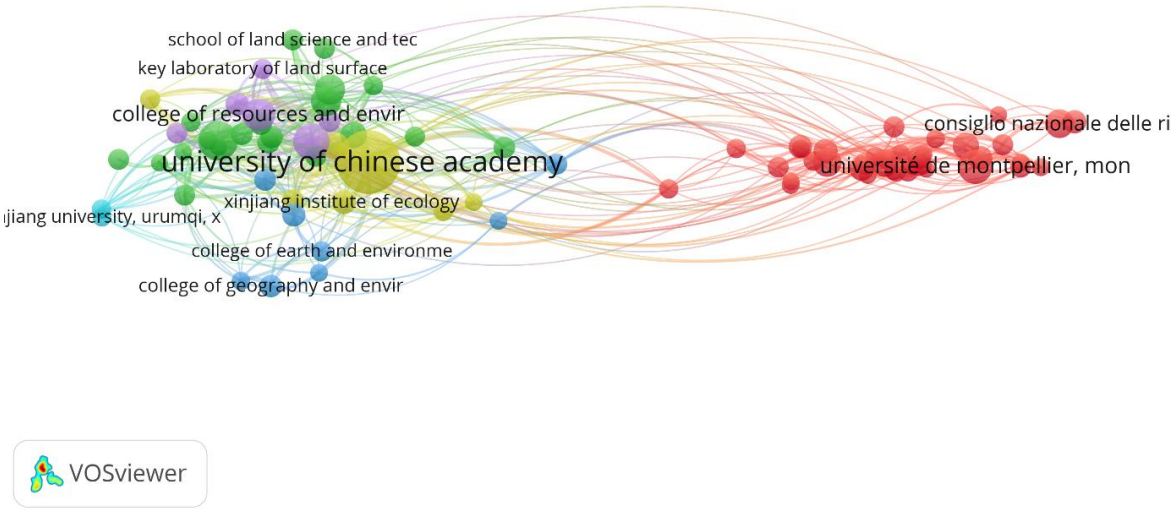

Figure 2. Affiliation Visualization
Source: Data Analysis

Figure 2 illustrates a highly centralized yet internationally connected structure within ecosystem services research. The University of Chinese Academy of Sciences emerges as the dominant hub, strongly linked with multiple domestic institutions such as specialized laboratories, colleges of geography, land science, ecology, and environmental studies, indicating intensive intra-national collaboration and a well-integrated research ecosystem in China. This dense clustering reflects China's strong institutional capacity and coordinated research agenda in ecosystem services. In contrast, European institutions, most notably Université de Montpellier and the Conseil National de la Recherche form a distinct but tightly connected cluster that maintains robust collaborative ties with the Chinese core. The presence of numerous cross-cluster links between these major institutional hubs suggests active international collaboration, particularly between Chinese and European research centers.

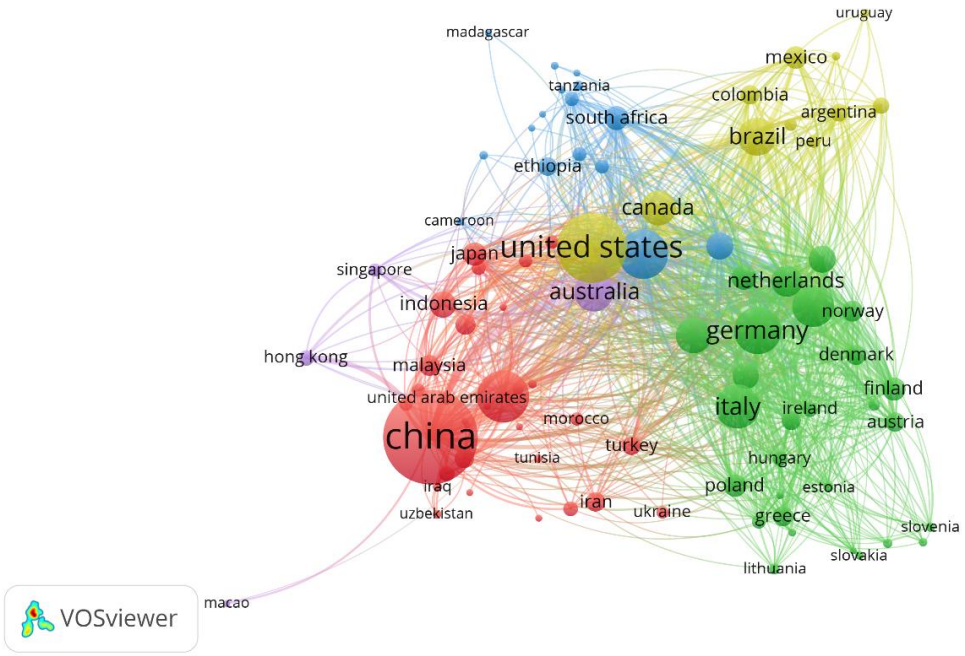

Figure 3. Country Visualization
Source: Data Analysis

Figure 3 demonstrates a highly interconnected global structure of ecosystem services research, with several dominant hubs and regionally clustered partnerships. China and the United States emerge as the most influential contributors, occupying central positions with extensive collaborative links that connect multiple regional clusters. China's prominence reflects its rapid expansion in ecosystem services research and strong engagement with both Asian and European partners, while the United States acts as a key bridging country linking research communities across Europe, Asia, and the Global South. European countries (particularly Germany, the Netherlands, Italy, and the Nordic nations) form a dense and cohesive cluster, indicating strong intra-European collaboration and methodological integration. Meanwhile, countries from Latin America (e.g., Brazil, Mexico, Colombia) and Africa (e.g., South Africa, Ethiopia, Tanzania) are increasingly integrated into the global network, often through partnerships with major research hubs.

Citation Analysis

Table 1. Most Cited Article

Citations	Author and Year	Title
337	[11]	Impacts of climate change on the fate of contaminants through extreme weather events
273	[12]	Generative AI in healthcare: an implementation science informed translational path on application, integration and governance
232	[13]	Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering
209	[14]	Challenges and strategies for wide-scale artificial intelligence (AI) deployment in healthcare practices: A perspective for healthcare organizations
186	[15]	A global analysis of the determinants of maternal health and transitions in maternal mortality

Citations	Author and Year	Title
157	[16]	Synergistic industrial agglomeration, new quality productive forces and high-quality development of the manufacturing industry
152	[17]	Water Quality, Air Pollution, and Climate Change: Investigating the Environmental Impacts of Industrialization and Urbanization
149	[18]	Impacts of Climate Change on Marine Foundation Species
148	[19]	Spatiotemporal heterogeneity of ecosystem service interactions and their drivers at different spatial scales in the Yellow River Basin
147	[20]	Global trends and scenarios for terrestrial biodiversity and ecosystem services from 1900 to 2050

Source: Scopus, 2025

Keyword Co-Occurrence Analysis

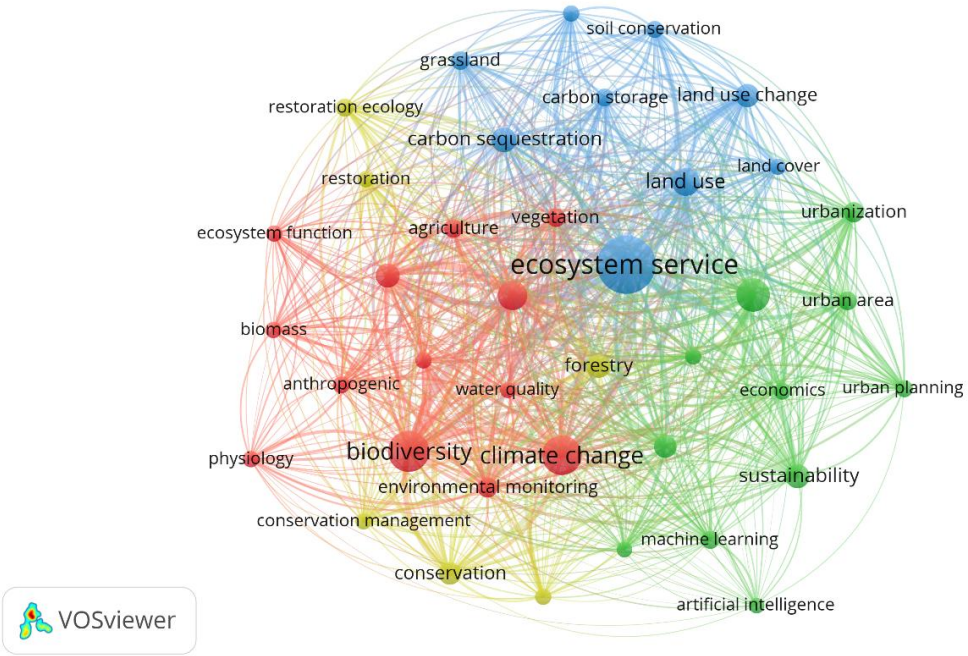

Figure 4. Network Visualization
Source: Data Analysis

Figure 4 reveals "ecosystem service" as the central and most dominant concept, functioning as an integrative hub that connects multiple thematic clusters within the field. Its central position and dense linkages indicate that ecosystem services research is inherently interdisciplinary, drawing simultaneously on ecological science, land-use studies, climate research, conservation, and socio-economic analysis. The tight interconnections among keywords suggest that studies rarely examine ecosystem services in isolation; instead, they emphasize interactions, trade-offs, and synergies across environmental and human systems. One prominent cluster centers on land-use dynamics and biophysical regulation, highlighted by keywords such as land use, land cover, soil conservation, carbon storage, carbon sequestration, and grassland. This cluster reflects a strong emphasis on understanding how changes in land management and land-cover patterns affect regulating services, particularly carbon-related functions and soil protection. The density of connections within this

cluster indicates that land-use change remains a foundational analytical lens in ecosystem services research, closely linked to climate mitigation and ecosystem resilience agendas.

A second major cluster focuses on biodiversity, climate change, and conservation, featuring terms such as biodiversity, climate change, conservation, environmental monitoring, and conservation management. This cluster highlights the role of ecosystem services as a bridge between biodiversity conservation and global environmental change research. The strong co-occurrence of these terms suggests that ecosystem services are increasingly used to frame conservation outcomes in ways that align ecological integrity with human benefits, reinforcing their relevance for policy-oriented sustainability discourse. The urban and socio-economic cluster—including keywords such as urban area, urbanization, urban planning, economics, and sustainability—indicates the growing application of ecosystem services concepts in urban contexts. This reflects a shift from traditional rural and natural ecosystem studies toward urban ecosystems, where services such as climate regulation, water purification, and cultural benefits are critical for human well-being. The close association between urban terms and sustainability underscores the use of ecosystem services as a planning and decision-support tool for sustainable urban development.

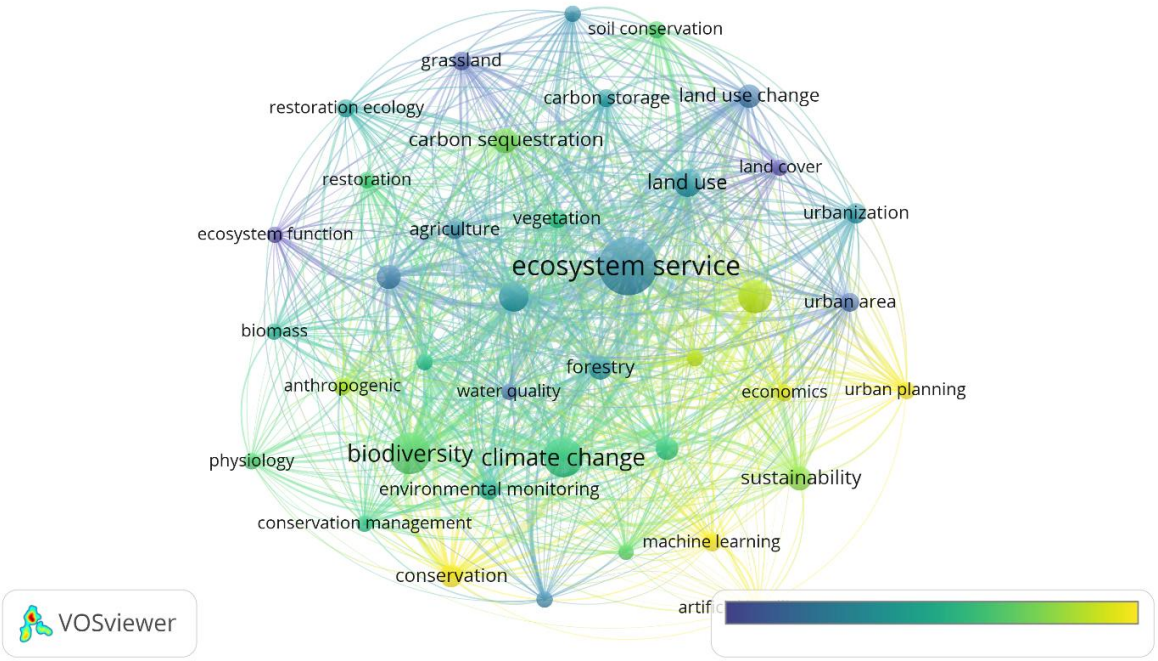

Figure 5. Overlay Visualization
Source: Data Analysis

Figure 5 highlights the temporal evolution of ecosystem services research by showing how research themes have shifted over time. Core concepts such as ecosystem service, biodiversity, land use, and climate change appear in cooler colors, indicating their earlier emergence and long-standing dominance in the literature. These foundational themes form the conceptual backbone of the field, reflecting early research efforts that focused on biophysical processes, land-cover change, and the ecological basis of ecosystem services. In contrast, keywords displayed in warmer colors (such as urban area, urban planning, economics, and sustainability) represent more recent research emphases. Their prominence suggests a growing interest in applying ecosystem services frameworks to socio-economic systems, particularly in urban contexts where environmental pressures and human demands intersect. This shift reflects an increasing policy relevance of ecosystem services research, as scholars seek to inform sustainable development strategies, urban resilience planning, and integrated land-use governance. Notably, the appearance of terms such as machine learning and artificial intelligence among the most recent keywords signals an emerging

methodological frontier in the field. The integration of advanced computational approaches with ecosystem services assessment indicates a transition toward data-intensive, predictive, and spatially explicit analyses.

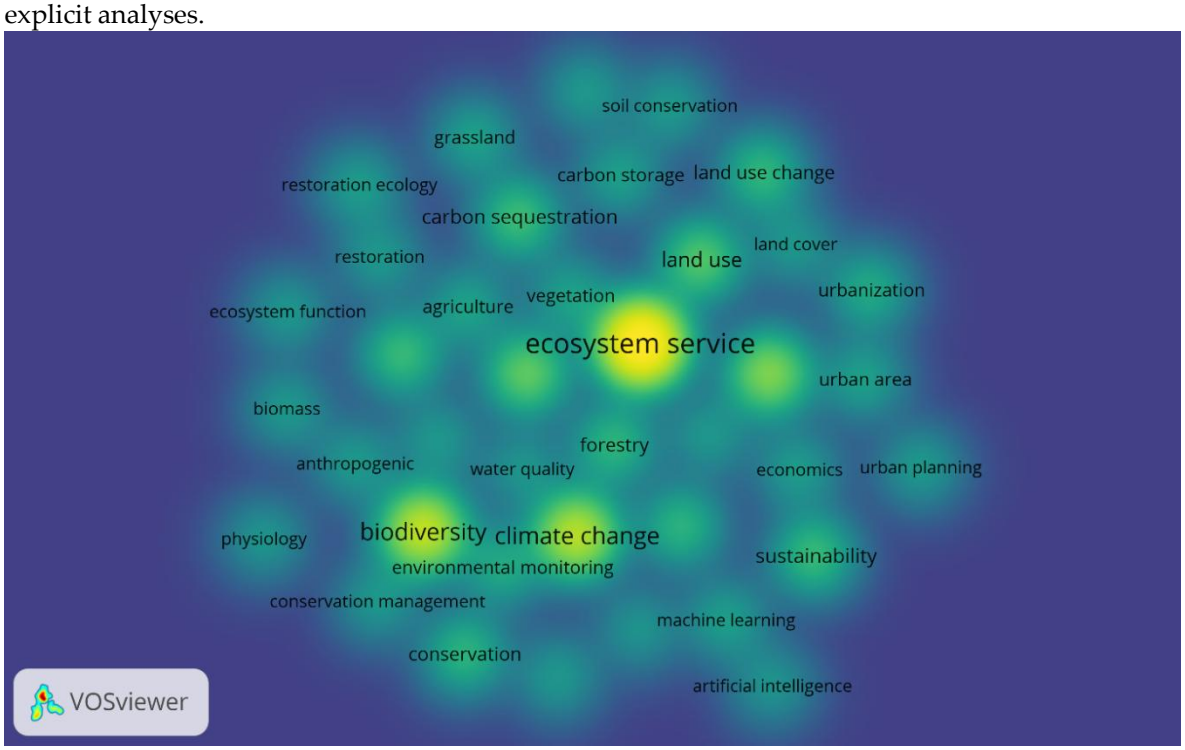

Figure 6. Density Visualization
Source: Data Analysis

Figure 6 highlights the core concentration areas of ecosystem services research by showing where keywords appear most frequently and are most strongly interconnected. The brightest and most intense area is centered on ecosystem service, confirming its role as the primary conceptual anchor of the field. Surrounding this core are high-density terms such as biodiversity, climate change, land use, land cover, and carbon sequestration, indicating that these themes have consistently dominated the literature and form the foundational knowledge base of ecosystem services scholarship. The close proximity of these terms reflects sustained scholarly attention to the ecological processes and environmental changes that underpin ecosystem service provision. In contrast, keywords displayed in lower-density areas such as urban planning, economics, machine learning, and artificial intelligence represent emerging or more specialized research directions that, while less frequent, are gaining visibility within the field. Their spatial positioning away from the central core suggests that these topics are still developing and have not yet reached the same level of integration as traditional ecological themes. Nevertheless, their presence in the density map indicates a gradual expansion of ecosystem services research toward interdisciplinary, technology-driven, and policy-oriented approaches, signaling future opportunities for methodological innovation and broader societal application.

Discussion

Practical Implication

The bibliometric findings of this study offer several important practical implications for policymakers, planners, and environmental managers. First, the dominance of themes related to land use, biodiversity, climate change, and carbon-related services indicates that ecosystem services research has matured into a robust evidence base for informing land-use planning, climate mitigation strategies, and conservation policy. Decision-makers can leverage this consolidated knowledge to design integrated policies that balance ecological protection with development objectives, particularly in sectors such as agriculture, forestry, and urban expansion. The increasing

linkage between ecosystem services and urban planning further suggests that the framework is becoming a valuable tool for guiding sustainable urban development, green infrastructure planning, and nature-based solutions in rapidly urbanizing regions.

Theoretical Contribution

From a theoretical perspective, this study contributes to ecosystem services scholarship by providing a comprehensive, longitudinal mapping of the field's intellectual structure from 2000 to 2025. By integrating co-authorship, institutional collaboration, country networks, and keyword co-occurrence analyses, the study clarifies how ecosystem services research has evolved from a predominantly ecological and valuation-oriented framework toward a more integrated socio-ecological and sustainability-oriented paradigm. The identification of distinct yet interconnected thematic clusters—such as land-use regulation, biodiversity conservation, urban sustainability, and computational methods—demonstrates how the ecosystem services concept functions as a boundary object that bridges multiple disciplines and theoretical traditions.

Limitation of this Study

Despite its contributions, this study has several limitations that should be acknowledged. First, the analysis is based solely on the Scopus database, which, while comprehensive, may exclude relevant publications indexed in other databases or regional journals, particularly those published in non-English languages. As a result, some locally significant research contributions may be underrepresented. Second, bibliometric analysis relies on metadata such as titles, abstracts, keywords, and citations, which may not fully capture the substantive depth or contextual nuances of individual studies. Consequently, the findings should be interpreted as indicative of structural patterns rather than as a substitute for in-depth systematic or qualitative reviews.

CONCLUSION

This bibliometric study provides a comprehensive overview of the evolution, structure, and emerging directions of ecosystem services research from 2000 to 2025. The findings reveal a rapidly expanding and increasingly interconnected field, anchored by core ecological themes such as biodiversity, land use, and climate change, while progressively incorporating socio-economic, urban, and technological perspectives. The analysis highlights the central role of a limited number of countries and institutions in shaping global research collaboration, alongside growing participation from diverse regions. Moreover, the emergence of data-driven approaches, including machine learning and artificial intelligence, signals a methodological shift toward more advanced and integrative assessments. This study contributes to a clearer understanding of how ecosystem services scholarship has matured into an interdisciplinary domain with strong policy relevance, while also identifying future research opportunities to enhance theoretical integration, methodological innovation, and global knowledge exchange.

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