ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 73 11 Number 2, 2025

BIBLIOMETRIC ANALYSIS OF FOREST RESOURCE ASSET MANAGEMENT LITERATURE FROM 2000 TO 2023

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Link to this article: https://doi.org/10.11118/actaun.2025.011
Received: 20. 8. 2024, Accepted: 12. 3. 2025

Abstract

Forest resource asset management is a crucial area of research in sustainable development and ecological economics. This study systematically analyzes the development of research in this field using bibliometric and text-mining methods, based on data from the Web of Science Core Collection (2000–2023). Key aspects examined include research trends, core countries and institutions, journal distribution, research hotspots, and future directions. The findings reveal the following:

1) Research on forest resource asset management has grown rapidly, though the average citation count has declined.
2) Developed countries dominate this field, with the United States, Australia, and China being the leading contributors; however, China's international academic influence requires enhancement.
3) Highly influential journals in this field include *Ecological Economics*, *Forest Ecology and Management*, and *Forest Policy and Economics*, while open-access journal publications have significantly increased in recent years.
4) Research hotspots focus on sustainable forest management, ecosystem services, valuation, carbon sink markets, and policy decision-making, reflecting an increasing integration of natural and social sciences.
5) Future research should emphasize data-driven intelligent analysis, interdisciplinary integration, multi-scale governance systems, and policy optimization to enhance the scientific and sustainable management of forest resource assets. This study contributes to the construction of a knowledge framework for this field and provides insights for policy formulation and practical applications.

Keywords: forest resource assets, asset management, sustainable management, bibliometric, research hotspots

INTRODUCTION

Forests are a fundamental component of terrestrial ecosystems and serve as the essential infrastructure for human survival and development (Wang and Wang, 2011). Forest resources play a critical role in regulating climate change and preserving biodiversity (Gu *et al.*, 2023). Given their ecological significance and biological benefits, the management

of forest resource assets has emerged as a key strategic priority (Xu *et al*., 2022), with its core objective being the transformation of forest resources into economic assets. This involves valuing forest resources through market mechanisms, managing and developing them as assets, and reinvesting the generated revenue into subsequent conservation and development initiatives (Ameha *et al*., 2014). This approach not only compensates for the physical depletion of forest resources in monetary terms but also facilitates their preservation and appreciation in value. However, for a long time, the ownership attributes of forest resources have been poorly understood, leading to unregulated and excessive exploitation, which has caused severe degradation. The absence of economic compensation mechanisms has further hindered reforestation efforts, resulting in a significant loss of forest resources and a decline in their overall quality (Sweya *et al*., 2022).

Maclennan (1963) was the first to introduce the concept of "natural assets." Subsequently, scholars began advocating ecosystem management as the preferred modern approach to managing natural assets and ecosystems (Lackey, 1998). Societal interest also grew in the concept of national forest management, encompassing biodiversity, ecological balance, timber production, social value, and the aesthetic and structural integrity of natural landscapes (Kessler *et al*., 1992). Since the introduction of the concept of "sustainable forest management," forest resource asset management has advanced to a new level. Wassenaer *et al*. (2000) highlighted that urban forests, as valuable assets, have been largely overlooked. They emphasized the need for an ecosystem-based approach to urban forest management while recognizing the indispensable role of human interaction within these ecosystems. Fujisawa (2004) proposed the separation of forest management from ownership at the compartmental level and the establishment of a consolidated management system to enable forest owners to invest in their lands. Thanh and Sikor (2006) examined the effects of decentralization–specifically, the transfer of forest management rights from the state to local actors–on property rights in two villages in Dak Lak Province, Vietnam. Pérez-Cirera and Lovett (2006) developed a recursive model linking power imbalances with the collective benefits and costs associated with local common-property forest governance. Knoke *et al*. (2011) conducted a comparative study on the impact of deforestation on carbon sequestration under different land-use practices, demonstrating that effective management strategies and risk mitigation measures could reduce forest loss. Xu *et al*. (2022) proposed that forest rights mortgages serve as a viable forest resource asset management strategy, converting undeveloped resources owned by forest farmers into liquid assets while alleviating financial constraints, fostering financial innovation, and enhancing forest conservation. Today, forest resource asset management has emerged as a crucial aspect of natural resource management, gaining significant attention in academic research, as evidenced by the growing body of literature in this field.

Despite this, comprehensive reviews of forest resource asset management remain relatively scarce at both domestic and international levels. Existing literature reviews primarily rely on qualitative summaries and lack systematic bibliometric analyses (Fujisawa, 2004; Miller *et al*., 2021; Yousefpour *et al*., 2012). Employing bibliometric techniques and content mining can provide a structured understanding of research developments, key themes, and emerging trends in forest resource asset management, thereby offering valuable insights for long-term research and policy formulation in this domain.

This study applies bibliometric and text-mining methodologies to explore several key issues in forest resource asset management research:

1) What are the trends in publication volume?
2) Which countries and institutions are the main contributors, and what is their academic impact?
3) Which journals and papers exert the greatest influence?
4) What are the primary research hotspots?

By addressing these questions, this study aims to assess the academic landscape of forest resource asset management, provide references for future research, and contribute to the development of a structured natural resource asset management framework.

MATERIALS AND METHODS

Data Collection

All data were obtained from the Web of Science Core Collection, which is widely regarded as one of the world's leading scientific research databases. A thematic retrieval strategy was employed, utilizing field tags, Boolean operators, parentheses, and query sets to refine the search results. The index categories were restricted to the Science Citation Index Expanded (SCI-EXPANDED) and the Social Sciences Citation Index (SSCI). The search query used was TS=("forest resource asset" OR "forest resource assets" OR "forest asset" OR "forest assets" OR "forestry asset" OR "forestry assets") AND TS=("management" OR "governance"). The document types were limited to articles, conference proceedings, and review papers, with the language set to English. The search period covered January 1, 2000, to December 31, 2023. The search was conducted on March 19, 2024.

To ensure the rigor of the data, the following exclusion criteria were applied in this study:

1) non-peer-reviewed papers, such as conference abstracts, editorials, and review articles;

2) literature unrelated to forest resource asset management, determined through title and abstract screening;
3) duplicate records of papers, removed based on DOI; and
4) literature with incomplete or inaccessible data.

After manual screening, a total of 768 high-quality papers that met the search criteria were retained as the foundation for this study.

This study selected Web of Science as the primary data source due to its extensive application and high-quality data coverage in forest resource management and ecological economics research. Additionally, Web of Science provides standardized bibliometric data, such as citation frequency and impact factor, enhancing data comparability and analytical reliability. In contrast, Google Scholar was deemed unsuitable for this study due to its heterogeneous data sources and high prevalence of duplicate records. While Scopus offers broad coverage, Web of Science includes a more comprehensive selection of high-impact journals. Therefore, Web of Science was prioritized as the core database to ensure data accuracy and authority.

Research Methods

Bibliometric analysis is a widely applied approach for examining research trends, hotspots, and developmental trajectories across various academic fields. This study employed software tools such as Excel, CiteSpace, and HistCite to analyze eight key bibliometric indicators:

1) publication volume,
2) trends in publication growth,
3) country-level research influence and collaboration,
4) disciplinary distribution across different countries,
5) institutional influence and collaboration,
6) impact of major journals and papers,
7) identification of core publications, and
8) research hotspots.

By systematically analyzing these indicators, this study constructed a comprehensive knowledge map of forest resource asset management research (Fig. 1).

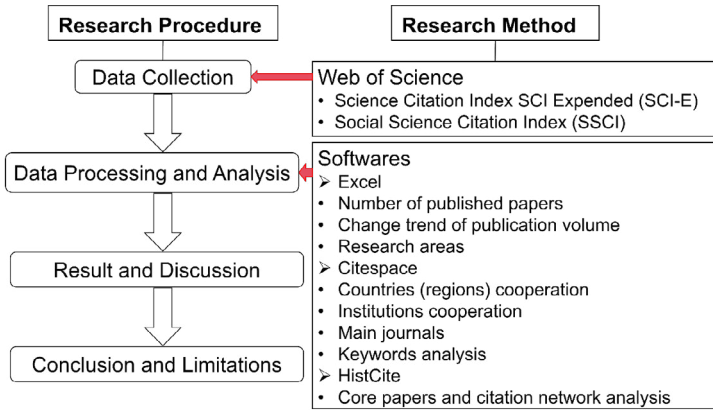
This study selects CiteSpace as the core analysis tool due to its advantages in knowledge mapping, co-word analysis, emergent term identification, and tracking the evolution of research hotspots. Compared with VOSviewer, CiteSpace excels in temporal evolution analysis, emergent term detection, and knowledge structure exploration, whereas VOSviewer is more suitable for constructing collaboration networks and clustering visualization. Given that the primary objective of this study is to examine the evolution of research hotspots and the academic development trajectory of forest resource asset management, CiteSpace is better suited to meet these research needs. Additionally, HistCite provides valuable support in local citation network analysis, allowing this study to systematically identify high-impact papers and their citation relationships.

RESULTS

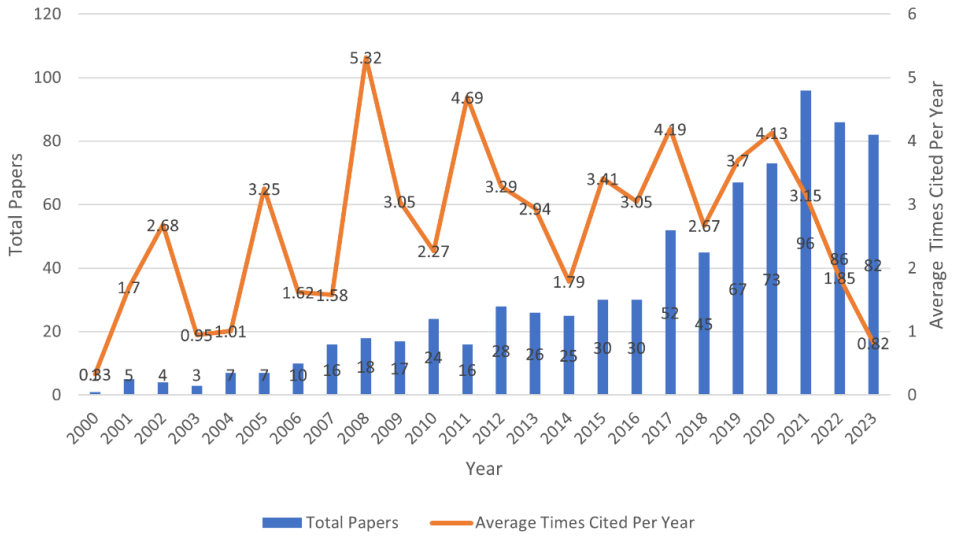
Analysis of Changes in Publication Volume

The analysis of publication trends reveals that research on forest resource asset management experienced rapid growth from 2000 to 2023, reaching its peak in 2021. After 2021, the annual number of publications began to decline slightly (Fig. 2). According to Web of Science search results, discussions on forest resource management can be traced back to the article “Evaluating Forest Management Investments: The Capital-Asset Pricing Model and the Income Growth Model” by Wagner and Rideout (1991). However, it was not until 1994 that Gowen *et al.* (1994) introduced the concept of managing forest resources as assets. Since then, scholarly literature on forest resource asset management has gradually expanded.

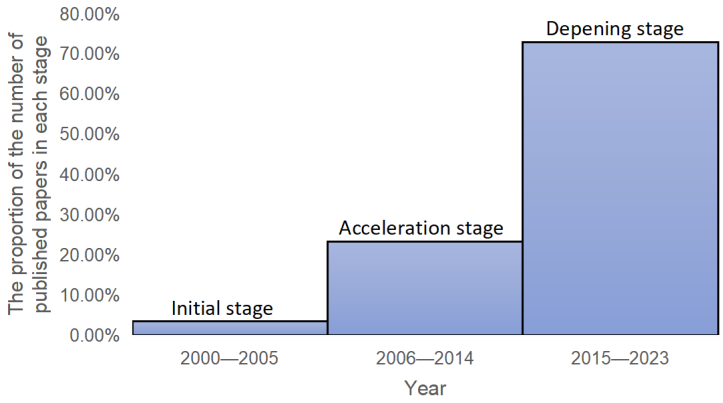
Prior to 2006, research on forest resource asset management was relatively limited. However, following this period, the volume of publications in this field increased significantly. This growth can be attributed to the rising global concern over climate change. In particular, the adoption of the Kyoto



1: *Workflow of The Study*



2: *Total Number of Papers and Citation Counts Per Year from 2000 to 2023*



3: *Stages of Development in Forest Resource Asset Management Research*

Protocol in 2005 heightened the recognition of sustainable forest management as a crucial strategy for carbon emissions reduction and climate change mitigation. Developed countries, in particular, have focused on achieving quantitative carbon reduction targets (Cihlar, 2007). The escalating threats posed by global climate change to the integrity of forest ecosystems and their associated services (Park *et al.*, 2014) further emphasized the need for effective forest resource asset management.

Following the enactment of the Paris Agreement in 2015, countries began integrating and optimizing forest resource asset management strategies. The development of sustainable and adaptive management plans has since become a key priority. Various stakeholders, including governments, research institutions, and industry players, have actively contributed to this process (Beguin *et al.*, 2016), generating widespread interest in forest resource assets and driving rapid advancements in related research.

By examining the trends in publication volume from 2000 to 2023, the evolution of research on forest resource asset management can be categorized into three distinct phases: the initial stage, the acceleration stage, and the deepening stage (Fig. 3).

In the initial stage (2000–2005), research on forest resource asset management remained relatively limited, with only 27 publications, accounting for 3.52% of the total, averaging 4.5 papers per year. Research during this period was largely fragmented and lacked a systematic framework. Studies primarily focused on forestry, environmental science, and economics, addressing key topics such as forest planning systems (Fujisawa, 2004), public property resource management (Adhikari, 2005), and conflicts over forest tenure rights (Mvondo and Oyono, 2004).

During the acceleration stage (2006–2014), research in this field expanded significantly, with 180 articles published, accounting for 23.44% of the total, averaging 20 publications per year. This stage marked the rapid development of forest resource asset management research, with the field broadening to include disciplines such

as environmental studies, ecology, economics, biodiversity conservation, regional urban planning, and geography. Key research topics during this period included innovative forestry accounting, participatory forest management (Ali *et al*., 2007a, 2007b; Ameha *et al*., 2014; Shahbaz *et al*., 2012), the relationship between forest co-management and poverty alleviation (Debnath and Dasgupta, 2006), and the sustainable management capacity of small and medium-sized private forest enterprises (Cossio *et al*., 2011).

In the deepening stage (2015–2023), research on forest resource asset management continued to expand, with publication volume surging to 561 articles, representing 73.05% of the total, averaging 62.3 papers per year. This stage saw an increasing focus on environmental science, green sustainable science and technology, interdisciplinary research, urban studies, and remote sensing technology, demonstrating both the broadening and deepening of the field. Driven by global climate change, research in this phase focused on assessing the value of natural assets (Hashida and Fenichel, 2022), identifying mechanisms for forest resource asset management (Mbuvi *et al*., 2015), evaluating the effectiveness of management policies (Atmiş and Günşen, 2018), enhancing forest carbon sequestration through improved management practices (Zhang *et al*., 2020), and addressing challenges related to the adaptability and sustainability of forest resource asset management (Rammer and Seidl, 2015; Torres-Rojo *et al*., 2016; Yousefpour *et al*., 2017). These studies aim to strengthen the resilience of forest ecosystems in response to environmental challenges.

Examining the evolution of research across these three stages reveals that forest resource asset management has gradually developed into an interdisciplinary research field, integrating economics, ecology, sociology, and other disciplines. The field has expanded its research scope beyond traditional ecological issues to encompass broader spatial scales, including geography, environmental studies, and regional urban planning. Additionally, the integration of emerging disciplines such as green sustainable science and remote sensing technology signifies a shift from theoretical exploration to more practical and dynamic management strategies.

The objectives of forest resource asset management have evolved from an initial focus on economic benefits to enhancing forest adaptability to climate change and, ultimately, achieving long-term sustainability. As a result, the field has adopted a more comprehensive and holistic approach. Compared to early research, contemporary studies benefit from a broader perspective and significantly improved accuracy in data acquisition. Given the continued growth in publication volume, forest resource asset management is expected to remain a key research area in the future.

However, despite the increase in research output, the average citation count per paper has shown a gradual decline (Fig. 2). Considering that publication date influences citation counts, the annual average citation rate was used to minimize this bias. This metric is calculated by dividing the total citations of a paper by the number of years since its publication. For example, if the average number of citations per paper in 2015 is 30.7 and the number of years since publication is nine, the annual average citation count would be 3.41. Since 2020, the annual average citation count per paper has steadily declined, falling below 1 in 2023. This trend has raised concerns among researchers. As the number of publications on forest resource asset management continues to rise, ensuring the overall quality and impact of research in this field should be a key priority moving forward.

Analysis of Research Strengths

Analysis of Major Research Countries

Analysis of Publication Trends

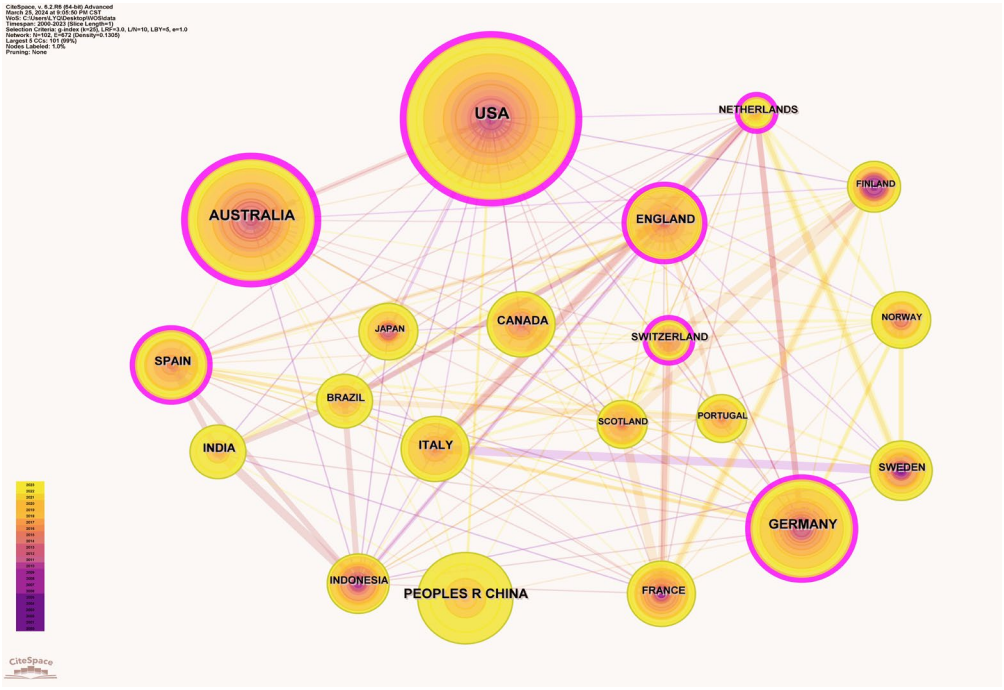
According to the search results, a total of 105 countries and regions have contributed to research on forest resource asset management. This study conducted a statistical analysis of the top 20 countries (regions) based on the total number of published papers (Tab. I). The results indicate that research in developed countries is significantly more advanced compared to that in developing nations. Among these, the United States leads with 180 publications, accounting for 23.44% of the total literature, thereby holding a dominant position in this field. Australia follows with 97 publications, while China ranks third with 63 publications. Germany is fourth with 57 papers. The remaining countries have fewer than 50 publications each.

These findings suggest that the United States, Australia, and China are the primary contributors to forest resource asset management research. Notably, China leads other developing countries in publication volume, which can be attributed to its recent policy initiatives aimed at reforming the natural resource asset management system, promoting sustainable resource utilization, and advancing ecological civilization construction.

Considering both publication volume and average citations per paper (Tab. I), it is evident that the United States, Australia, England, and Italy exert relatively higher overall influence in the field of forest resource asset management. However, a high publication volume does not necessarily equate to high academic impact. For instance, although China has a relatively large number of publications, its average citations per paper remain low, indicating comparatively weaker influence. This discrepancy may be attributed to the relatively recent emergence of forest resource asset management as a research focus in China.

I: *Publication Statistics of the Top 20 Countries (Regions) by Total Number of Papers*

No.	Country	Centrality	Number of published papers	The proportion of the number of publications	Total citation frequency	Average citation frequency per article
1	USA	0.33	180	23.44%	4568	25.38
2	Australia	0.22	97	12.63%	2770	28.56
3	China	0.02	63	8.20%	641	10.17
4	Germany	0.17	57	7.42%	1414	24.81
5	England	0.14	48	6.25%	2572	53.58
6	Canada	0.03	47	6.12%	1026	21.83
7	Spain	0.12	44	5.73%	870	19.77
8	India	0.02	40	5.21%	916	22.90
9	Italy	0.06	38	4.95%	1523	40.08
10	Brazil	0.02	31	4.04%	868	28.00
11	Netherlands	0.20	26	3.39%	801	30.81
12	Switzerland	0.14	26	3.39%	1178	45.31
13	France	0.07	24	3.13%	888	37.00
14	Indonesia	0.04	21	2.73%	907	43.19
15	Sweden	0.05	21	2.73%	437	20.81
16	Japan	0.02	20	2.60%	309	15.45
17	Norway	0.03	20	2.60%	372	18.60
18	Finland	0.04	18	2.34%	443	24.61
19	Portugal	0.00	17	2.21%	289	17.00
20	Scotland	0.05	17	2.21%	552	32.47



4: *Cooperation Network Among the Top 20 Countries by Total Number of Papers*

Analysis of International Cooperation

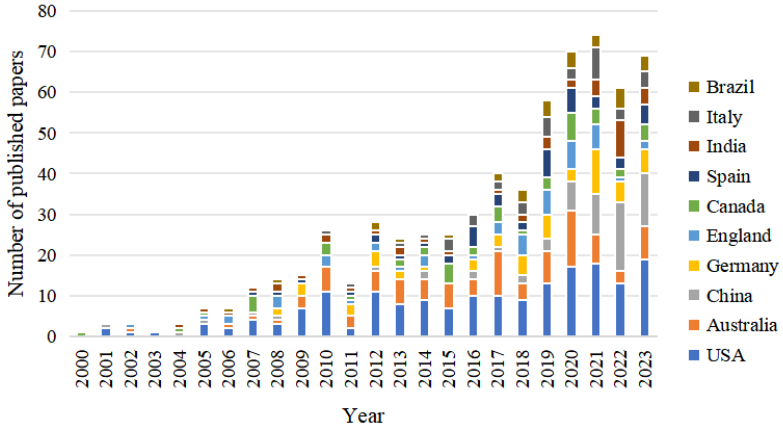
This study utilized a co-authorship matrix to construct a cooperation network for the top 20 countries based on the total number of publications (Fig. 4). Analysis of these collaboration links reveals that the United States, Germany, England, Australia, and Italy maintain relatively strong research partnerships with other countries. Among them, the United States exhibits the highest centrality (0.33), followed by Australia (0.22), indicating that most countries have either direct or indirect collaborations with these two nations.

As shown in Fig. 4, the United States collaborates with 18 of the 19 other top-publishing countries, with the exception of Portugal. Among its partnerships, the highest number of co-authored papers is with Australia, followed by Japan. In addition to the United States, Australia's primary research partners include Germany and England. China's most frequent collaborators are the United States and Japan, while Germany primarily cooperates with the Netherlands, Italy, and Norway. Notably, Sweden exhibits the strongest research collaboration with Italy, surpassing its partnerships with England and the United States. Overall, the findings suggest that the top 20 countries maintain relatively close international research collaborations in the field of forest resource asset management.

Analysis of Publication Trends

This study examines the top 10 countries based on publication volume. Analysis of their annual publication trends (Fig. 5) indicates that the United States initiated research on forest resource asset management earlier than other nations, maintaining a leading role in terms of publication volume and academic influence.

In the early stages of development, China placed relatively less emphasis on the ecological carrying capacity, resulting in increased conflicts between economic growth, resource utilization, and environmental sustainability. However, with the introduction of the scientific concept “Lucid waters and lush mountains are invaluable assets,” China has increasingly acknowledged that economic development should not come at the cost of environmental degradation. As a crucial component of natural resource assets, forest resources have attracted significant attention from the Chinese academic community. Consequently, research on



5: *Publication Trends of the Top 10 Countries by Publication Volume (2000–2023)*

II: *Distribution of Research Areas for the Top 10 Countries by Number of Publications*

	USA	Australia	China	Germany	England	Canada	Spain	India	Italy	Brazil
Forestry	45	28	7	15	2	13	12	3	8	9
Environmental Sciences	50	23	26	16	13	14	9	13	11	9
Environmental Studies	51	17	14	16	21	5	11	11	8	6
Ecology	24	25	3	9	5	4	3	4	3	3
Economics	26	6	2	9	5	5	4	3	3	2
Green Sustainable Science Technology	11	1	8	4	2	1	1	2	4	1
Biodiversity Conservation	11	9	2	4	2	3	3	1	0	4
Water Resources	5	4	3	5	1	1	2	1	1	1
Geosciences Multidisciplinary	9	2	3	2	1	0	4	1	3	2
Geography	6	3	1	2	5	1	3	2	1	1

forest resource asset management in China has expanded rapidly, achieving substantial progress within a relatively short period and positioning itself at the forefront of global research in this field.

Analysis of Research Areas

The Web of Science database assigns at least one research area tag to each research paper, categorizing them into various fields. Analyzing the research areas of different countries provides insight into their academic focus and helps identify national research priorities.

According to statistical data, the primary research areas in forest resource asset management include Forestry (200), Environmental Sciences (191), Environmental Studies (178), Ecology (94), Economics (85), Green Sustainable Science and Technology (44), Biodiversity Conservation (41), Water Resources (33), Geosciences Multidisciplinary (31), and Geography (29). These 10 fields collectively account for 926 papers, representing 66% of the 1,395 publications spanning 99 research areas.

In this study, we selected the top 10 research areas and compiled a table illustrating the distribution of papers from different countries across these fields (Tab. II).

Tab. II shows that Forestry constitutes the largest proportion of research papers globally. Specifically, Australia has published 28 papers, while Spain has contributed 12, accounting for 23.73% and 23.08% of the total, respectively. Beyond Forestry, each country exhibits distinct research priorities. For instance, the United States and England lead in Environmental Studies, ranking first in this category. China, Canada, India, and Italy focus more on Environmental Sciences. Germany allocates equal attention to Environmental Sciences and Environmental Studies, whereas Brazil places equal emphasis on Forestry and Environmental Sciences.

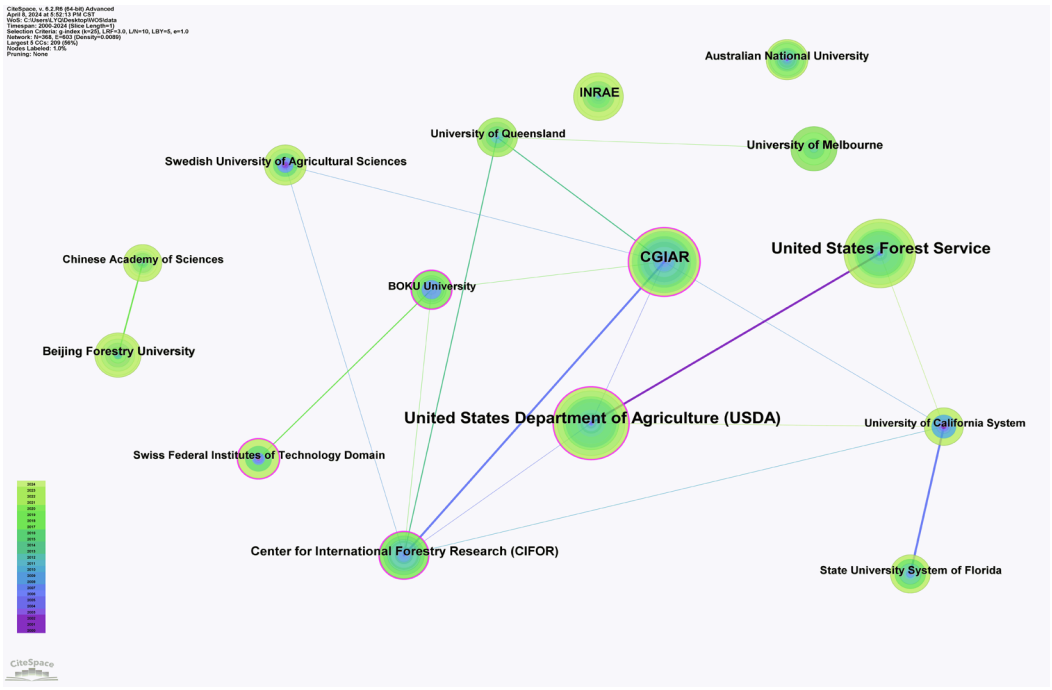
It is notable that eight countries–the United States, Australia, China, Germany, England, Spain, India, and Brazil–have published papers across all research fields examined in this study. In contrast, Canada covers nine research areas but does not include publications in Geosciences Multidisciplinary. Similarly, Italy spans nine research areas but lacks contributions to Biodiversity Conservation.

Analysis of Major Research Institutions

In this study, we utilized the institutional collaboration feature of CiteSpace to generate a network map illustrating collaboration among major publishing institutions (Fig. 6). Additionally, we analyzed key indicators, including the average publication year, average citation frequency per paper, and predominant research themes of the leading institutions (Tab. III). This analysis provides a macro-level perspective on the most influential institutions in the field of forest resource asset management and their academic impact.

According to the search results, a total of 241 institutions worldwide have contributed to research on forest resource asset management. By setting a minimum threshold of eight publications per institution, we identified 15 core institutions.

In Fig. 6, the size of the circles represents the total strength of institutional connections; the larger the circle, the more significant the institution's role in the collaboration network. The color of the circles indicates the publication year of the papers, while



6: *Collaboration Network of Major Institutions*

III: *Publication Status and Research Themes of Major Institutions*

No.	Institution	Number of published papers	Average publication year	Average citation frequency of each article	Research topic
1	United States Department of Agriculture (USDA)	38	2016	27.92	risk assessment, decision support, forest management, urban forestry, burn probability, wildfire risk management
2	United States Forest Service	35	2016	29.34	risk assessment, decision support, forest management, burn probability, wildfire risk management, fire management
3	CGIAR	25	2014	53.24	ecosystem services, livelihood assets, food security, environmental degradation, forest dependence, natural resource management, natural resources degradation
4	INRAE	16	2019	19.44	climate change, ecosystem services, forest management, stochastic dynamic programming, wildland-urban interface, north Africa, hydraulic efficiency
5	University of California System	15	2015	51.00	ecosystem services, forest management, prescribed fire, machine learning, municipal forest, agrarian policy, treatment pace and scale
6	University of Melbourne	14	2017	23.93	controlled burn, carbon stocks, value conflict, social construction of bushfire, operational research, mediterranean basin, disaster planning
7	State University System of Florida	14	2015	21.64	extractive reserves, agrarian policy, random forests, multivariate statistical methods, biodiversity conservation, sustainable livelihood, prescribed burn
8	Center for International Forestry Research (CIFOR)	13	2013	65.46	multifunctional landscapes, human well-being, non-timber forest products, forest conservation, social-ecological domain, market and livelihoods, forest landscape
9	Swedish University of Agricultural Sciences	13	2014	27.62	breeding strategy, price uncertainty, non-timber forest products, participatory field point sampling, environmental degradation, mean-variance analysis, timber harvest
10	University of Queensland	13	2016	40.92	decision support tool, dynamic land cover, multifunctional landscapes, bushfire risk, integer linear programming, livelihood strategies, mediterranean basin
11	Swiss Federal Institutes of Technology Domain	12	2015	56.50	natural hazards, protection forests, climate change, environmental services, bacterial regrowth, abiotic and biotic risk, community forestry
12	Beijing Forestry University	11	2019	4.91	policy making, social-ecological system, fixed assets, income groups, ecosystem services, community livelihood, system analysis
13	Australian National University	10	2015	40.10	carbon sequestration, forest value, urban areas, radiata pine, urban planning, Adelaide-mount lofty, conservation reserve
14	Chinese Academy of Sciences	9	2019	19.67	Bishan county, ecosystem services, remote sensing, cultivated land gradation, semi-structure interview, land management, Baiyangdian river basin
15	BOKU University	8	2013	18.25	performance measurement, forest accountancy, age constants, landslides root reinforcement, sustainability control, socio-cultural transformation, regional variation

the thickness of the connecting lines reflects the strength of collaboration between institutions. A thicker line signifies a higher number of co-authored publications between two institutions.

The figure shows that CGIAR plays a central role in the network, maintaining strong connections with various institutions, particularly with the Center for International Forestry Research (CIFOR), its closest collaborator. Additionally, the United States Department of Agriculture (USDA) has a strong research partnership with the United States Forest Service, while the University of California System collaborates closely with the State University System of Florida. Similarly, the Chinese Academy of Sciences maintains a strong research relationship with Beijing Forestry University. However, INRAE and Australian National University do not appear to have established significant collaborations with other institutions.

Tab. III provides additional insights, revealing that the USDA, United States Forest Service, CGIAR, INRAE, and the University of California System have collectively contributed 129 papers to the field of forest resource asset management, making substantial academic contributions. Although China has a high overall research output, only two Chinese institutions–Beijing Forestry University and the Chinese Academy of Sciences–are among the top 15, ranking 12th and 14th, respectively. This highlights a notable gap between Chinese institutions and the leading global research institutions in this field.

Examining the average publication year of each institution, INRAE, Beijing Forestry University, and the Chinese Academy of Sciences have an average publication year post-2019, indicating their emergence as significant research contributors in forest resource asset management. In contrast, CIFOR and BOKU University represent long-established research institutions in this field. Regarding academic influence, institutions such as CIFOR, the Swiss Federal Institutes of Technology Domain, CGIAR, and the University of California System have an average citation rate exceeding 50, significantly surpassing other institutions and underscoring their impact on global research.

In response to global climate change, different institutions have prioritized various research topics, including risk assessment, decision support, forest management, fire probability modeling, wildfire risk management, ecosystem services, environmental degradation, climate change, carbon sequestration, and sustainable livelihoods. These research focuses align with national development priorities, reflecting regional differences in forest resource asset management. Notably, Beijing Forestry University and the Chinese Academy of Sciences in China emphasize policy formulation, land-use planning, ecosystem services, and land management.

High-Impact Journals and Papers

Analysis of Source Journals

The number of articles published in academic journals reflects the research focus on a given topic over a specific period. To determine whether the distribution of journals in the field of forest resource asset management aligns with established patterns in scientific research, this study applied Bradford's Law and insights from previous bibliometric studies to analyze journal concentration, academic dissemination patterns, and the evolution of research themes in this field. Tab. IV presents the top

IV: *Main Journals for Publications on Forest Resource Asset Management Research*

No.	Journal	Country of publication	Journal impact factor (2022)	Volume of articles	Proportion of articles published	Average publication year	Citation frequency of each article
1	Forest Policy and Economics	Netherlands	4.0	28	3.65%	2015.18	24.39
2	Forests	Switzerland	2.9	26	3.39%	2021.12	9.27
3	Sustainability	Switzerland	3.9	22	2.86%	2020.32	8.23
4	Land Use Policy	England	7.1	18	2.34%	2018.17	22.50
5	Journal of Environmental Management	England	8.7	16	2.08%	2016.31	19.75
6	Ecological Economics	Netherlands	7.0	15	1.95%	2011.60	33.07
7	Forest Ecology and Management	Netherlands	3.7	15	1.95%	2015.40	25.13
8	International Journal of Wildland Fire	Australia	3.1	12	1.56%	2016.33	21.50
9	International Forestry Review	England	1.6	11	1.43%	2013.64	14.73
10	Land	Switzerland	3.9	9	1.17%	2021.00	3.78

10 SCI and SSCI journals with the highest number of publications on forest resource asset management within the Web of Science Core Collection.

Firstly, regarding journal concentration, the 10 journals listed in Tab. IV account for 22.40% of the total publications in the field of forest resource asset management, indicating the formation of a core group of journals in this research area. However, this proportion remains relatively dispersed compared to the distribution pattern predicted by Bradford's Law. In contrast, other disciplines often exhibit a more concentrated distribution of publications, where high-impact journals in fields such as medicine and environmental science publish a larger share of high-quality research (Kokol *et al*., 2021). This phenomenon suggests that research on forest resource asset management is still in its developmental stage and has not yet established a highly concentrated academic dissemination network.

Secondly, in terms of academic dissemination patterns, the journal with the highest impact factor in this field is the *Journal of Environmental Management*, with an impact factor of 8.7. The most frequently cited journals include *Ecological Economics*, *Forest Ecology and Management*, and *Forest Policy and Economics*, with average citation frequencies per article of 33.07, 25.13, and 24.39, respectively, underscoring their central role in global academic communication. This trend aligns with the general characteristics of journal distribution in scientific research, where high-impact factor journals typically lead academic dissemination (Vogel, 2012). However, since 2020, the number of papers published in open-access (OA) journals such as *Forests*, *Sustainability*, and *Land* has increased significantly. Despite their growing presence, these journals exhibit relatively low average citation frequencies per article (9.27, 8.23, and 3.78, respectively). This trend may be attributed to the rapid publication model of open-access journals, which facilitates broader dissemination but still requires further development to enhance academic influence.

Finally, from the perspective of research topic evolution, bibliometric studies indicate that most scientific fields progress through phases of initial dispersion, diversification, gradual concentration, and deepening of core issues over time (Feng *et al*., 2024). This study finds that in recent years, research hotspots in forest resource asset management have increasingly focused on policy analysis, sustainable management, and economic value assessment, while also exhibiting interdisciplinary characteristics. Additionally, the primary journals publishing research in this field are predominantly based in developed countries and regions, including the Netherlands, Switzerland, England, and Australia. However, leading multidisciplinary journals have shown relatively limited attention to this field, suggesting that research on forest resource asset management is still evolving and has not yet fully established a highly mature knowledge system.

Core Paper and Citation Network Analysis

Core papers play a critical role in knowledge transmission and the advancement of specific research fields. Analyzing the citation network of highly cited papers provides insights into the intellectual foundation and knowledge flow within a domain. Additionally, examining core papers helps in identifying emerging trends and future directions in the field.

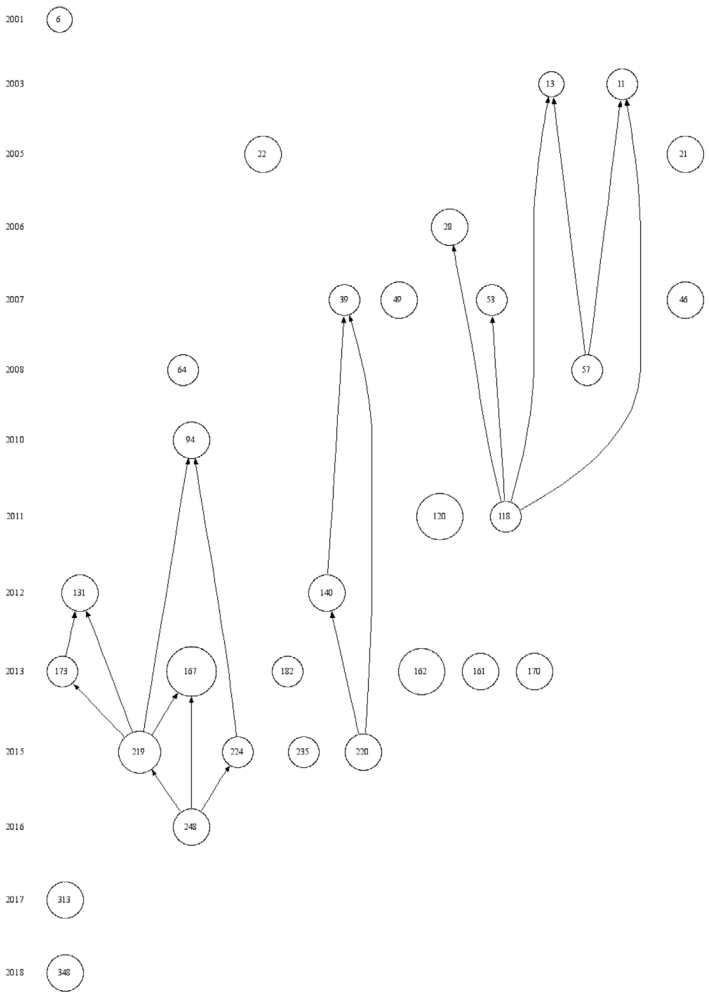
The HistCite software includes a metric known as the Local Citation Score (LCS), which measures the number of times a paper has been cited within the local citation set. Papers with higher LCS values are considered core papers, as they have undergone extensive peer review and exert significant influence in the field. In this study, HistCite was used to construct a citation network for forest

V: *Core Papers in the Citation Network of Forest Resource Asset Management*

No.	Literature	Topic	Keywords
167	(Thompson, Scott, Helmbrecht, *et al.*, 2013)	Integrated wildfire risk assessment: Framework development and application on the Lewis and Clark National Forest in Montana, USA	Wildfire; Ecological risk assessment; Environmental management; Simulation; Expert judgment; Multicriteria decision analysis
120	(Tumusiime *et al.*, 2011)	Breaking the law? Illegal livelihoods from a Protected Area in Uganda	Environmental income; Forest income; Illegal; Livelihoods; Protected area; Uganda
162	(Chen *et al.*, 2013)	Measurement and evaluation of livelihood assets in sustainable forest commons governance	Livelihood assets; Forest resources; Biodiversity conservation; Community participation; Capital; Governance; Powerful stakeholders
219	(Thompson *et al.*, 2015)	Development and application of a geospatial wildfire exposure and risk calculation tool	Decision support; Exposure analysis; Effects analysis; GIS; Risk assessment; Wildfire
21	(Adhikari, 2005)	Poverty, property rights and collective action: understanding the distributive aspects of common property resource management	Poor; Forests; Determinants; Inequality; Impact

No.	Literature	Topic	Keywords
22	(Badola and Hussain, 2005)	Valuing ecosystem functions: An empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India	Attitudes; Economic valuation; Ecosystem services; Local people; Mangrove ecosystem; Storm protection function
28	(Rocha *et al.*, 2006)	The market value of forest concessions in the Brazilian Amazon: a Real Option approach	Amazon forest; Real options; Forest concession asset pricing; Timber prices
46	(Ali *et al.*, 2007b)	Impact of participatory forest management on vulnerability and livelihood assets of forest-dependent communities in northern Pakistan	Sustainable forest management; Vulnerability; Livelihood; Participation
49	(Ali *et al.*, 2007a)	Impact of participatory forest management on financial assets of rural communities in Northwest Pakistan	Northwest Pakistan; Participatory forestry; Financial assets; Livelihood strategies
94	(Atkinson *et al.*, 2010)	Implementation of quantitative bushfire risk analysis in a GIS environment	Bushfire simulation; Fire behaviour; Fire probabilities; Modelling; Tasmania; Wildfire threat analysis
131	(Scott *et al.*, 2012)	Quantifying the threat of unsuppressed wildfires reaching the adjacent wildland-urban interface on the Bridger-Teton National Forest, Wyoming, USA	Burn probability; Fire management; Fire occurrence; FSim; Simulation modeling; Wildfire hazard
140	(Akamani, 2012)	A Community Resilience Model for Understanding and Assessing the Sustainability of Forest-Dependent Communities	Capabilities; Capital assets; Community capacity; Community resilience; Sustainable forestry
161	(Zenteno *et al.*, 2013)	Livelihood strategies and forest dependence: New insights from Bolivian forest communities	Non timber forest products; Forest governance reforms; Community forestry; Brazil nut; Northern Bolivian Amazon
170	(Prado Córdova *et al.*, 2013)	Rural income and forest reliance in highland Guatemala	Central America; Environmental income; Household surveys; Livelihoods
220	(Akamani and Hall, 2015)	Determinants of the process and outcomes of household participation in collaborative forest management in Ghana: A quantitative test of a community resilience model	Co-management; Community capitals; Forest-dependent communities; Household capabilities; Household resilience; Institutions
248	(Alcasena *et al.*, 2016)	A fire modeling approach to assess wildfire exposure of valued resources in central Navarra, Spain	Wildfire risk; Wildfire simulation; Highly valued resources and assets; Mediterranean areas; Forest rural urban intermix
313	(Keith *et al.*, 2017)	Ecosystem accounts define explicit and spatial trade-offs for managing natural resources	Water-balance; Services; Valuation; Catchment; Management; Framework; Worlds
348	(Caradot *et al.*, 2018)	Practical benchmarking of statistical and machine learning models for predicting the condition of sewer pipes in Berlin, Germany	Asset management; CCTV; Machine learning; Random forest; Sewer; Survival analysis
11	(Heikkinen, 2003)	Timber harvesting as a part of the portfolio management: a multiperiod stochastic optimisation approach	Timber harvesting; Stochastic optimization; Cointegration
39	(Donoghue and Sturtevant, 2007)	Social science constructs in ecosystem assessments: Revisiting community capacity and community resiliency	Community capacity; Community resiliency; Ecosystem assessment; Forest-based communities; Social assessment; Social science constructs
53	(Insley and Lei, 2007)	Hedges and trees: incorporating fire risk into optimal decisions in forestry using a no-arbitrage approach	Fire risk; Forest value; Hedging; Jumps; No-arbitrage; Optimal harvesting; Poisson process; Real options
57	(Hyytiäinen and Penttinen, 2008)	Applying portfolio optimisation to the harvesting decisions of non-industrial private forest owners	Clearcutting; Efficient frontier; Forest management planning; Portfolio optimisation
64	(Couture and Reynaud, 2008)	Multi-stand forest management under a climatic risk: do time and risk preferences matter?	Forest economics; Stochastic dynamic programming; Non-expected utility; Climate risk

No.	Literature	Topic	Keywords
118	(Hildebrandt and Knoke, 2011)	Investment decisions under uncertainty–a methodological review on forest science studies	Uncertainty; Diversification; Expected utility; Mean-variance; Option pricing; Stochastic dominance; Downside risk; Lower partial moment; Information-gap decision theory; Robust optimisation
173	(Thompson, Scott, Kaiden, *et al*., 2013)	A polygon-based modeling approach to assess exposure of resources and assets to wildfire	Risk assessment; Exposure analysis; Burn probability modeling; FSim; Simulation
182	(Young, 2013)	Mainstreaming urban ecosystem services: a national survey of municipal foresters	Green infrastructure; Ecosystem services; Political support; Information; Society of Municipal Arborists; Urban forest; Implementation
224	(Alcasena *et al*., 2015)	Assessing landscape scale wildfire exposure for highly valued resources in a Mediterranean area	Fire exposure; Fire risk; Highly valued resources and assets; Mediterranean areas; MTT algorithm
235	(Norbury *et al*., 2015)	Density-impact functions for terrestrial vertebrate pests and indigenous biota: guidelines for conservation managers	Density-impact; Damage function; Pest impact; Indigenous biota; Introduced mammal
6	(Jim and Liu, 2001)	Patterns and dynamics of urban forests in relation to land use and development history in Guangzhou City, China	China; Guangzhou; Urban trees; Urban greening; Land use; Development history
13	(Gong and Löfgren, 2003)	Risk-aversion and the short-run supply of timber	Price uncertainty; Timber harvest; Optimal portfolio; Mean-variance analysis



7: *Citation Network of Forest Resource Asset Management*

resource asset management research from 2000 to 2023, visualizing the top 30 papers ranked by LCS (Fig. 7). These papers were subsequently analyzed in detail to explore the intellectual heritage of forest resource asset management.

Tab. V presents the 30 core papers identified in the analysis. In Fig. 7, each circle represents a cited paper, with the size of the circle proportional to its LCS value. The number inside each circle corresponds to the sequence number of the paper. These sequence numbers are automatically assigned based on publication year and title within the software and do not carry statistical significance. The lines connecting the circles represent citation relationships, with arrows indicating the direction of citation towards referenced literature.

In the citation network, the paper published in 2001 (Issue 6) is identified as an early high-impact study. However, the 2010 publication (Issue 94) has a notably high Local Citation Score (LCS) and is cited by papers numbered 219 and 224, which, in turn, influence paper 248. This process illustrates the transmission of knowledge within the field.

Several papers, including No. 167, No. 219, No. 94, No. 131, No. 248, No. 173, and No. 224, primarily explore risk assessment methods for forest wildfires. These studies form a closely interconnected cluster within the citation network. Analyzing citation relationships helps trace knowledge transfer, identify key publications in specific research domains, and assess the trajectory of knowledge development in forest resource asset management.

Through an in-depth examination of core papers, we observe a shift in forest resource asset management research from a sole emphasis on ecological protection toward integrated asset management. Traditional forest governance models have predominantly focused on ecosystem protection (Badola and Hussain, 2005). However, recent studies increasingly highlight the market valuation of forest resources (Chen *et al.*, 2013), optimization of property rights systems (Yang *et al.*, 2021), and improvements in management models (Minkova and Arnold, 2020). Defining clear property rights is regarded as key to enhancing management efficiency. Studies indicate that well-defined property rights structures reduce disorderly exploitation and promote sustainable management (Adhikari, 2005).

Additionally, the Participatory Forest Management (PFM) model has gained traction in many countries. However, research suggests that community involvement alone is insufficient; economic incentives, such as ecological compensation and benefit-sharing mechanisms, must be incorporated to ensure policy sustainability (Ali *et al.*, 2007a, 2007b). Furthermore, risk control in forest resource management–addressing threats such as wildfires, illegal logging, and climate change–has become increasingly vital. Research demonstrates that integrating Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) enhances disaster prevention resource allocation and strengthens the long-term stability of forest assets (Thompson *et al.*, 2015; Thompson, Scott, Helmbrecht, *et al.*, 2013). This trend suggests that forest resource asset management is evolving toward a model that integrates market incentives, property rights optimization, and risk management–balancing ecological benefits with economic viability and social equity.

From a methodological perspective, core papers reveal a transition from traditional qualitative analysis to data-driven quantitative modeling, improving the precision, comparability, and policy relevance of research findings. The application of econometric models has significantly advanced the valuation of forest resources (Tumusiime *et al.*, 2011). For instance, the real options pricing model is widely used in forest concession pricing, carbon trading mechanisms, and ecological compensation calculations (Rocha *et al.*, 2006). Compared to the traditional net present value (NPV) approach (Thompson *et al.*, 2015), this model better accounts for market volatility and investment flexibility. Additionally, GIS and spatial analysis tools have facilitated more precise forest resource asset management. By integrating remote sensing technology, spatial statistics, and ecological models, researchers can monitor forest cover changes, optimize resource allocation, and improve the accuracy of wildfire predictions (Thompson, Scott, Helmbrecht *et al.*, 2013). Moreover, socio-economic research methodologies have also evolved, incorporating experimental and control group comparisons to assess the impact of PFM on rural community asset development. The use of focus group discussions (FGD) and key informant interviews (KII) further enhances policy applicability (Ali *et al.*, 2007a, 2007b). Overall, these methodological innovations have driven forest resource asset management toward a multi-scale, interdisciplinary, and data-driven decision-making approach, improving both the scientific rigor and practical implementation of policies.

The influence of core papers is largely attributed to their alignment with global environmental policy agendas, such as the Sustainable Development Goals (SDGs), the REDD+ carbon compensation mechanism, and forest concession marketization, thereby providing a scientific foundation for global forest governance. Additionally, the adoption of quantitative analysis methods ensures that research findings extend beyond theoretical discussions and contribute directly to policymaking. For instance, forest resource valuation methods inform government-set auction reserve prices (Rocha *et al.*, 2006), fire risk assessment tools optimize disaster prevention fund allocation (Thompson, Scott, Helmbrecht *et al.*, 2013), and ecological compensation calculations facilitate REDD+ implementation. Furthermore, these studies demonstrate strong methodological replicability, making their approaches widely applicable across

different countries and regions, thereby enhancing both academic dissemination and practical relevance. Lastly, forest resource asset management research exhibits increasing interdisciplinary integration, drawing from economics, policy science, spatial analysis, and social sciences. This interdisciplinary convergence, coupled with real-world policy demands, has significantly amplified the academic and policy influence of high-impact papers, reinforcing their role in global forest governance.

Methodological Analysis

Evolution of Research Methods

Research methods in forest resource asset management have undergone significant evolution over the past two decades, transitioning from qualitative exploratory studies to comprehensive evaluations incorporating quantitative techniques.

Early research primarily relied on qualitative methods, such as case studies, policy analysis, and literature reviews, focusing on policy frameworks, community participation models, and socio-economic impacts of forest resource management (Ali *et al*., 2007a, 2007b; Ameha *et al*., 2014). These studies provided foundational theoretical support but lacked systematic quantitative analysis, limiting the generalizability and objectivity of their conclusions. In recent years, advancements in data acquisition and analytical tools have driven a shift toward quantitative approaches, including econometrics (Gu *et al*., 2023), GIS spatial analysis (Ying *et al*., 2019), and remote sensing technology (Foody, 2003), which have enhanced research accuracy and applicability. The integration of remote sensing and Internet of Things (IoT) technology has further enabled the application of machine learning in forest resource asset prediction and management optimization (Chen *et al*., 2024), providing new technological support for this field.

Despite methodological advancements, several challenges persist. First, interdisciplinary integration remains inadequate, and cross-disciplinary applications are still in the early stages. While econometrics, GIS spatial analysis, and machine learning have been increasingly employed, they often function as standalone analytical tools rather than being combined under a unified theoretical framework. For example, remote sensing and GIS technologies primarily focus on forest resource distribution and monitoring, while econometric models emphasize valuation assessments, lacking cohesive integration in data analysis and interpretation. This fragmentation limits the holistic understanding of forest resource asset management. Second, data quality and methodological applications require further improvement. While high-resolution remote sensing and UAV monitoring data are increasingly available, their effective utilization depends on optimized analytical methods. For instance, machine learning models exhibit varying sensitivity to input variables in forest resource predictions, and without a deep ecological understanding, prediction stability may be compromised. Similarly, traditional econometric models often assume time series stability, yet forest resource asset values are influenced by dynamic market fluctuations and policy changes, necessitating more advanced modeling approaches.

Research Subjects and Data Sources

Geographically, research has predominantly focused on countries with well-established forest resource asset management systems and comprehensive data availability (Ameha *et al*., 2014; Barnes *et al*., 2010; Gu *et al*., 2023; Ying *et al*., 2019). While these studies provide valuable insights, they highlight global research imbalances. Latin America, Southeast Asia, and parts of Africa remain underrepresented, limiting the applicability of global forest management policies. Moreover, research has primarily focused on tropical and temperate forests, with limited attention to boreal, arid, and urban forests, affecting the comprehensiveness of forest resource asset management studies.

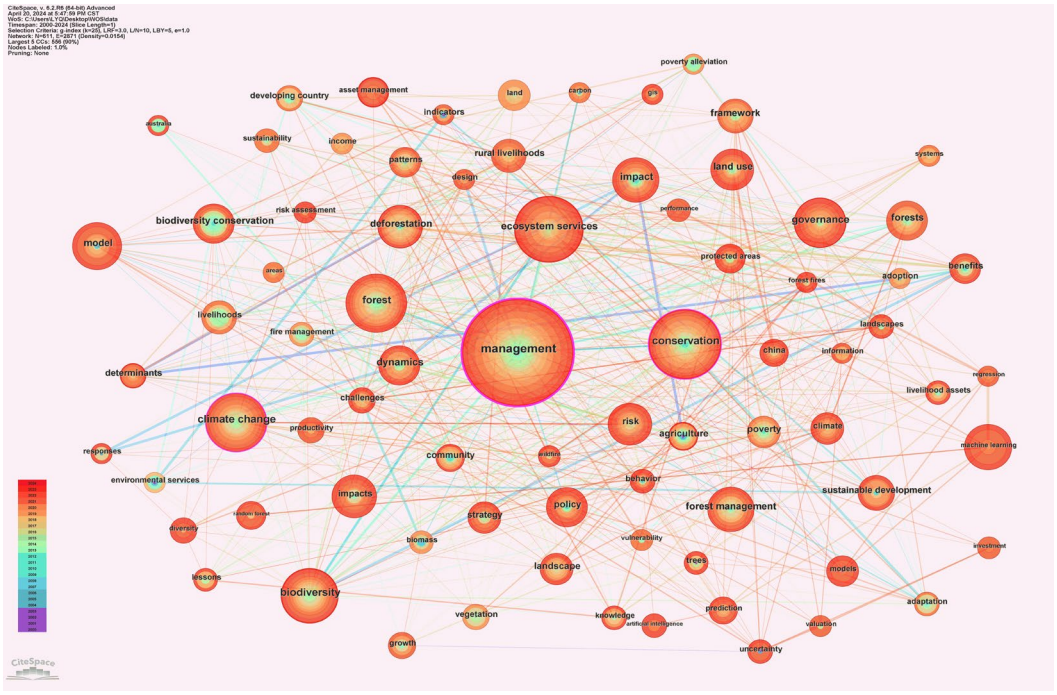
Analysis of Research Hotspots and Trends

Analysis of Research Hotspots

Keywords serve as condensed representations of core research themes, capturing prevailing trends in the field. High-frequency keywords indicate research priorities and emerging areas of interest. This study extracted keywords from forest resource asset management papers published between 2000 and 2023 and employed CiteSpace to construct a keyword co-occurrence network, identifying current research hotspots. A total of 594 keywords were extracted, with 78 high-frequency keywords meeting the co-occurrence threshold of six (Fig. 8). Based on their attributes, key research themes were categorized into five clusters (Tab. VI).

In Fig. 8, the size of the circles represents the frequency of keyword occurrences, with larger circles indicating higher occurrence rates. The lines connecting two keywords represent their co-occurrence strength, where thicker lines indicate more frequent co-occurrences. The color of the circles corresponds to the publication year of the keywords. Red denotes newer keywords, signifying emerging research hotspots in forest resource asset management. In contrast, purple represents older, less frequently studied topics, while green indicates keywords with mid-range publication years, reflecting consistent research interest over time.

Each cluster in the network maintains close connections. As shown in Tab. VI, the first cluster, Forest Conservation Management and Sustainable Development, comprises eight keywords:



8: *CiteSpace Co-Occurrence Network of Keywords in Forest Resource Asset Management Research*

VI: *High-Frequency Keywords in Forest Resource Asset Management Research*

No.	Hotspots	Keywords	Total keywords frequency	Average Publication Year
1	Forest conservation management and sustainable development	management, conservation, forest management, deforestation, sustainable development, protected areas, fire management, forest fires	365	2017.28
2	Forest ecosystem services and biodiversity	ecosystem services, forest, biodiversity, land use, biodiversity conservation, landscape, benefits, vegetation, livelihood assets, biomass, environmental services	295	2017.24
3	Value evaluation and dynamic monitoring	model, risk, machine learning, dynamics, poverty, asset management, prediction, uncertainty, artificial intelligence, risk assessment, valuation, GIS, indicators, regression	214	2018.03
4	Climate change and carbon sink markets	climate change, impact, framework, carbon, adaptation	123	2017.88
5	Policy and decision making	governance, policy, strategy, determinants, poverty alleviation	97	2017.72

management, conservation, forest management, deforestation, sustainable development, protected areas, fire management, and forest fires. The second cluster, Forest Ecosystem Services and Biodiversity, includes 11 keywords: ecosystem services, forest, biodiversity, land use, biodiversity conservation, landscape, benefits, vegetation, livelihood assets, biomass, and environmental services. The third cluster, Value Evaluation and Dynamic Monitoring, contains 14 keywords, including model, risk, machine learning, dynamics, poverty, asset management, prediction, uncertainty, artificial intelligence, risk assessment, valuation, GIS, indicators, and regression. The fourth cluster, Climate Change and Carbon Market, consists of five keywords: climate change, impact, framework, carbon, and adaptation. The fifth cluster, Policy and Decision-Making, includes governance, policy, strategy, determinants, and poverty alleviation, totaling five keywords.

Using CiteSpace, this study identified the top 15 most frequently occurring keywords: management, conservation, ecosystem services, climate change, forest, biodiversity, governance, model, impact, forest management, machine learning, risk, land use, forest, and dynamics. Their average publication years range from 2016.70 to 2019.63 (Fig. 6). Among them, “management”

ranks first with 183 occurrences and an average publication year of 2017.22, indicating its central role in recent international research on forest resource asset management. "Conservation" appears 77 times, with an average publication year of 2016.88, aligning with the global trend of increasing attention to ecological conservation and restoration. Additionally, key scientific topics such as ecosystem services, climate change, forest, biodiversity, and fire management have been major international research focuses in recent years.

From an economic perspective, research has also emphasized asset management, forest management, livelihoods, and poverty. This suggests that in recent years, forest resource asset management research has achieved a well-balanced development between scientific and humanities-oriented studies.

1) Forest Conservation Management and Sustainable Development. Increasing conflicts in forest management have driven extensive research into forest resource asset management. The effective protection and management of forests as assets are crucial, directly influencing the stability of forest ecosystems and the sustainable development of forest resources. This issue remains a major concern for both natural resource managers and the academic community (Jaroszewicz *et al.*, 2019; Southwold-Llewellyn, 2006). Research has focused on property rights management (Fujisawa, 2004; Lambini and Nguyen, 2014; Miller *et al.*, 2021), asset valuation (Chen *et al.*, 2013; Seymour *et al.*, 2010), and dynamic monitoring (Lindenmayer and Taylor, 2020; Scott *et al.*, 2012). However, challenges persist in defining the key components of forest asset management, determining the scope of asset management, establishing the linkages between asset management and sustainable development, and assessing the impacts of different management models on forest ecosystems and their interactions with human activities.
2) Forest Ecosystem Services and Biodiversity. Forest ecosystems play a critical role in maintaining biodiversity, which serves as both a tangible and intangible asset. These two elements complement each other to form an integrated system. There is growing recognition that forest ecosystems and biodiversity represent invaluable global assets. However, they face increasing threats of degradation and loss due to human activities (Kiley *et al.*, 2017). Consequently, forest resource management from the perspective of ecosystem services and biodiversity has become a focal area for policymakers and researchers (Carvalho-Santos *et al.*, 2016). Despite progress, further efforts are needed to clarify conceptual definitions, establish content structures, and develop comprehensive frameworks. Additionally, fostering a shared global consensus on forest ecosystem and biodiversity conservation will be essential in advancing solutions to these pressing challenges (Gardner *et al.*, 2012).
3) Value Evaluation and Dynamic Monitoring. Accurate value assessment is a prerequisite for effective asset management, as it enables the market valuation of forest resources. The development of theoretical frameworks, valuation models, and evaluation indicators constitutes a core research focus in forest resource asset management (Chen *et al.*, 2013; Hildebrandt and Knoke, 2011; Ovando *et al.*, 2016). Current assessments primarily emphasize static value indicators such as biodiversity, invasive species, productivity, and landscape structure. However, variations in indicator selection and assessment methodologies often lead to significant discrepancies in valuation results for the same resource (Akamani and Hall, 2019). Most valuation methods rely on economic accounting approaches (Geng and Liang, 2021; Hojo *et al.*, 2021). However, these methods exhibit certain limitations, including an underdeveloped pricing foundation, subjective biases, and the potential neglect of ecosystem services. Additionally, current approaches do not sufficiently quantify the varying degrees of forest dependence among different income groups (Lambini and Nguyen, 2014; Nerfa *et al.*, 2020), leading to a lack of detailed spatial analyses in impoverished regions. This limitation hinders the ability to translate findings across different spatial scales, reducing the precision and reliability of valuation outcomes (Dokken and Angelsen, 2015; Huber *et al.*, 2019). To improve the dynamic monitoring of forest resources, it is essential to explore innovative technologies and develop process-based assessment indicators and models. For example, drone remote sensing technology can be used to monitor forest fires and tree inventories (Dainelli *et al.*, 2021; Pastor *et al.*, 2011), while big data analytics can integrate monitoring data to quantitatively reflect regional forest resource asset trends (Huang *et al.*, 2020). Despite advancements, challenges remain in establishing a comprehensive valuation system, enhancing the adaptability of monitoring technologies, and achieving seamless integration among assessment models.
4) Climate Change and Carbon Sink Markets. Climate change driven by human activities is having an increasingly profound global impact (Akpodiogaga-a and Odjugo, 2010; Ćwik *et al.*, 2021; Negi *et al.*, 2017; Poppy *et al.*, 2014). Forests serve as critical carbon reservoirs, storing over 80% of terrestrial vegetation carbon stocks and playing a vital role in maintaining the global carbon balance and mitigating climate change

(Gower, 2003; Mitchard, 2018). Reducing carbon emissions resulting from deforestation has become a central strategy in climate mitigation efforts. As a result, many countries are striving to achieve carbon neutrality through the strategic use of forest carbon sinks (Law and Harmon, 2011; Martes and Köhl, 2022). To strengthen these efforts, a comprehensive framework is needed to clarify the interactions between forest ecosystems and climate change (Nunes *et al.*, 2019) and to analyze variations in carbon sequestration capacity across different spatial scales (Knoke *et al.*, 2011). Further enhancements in market mechanisms under international climate agreements are also necessary, particularly in addressing institutional differences and stakeholder roles in carbon trading processes.

5) Policy and Decision-Making. Policies play a fundamental role in shaping scientific research and directly influence the utilization of forest resources. Changes in policy frameworks can significantly impact forest ecosystems, their structure, and the benefits derived from forest assets. Governments worldwide adjust forest resource utilization based on asset-based management approaches, spatial planning strategies, incentive mechanisms, and stakeholder participation. These approaches not only affect forest ecosystems but also reshape forest asset benefits and ecosystem service provision (Clement, 2010; Lindenmayer and Taylor, 2020).

Future Research Directions

Research on forest resource asset management is undergoing rapid development, with an expanding range of topics. However, bibliometric analysis suggests that several areas require further in-depth exploration. While current research focuses on the sustainable management of forest resources, ecosystem service valuation, carbon sink markets, and policy optimization, limitations remain in research methodologies, spatial scales, and interdisciplinary integration. In particular, dynamic changes in research hotspots indicate that data-driven intelligent analysis, interdisciplinary integration, and multi-scale research linking regional and global perspectives are still in their early stages and require further advancement.

1) Emphasizing Emerging Trends and Enhancing Data-Driven Research Capabilities

   Literature analysis reveals that, although the application of remote sensing, Geographic Information Systems (GIS), and machine learning in forest resource asset management has increased, it remains largely concentrated on forest cover monitoring and carbon stock estimation. There is limited application in the dynamic optimization of forest resource asset management and policy decision support. The integration of artificial intelligence (AI) and big data analysis is still in its infancy, with most studies focused on static assessments that fail to capture the complexity and dynamics of forest resource asset management. Future research should strengthen data-driven intelligent analysis methods, establish high-precision monitoring systems for forest resource assets, and explore AI integration with remote sensing, deep learning, and dynamic optimization models. These advancements will improve the accuracy of forest resource valuation, carbon sink capacity prediction, and risk management. Additionally, as the market-oriented operation of forest resource assets is still in an exploratory stage and carbon sink trading mechanisms remain underdeveloped, future research should optimize forest carbon sink trading models, incorporate forest carbon stocks into capitalization frameworks, and enhance the economic value of forest resources while ensuring the long-term stability of carbon sink capacity.

2) Strengthening Interdisciplinary Integration and Constructing an Integrated Management Framework

   Keyword co-occurrence analysis and research trend evolution indicate that forest resource asset management is increasingly interdisciplinary. However, integration among economics, ecology, environmental science, and policy studies remains insufficient. Existing research faces challenges related to property rights systems, market incentive mechanisms, and policy implementation evaluation, making it difficult to comprehensively model the systematic operation of forest resource asset management. Future studies should strengthen the synergy between forest resource asset management and sustainable forest development, construct a universal management framework, and provide a scientific foundation for prioritizing management strategies, defining conservation targets, and designing institutional mechanisms. Additionally, a deeper understanding of the complex interactions between forest ecosystems, biodiversity, and human well-being is necessary. Future research should systematically quantify the relationships between management measures, market responses, ecological processes, policy interventions, and sustainable development pathways to enhance the scientific rigor and adaptability of management systems.

3) Balancing Regional Differences with a Global Perspective and Optimizing Multi-Scale Governance Systems

   Analysis of research strengths reveals significant disparities in global forest resource asset management research. Developed countries contribute the majority of high-impact studies,

while developing nations have fewer systematic studies, often focusing on case analyses and policy discussions without a stable theoretical framework. Furthermore, most studies examine forest resource asset management at national or regional scales, with limited research on global governance, transboundary carbon trading, and international ecological compensation mechanisms. Future research should expand comparative studies across regions, explore effective forest resource asset management strategies under varying levels of economic development, and strengthen multi-scale governance systems. Within the framework of the global carbon market and the Sustainable Development Goals (SDGs), further exploration is needed on how to coordinate forest resource management policies across different countries and regions to enhance the effectiveness of transboundary carbon sink trading.

4) Deepening Policy Assessment and Optimizing Forest Resource Asset Management Mechanisms

Research hotspot analysis highlights the crucial role of policies and governance in forest resource asset management. However, existing research primarily focuses on policy framework construction, with limited empirical analysis of policy response mechanisms. The effectiveness of forest resource asset management policies is influenced by multiple factors, including economic incentives, market dynamics, and social participation, yet the interactions among these variables have not been systematically quantified. Future research should focus on policy feedback mechanisms, exploring how participatory management models can enhance social engagement and promote equitable benefit distribution. Additionally, innovation in policy tools for forest resource asset management is necessary. Strategies such as integrating forest trusts, green bonds, and other financial instruments can enhance the management of forest assets. Policy evaluation methods should also be refined by incorporating econometrics, experimental research, and social network analysis to quantify the impact of various policy tools on forest resource asset management performance. These improvements will contribute to the development of more effective and sustainable forest resource management strategies and decision-making frameworks.

Comparison with Previous Bibliometric Studies

Bibliometric analysis methods are widely applied in natural resource management, ecological economics, and environmental science to identify research hotspots, track evolutionary trends, and map academic collaboration networks (Song and Zhao, 2013). Existing studies primarily employ indicators such as the H-index, co-authorship network analysis, and keyword contribution analysis, using tools like VOSviewer and CiteSpace for data visualization and knowledge mapping (Uribe-Toril *et al*., 2019; Zhang *et al*., 2022). These studies identify core research themes through co-word analysis and assess the research landscape of forest resource management (Ciccarino and Fernandes, 2023) and ecosystem services (Chen *et al.*, 2022) based on citation analysis. However, most current bibliometric studies focus on general forest management topics, while studies specifically addressing forest resource asset management remain limited. Moreover, existing research faces methodological constraints, data acquisition challenges, and a lack of multi-dimensional analytical approaches.

Unlike traditional bibliometric analyses in forest management, this study focuses on forest resource asset management, which conceptualizes forest resources as both economic and ecological assets. It explores mechanisms for value realization, property rights management models, and market-oriented operational strategies. Forest resource asset management encompasses not only the conservation and utilization of forest ecological functions but also natural capital accounting, market valuation of forest resources, and the optimization of policy tools. Compared with traditional bibliometric studies in forest management (Zhang *et al*., 2022), this research expands the scope of analysis by considering both the ecological roles of forests and their asset attributes within the economic system, thus constructing a more comprehensive framework for sustainable forest resource management.

In terms of methodology, while this study utilizes CiteSpace for quantitative analysis, similar to many bibliometric studies, it introduces several methodological enhancements in data acquisition and analysis. This study incorporates a broader dataset, including both core journal literature and high-impact interdisciplinary research, ensuring a more comprehensive and representative dataset. It examines not only the evolution of research hotspots but also the interconnections among different research topics. This research integrates multiple analytical methods, such as keyword co-occurrence analysis, emergent word analysis, and citation network analysis, to uncover key research drivers and their interactions with ecological economic policies in forest resource asset management. Covering the period from 2000 to 2023, this study provides a more systematic and extensive review of the evolutionary trends in forest resource asset management research. It also employs detailed emergent word analysis to track changes in research hotspots over specific time periods, addressing the limitations of traditional keyword co-occurrence analysis in identifying emerging research frontiers. In contrast, existing studies primarily rely on conventional co-

occurrence analysis and H-index calculations, which fail to fully capture the dynamic evolution of forest resource asset management research (Uribe-Toril *et al.*, 2019). By incorporating these enhancements, this study offers a more detailed and precise bibliometric analysis, providing a more comprehensive perspective for future research in forest resource asset management.

This study significantly differs from previous bibliometric research in its approach to uncovering the evolution of forest resource asset management research and its future development directions. Existing studies typically provide macro-trend analyses but offer limited in-depth exploration of this specific research domain (Chen *et al.*, 2022). In contrast, this study systematically traces the development trajectory of forest resource asset management literature from 2000 to 2023, identifying core research themes, the evolution of research hotspots, and key academic contributions within this field. From a research hotspot perspective, prior studies have shown that ecosystem valuation, payment for ecosystem services (PES) policies, and the impact of climate change on forest ecosystems have been long-standing research focal points (Chen *et al.*, 2022). However, this study reveals that recent research trends are shifting toward quantitative assessment, policy formulation, and sustainable development strategies. Notably, emerging research frontiers include innovations in forest resource accounting, advancements in asset valuation methodologies, and the optimization of ecological compensation mechanisms. Additionally, this study's keyword co-occurrence analysis highlights previously underexplored topics, such as forest carbon sink trading, natural capital accounting, and ecological compensation standard setting, which have not been fully examined in existing literature.

While previous studies typically provide broad recommendations for sustainable forest ecosystem management, such as emphasizing interdisciplinary collaboration and policy coordination (Chen *et al.*, 2022), this study offers more specific and actionable insights based on bibliometric analysis findings. It emphasizes the need to establish standardized frameworks for cross-regional and cross-border data integration and comparison to enhance data consistency and comparability. Additionally, it suggests incorporating advanced economic assessment models, such as ecological balance sheets and dynamic quantitative evaluation frameworks, to improve the empirical robustness and policy applicability of research findings. Furthermore, it highlights the importance of expanding the intersection of forest resource asset management with green finance, carbon trading markets, and sustainability finance to provide a scientific foundation for achieving global carbon neutrality goals. These targeted recommendations address gaps in existing research and offer practical guidance for advancing both academic studies and policy development in forest resource asset management.

DISCUSSION

1) It is time to focus more on the quality of research in forest resource asset management rather than merely pursuing quantity. A growing number of publications indicate that research in forest resource asset management has garnered widespread academic attention and achieved significant progress. However, the declining citation rates suggest that greater emphasis should now be placed on research quality rather than quantity. Quality and impact are not solely reflected in the number of published papers. This phenomenon is closely linked to research evaluation mechanisms and policy guidelines in many countries. By analyzing major journals, it is evident that since 2020, an increasing number of papers have been published in journals with high publication volumes, short publication cycles, and relatively lower impact factors. While this does not necessarily imply lower quality, in the current evaluation system, journals with higher impact factors are generally regarded as more authoritative. Therefore, it is recommended that evaluators prioritize impact assessment in forest resource asset management research, using paper quality rather than publication volume as the primary criterion for evaluating research contributions.
2) Research on forest resource asset management in developing countries needs to strengthen international cooperation. Analysis of international collaboration patterns indicates that forest resource asset management research is primarily concentrated in the United States and other major developed nations. This collaboration structure is closely related to the United States' leading position in theoretical and methodological innovation in this field. At the institutional level, collaborations mainly occur within the same country or region, with limited cross-national institutional partnerships. To enhance global knowledge exchange, developing countries should actively expand international research collaborations and strengthen cooperation across different regions. For example, multi-national collaborative studies could be conducted on transboundary forest ecosystems. Additionally, institutional cooperation should move beyond traditional collaboration networks by leveraging disciplinary strengths to foster large-scale, cross-border partnerships. This approach would allow institutions to maximize their technological, methodological, infrastructural, and human resource advantages, thereby enhancing the internationalization of forest resource asset management research.

3) Forest resource asset management requires the use of modern technology for monitoring and assessment. The ultimate goal of forest resource asset management research is to achieve sustainable management and utilization of forest resources, promote ecosystem restoration and conservation, and enhance their capacity to provide ecosystem services for human well-being. Analysis of research hotspots and trends in this study reveals that with the advancement of remote sensing, GIS, big data, and artificial intelligence technologies, the academic community is increasingly focused on applying these tools for dynamic monitoring, management, and assessment of forest resources. This shift aims to enhance management efficiency and accuracy. Future research should emphasize practical applications, utilizing modern information technologies to establish a more scientific system for assessing the value of forest resources. Based on their findings, researchers should provide specific policy recommendations that offer theoretical foundations, data support, and actionable insights for policymakers, thereby facilitating the formulation and effective implementation of evidence-based policies.
4) The practical application value of forest resource asset management research outcomes should be enhanced. The core objective of forest resource asset management research is to ensure that forest management practices meet present needs without compromising the needs of future generations, thereby achieving long-term sustainability. Currently, much of the research in this field focuses on forest property rights allocation, economic valuation of forest resources, and dynamic analysis of forest resource assets. However, there is often a gap between research findings and their application in decision-making. The primary purpose of research should be to provide policy support that maximizes human ecological well-being while strengthening ecosystem protection. Therefore, future research should place greater emphasis on the practical application of findings. Researchers should propose feasible, evidence-based recommendations that provide policymakers with comprehensive theoretical support, data-driven insights, and actionable guidance, thereby improving the effectiveness of policy design and implementation.
5) Limitations of this study. While this study is based on extensive literature analysis and aims to provide a comprehensive overview of international trends and research hotspots in forest resource asset management, several limitations remain. First, this study primarily relies on data from the Web of Science database and includes only English-language publications. This limitation excludes valuable non-English research findings from the analysis. For example, in research-leading countries such as China, many influential studies are published in Chinese. Future studies should address this issue by incorporating multilingual datasets. Second, this study employs a thematic search strategy, where subjective human factors inevitably influence the selection and formulation of search terms, increasing the risk of omitting relevant research. Finally, while bibliometric methods provide a valuable visualization of research hotspots based on publication volume, a more accurate assessment would require in-depth qualitative analysis of key papers. Therefore, future research should complement bibliometric analysis with a detailed review of foundational and high-impact studies to derive more precise insights.

CONCLUSION

This paper collected 768 publications on forest resource asset management from the Web of Science Core Collection between 2000 and 2023. Using bibliometric and text mining techniques, it conducted a detailed analysis of the international development, current status, and research hotspots in this field, leading to the following conclusions:

1) Research development trends. The number of papers on forest resource asset management has been growing at an average rate of 62.3 papers per year. The research in this field can be divided into three developmental stages. The first stage primarily focused on conceptual discussions and the consequences of non-market exploitation of forest resources. The second stage, influenced by growing concerns over climate change, emphasized the relationship between asset management, forest biodiversity, and ecosystem services. The third stage, with an increasing focus on adaptive management and sustainable development, has prioritized enhancing carbon sequestration capacity, assessing asset values, and reforming management systems. This shift has led to greater interdisciplinary integration, fostering further advancements in the field. However, the declining average citation count, which has fallen below one citation per paper in recent years, raises concerns about research quality and impact.
2) Research force distribution. Developed countries continue to dominate forest resource asset management research. The United States holds the greatest academic influence, accounting for 23.44% of total publications by research institutions and serving as the central hub of

international collaborations. Although China entered the field later, it has experienced rapid growth, now ranking third in publication output. Beijing Forestry University and the Chinese Academy of Sciences have emerged as major contributors in this field. Compared to developed countries such as Germany and the United Kingdom, China excels in publication volume but has a moderate research influence. Traditional research institutions, including the Center for International Forestry Research (CIFOR) and BOKU University, remain influential, while newer contributors such as INRAE, Beijing Forestry University, and the Chinese Academy of Sciences have increased their activity since 2019. In terms of impact, CIFOR, the Swiss Federal Institutes of Technology Domain, and CGIAR are among the most influential institutions in the field.

3) High-impact journals and research hotspots. The most frequently cited journals include *Ecological Economics*, *Forest Ecology and Management*, and *Forest Policy and Economics*, with average citation frequencies of 33.07, 25.13, and 24.39, respectively. Since 2020, an increasing number of papers have been published in *Forests*, *Sustainability*, and *Land*. Forestry and environmental science remain core research fields, with varying emphases across different countries. Keyword co-occurrence analysis identified 78 core keywords and five major research hotspots: forest protection management and sustainable development, forest ecosystem services and biodiversity, value evaluation and dynamic monitoring, climate change and carbon sink markets, and policy and decision-making. The findings indicate that international research has achieved a balanced integration of natural science and humanities research. Future research should focus on improving research quality, strengthening international collaboration, leveraging modern technology for monitoring and assessment, and enhancing the practical application value of findings in this field.
4) Policy implications. The results of this study provide a scientific basis for policymaking. Given the increasing attention on the carbon sink function of forests amid global climate change, research findings can help optimize carbon trading mechanisms and support the development of the forest carbon sink market. Additionally, studies on property rights management, ecological compensation mechanisms, and forest resource pricing can assist policymakers in designing more effective policies for sustainable forest resource utilization.
5) Funding allocation suggestions. Despite advancements, interdisciplinary research and data-driven approaches in forest resource asset management remain underdeveloped. Governments and research institutions should optimize funding allocation, prioritizing areas such as digital forest resource management, artificial intelligence applications, ecological compensation mechanisms, and market-oriented operational models. Increased investment in these areas can help refine forest resource asset management systems and enhance their effectiveness.
6) The practical value of forest resource asset management. The application of modern technologies in forest resource asset management is becoming increasingly important. Remote sensing and GIS can enhance the accuracy of forest asset evaluation, machine learning can optimize forest fire warning systems, and intelligent management models can improve the sustainable utilization of forest resources. It is recommended that forestry management agencies adopt digital management tools and establish dynamic monitoring systems to enhance the scientific rigor and operational efficiency of forest resource management.
7) Future research directions. Future research should strengthen interdisciplinary integration, fostering deeper collaboration among economics, ecology, environmental science, and related disciplines to build a comprehensive theoretical framework for forest resource asset management. Additionally, greater emphasis should be placed on data-driven approaches, incorporating big data, artificial intelligence, blockchain, and other advanced technologies to enhance analytical capabilities and management efficiency. A robust scientific policy evaluation framework should also be developed to optimize policy implementation and improve forest management precision. Expanding global collaborative research, particularly by fostering stronger networks in developing countries, will facilitate the sharing of knowledge and best practices. Furthermore, research should explore the pricing mechanisms of forest resource assets, incorporating forest carbon sinks and ecological compensation into financial systems to advance the marketization of forest resource assets. Overall, forest resource asset management research holds significant academic value and has profound implications for policymaking, financial investment, and practical management. Future studies should leverage modern technologies to enhance the scientific rigor and practical relevance of research in this field, ultimately promoting the sustainable utilization of global forest resources and ecological security.

CRediT Authorship Contribution Statement

Feng Yan: Conceptualization, Formal analysis, Methodology, Resources, Software, Visualization, Writing – original draft.
Fathin Faizah Said: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing.
Norlida Hanim Mohd Salleh: Resources, Software, Supervision, Validation, Writing – review & editing.
Naziatul Aziah Mohd Radzi: Supervision, Validation, Visualization, Writing – review & editing.
Li Yunqiao: Data curation, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

Acknowledgement

The authors thank team members of the School of Economics and Management at the National University of Malaysia and the anonymous reviewers for helpful comments on earlier drafts of the paper.

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