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Global research trends on forest rehabilitation and biodiversity: A bibliometric analysis

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ABSTRACT

Forest ecosystems play a crucial role in maintaining biodiversity, regulating climate systems, and supporting human well-being. However, widespread deforestation, land-use change, and climate change have caused severe forest degradation worldwide, making forest rehabilitation and biodiversity a global environmental priority. Although the scientific literature linking forest rehabilitation and biodiversity has grown rapidly, a comprehensive understanding of research trends, major contributors, and thematic evolution remains limited. This study presents a global bibliometric analysis of scientific publications on forest rehabilitation and biodiversity from 2000 to 2026 using data retrieved from the Scopus database. A total of 562 peer-reviewed articles were analyzed using the Bibliometrix package in R and the Biblioshiny interface to examine publication trends, authorship patterns, international collaboration networks, influential journals and articles, and thematic structures. The results revealed a steady increase in publication output, with significant acceleration after 2015, coinciding with growing global attention to forest rehabilitation and environmental sustainability issues. Research in this field is highly collaborative, with strong contributions from developed countries, particularly the United States, the United Kingdom, and China. Thematic analysis showed that reforestation, biodiversity, and conservation are the most central and well-developed themes, while climate change, ecosystem services, and land-use dynamics represent emerging areas receiving increasing attention. Overall, this study provides a comprehensive overview of the scientific landscape of research on forest restoration and biodiversity while identifying knowledge gaps and future research directions. These findings offer valuable insights for researchers, policymakers, and practitioners in developing evidence-based strategies for ecological restoration and biodiversity conservation.

Keywords: Bibliometric analysis, biodiversity, forest rehabilitation, R-studio

INTRODUCTION

Forests play a fundamental role in maintaining global ecological stability (Djafar et al., 2023), supporting biodiversity (Gunawan et al., 2024), regulating climate systems (Psistaki et al., 2024), and sustaining ecosystem services essential for human well-being. However, over the last several decades, forest ecosystems worldwide have undergone severe degradation driven by deforestation, land-use change, unsustainable resource extraction, and the accelerating impacts of climate change (Hermosilla-Palma et al., 2021). These pressures have resulted in significant losses of biodiversity,

disruption of ecological processes, and declining forest resilience (Hallaj et al., 2024), posing urgent challenges for conservation and sustainable management. In response, forest rehabilitation broadly defined as interventions aimed at restoring the ecological functions, productivity, and biodiversity of degraded forest landscapes has emerged as a central component of global environmental policy and scientific research (Buthelezi et al., 2025). Efforts such as reforestation, assisted natural regeneration, enrichment planting, and ecological restoration have been prioritized to recover ecosystem structure and enhance resilience in the face of ongoing ecological threats.

Forest restoration is one of the most promising and powerful approaches to tackle the grand challenges of climate change and biodiversity loss (Brancalion et al., 2025). Biodiversity serves as a key indicator of ecosystem health and stability, and its restoration is often a primary objective of forest rehabilitation programs (Brouwer et al., 2024). Healthy forests with high species diversity exhibit greater adaptive capacity, improved ecosystem functioning, and enhanced carbon sequestration potential all of which are essential for achieving global sustainability goals (Enríquez-de-Salamanca, 2022). International frameworks such as the UN Decade on Ecosystem Restoration (2021–2030), the Convention on Biological Diversity (CBD), and the Sustainable Development Goals (SDGs) have highlighted the role of forest rehabilitation as an indispensable strategy for addressing ecological degradation and biodiversity loss. As a result, scientific research in this domain has expanded rapidly, generating a diverse body of knowledge across ecological, environmental, and socio-economic dimensions.

Despite its growing significance, the scientific landscape of forest rehabilitation research, particularly its intersection with biodiversity, remains highly fragmented. Studies vary widely in thematic focus, terminology, methodological approaches, and spatial scales. While some research emphasizes ecological mechanisms and species-level responses, others examine restoration techniques, landscape-scale management, or policy implications. This diversity makes it challenging to synthesize global patterns and to identify dominant research directions, influential contributors, and emerging themes. Furthermore, the rapid expansion of literature over the past two decades necessitates systematic mapping to understand how the field has evolved in response to shifting ecological priorities and international policy initiatives.

Bibliometric analysis provides a powerful quantitative approach for analyzing the structure, productivity, and thematic evolution of a scientific field (Lim et al., 2024). By systematically evaluating publication trends, citation patterns, authorship networks, and keyword co-occurrences, bibliometric methods enable researchers to identify global knowledge structures and research hotspots. Previous bibliometric studies have explored restoration ecology (Shen et al., 2023), forest rehabilitation (Hayati et al., 2025), reforestation, and biodiversity (Bent et al., 2024; Priyono et al., 2023) separately; however, comprehensive analyses specifically linking forest rehabilitation and biodiversity remain limited. There is a need for an integrative assessment that examines how rehabilitation and biodiversity research have co-developed, which regions or countries lead the scientific discourse, and what themes or methods are shaping the direction of the field.

Therefore, this study aims to provide a global bibliometric analysis of scientific publications on forest rehabilitation and biodiversity from 2000 to 2026. Using data indexed in the Scopus database and analyzed through the Bibliometrix package in R and the Biblioshiny interface, this research examines publication trends, authorship and country collaboration networks, and thematic structures across the literature. Specifically, this study addresses three core objectives: (1) to map the temporal evolution of research productivity in

forest rehabilitation and biodiversity; (2) to analyze patterns of international collaboration and identify leading contributors; and (3) to explore major research themes, conceptual structures, and emerging trends within the field. By synthesizing these elements, the study offers a comprehensive overview of the scientific trajectory of forest rehabilitation and biodiversity research, providing insights that can guide future investigations, inform policy development, and strengthen global collaborative efforts toward ecological restoration and biodiversity conservation.

METHOD

Research setting and literature search

This study employs a bibliometric analysis approach to map the development of scientific knowledge on forest rehabilitation and biodiversity over the past two decades. Bibliometric analysis was selected because it provides a comprehensive overview of publication dynamics, international collaboration patterns, and the structure and evolution of research themes in a systematic manner. This approach also enables the identification of conceptual developments, influential research actors, and emerging future research directions. Therefore, bibliometric analysis is an appropriate method for depicting the scientific landscape of forest rehabilitation and biodiversity in a comprehensive, data-driven, and reproducible way.

The research data was sourced from the Scopus database, which is recognized as one of the largest and most credible international scientific publication indexes. Scopus was selected because it provides broad multidisciplinary coverage, standardized citation information, and compatibility with bibliometric software tools commonly used for science mapping analyses. Data collection covered the period 2000–2026 to capture both early and contemporary developments in forest rehabilitation and biodiversity studies. Article retrieval was conducted using the TITLE-ABS-KEY search field in Scopus with the following keyword combination: TITLE-ABS-KEY(("ecosystem rehabilitation" OR "forest landscape rehabilitation" OR reforestation) AND biodiversity), designed to encompass a broad spectrum of research linking forest rehabilitation with biodiversity aspects. The data retrieval process was conducted on December, 3rd 2025. The initial search yielded 3,068 documents. Subsequently, a screening process was applied using several inclusion criteria, namely document type (article), subject area (Environmental Sciences), publication source (scientific journals), open-access status, and English language. We used open-access articles due to limited funding for accessing subscription-based publications. In addition, only English-language articles were included because English is the most widely used international language in scientific publications. After all filters were applied, a total of 562 articles were identified as relevant and eligible for analysis. The data were then downloaded in BibTeX and CSV formats for further analysis using statistical and bibliometric software.

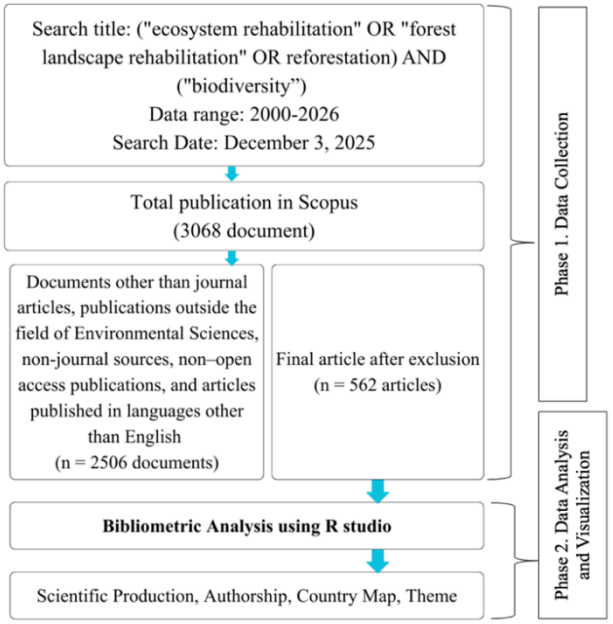


Figure 1. Flow chart of data collection, data analysis, and data visualization.

Data analysis

The analytical stages were conducted using R-studio with the Bibliometrix package and the

Biblioshiny visual interface to facilitate quantitative analysis and scientific mapping. The analysis procedure began with data cleaning, which included checking duplicate records, normalizing author and institutional names, ensuring keyword consistency, and harmonizing bibliographic variables. Subsequently, a performance analysis was performed to assess annual publication productivity, the most prolific authors and journals, the most highly cited articles, and visualizations of research growth trends. This analysis provides insight into the evolution of research volume and the contributions of key scientific actors in the field. The next stage involved collaboration analysis**,** which examined collaboration networks among countries, author groups, and institutional affiliations. This analysis included mapping co-authorship networks to explore scientific connectivity among researchers and to identify countries or institutions that function as global collaboration hubs. Network visualizations were presented in the form of network maps illustrating the intensity and direction of collaborative relationships.

The final stage focused on science mapping, aimed at revealing the intellectual structure and dynamics of the research field. This stage comprised keyword co-occurrence analysis to identify dominant keywords and major thematic clusters, thematic mapping to distinguish core, emerging, and declining themes, and thematic evolution analysis to track shifts in research focus over the two-decade period. Collectively, these mapping results provide a comprehensive overview of the scientific trajectory and key issues shaping the discourse on forest rehabilitation and biodiversity. Overall, this study focuses on three main bibliometric aspects: (1) publication trends and dynamics over time, (2) international collaboration patterns among countries and institutions, and (3) thematic mapping and conceptual evolution within global literature. Through this approach, the study offers empirical insights into how knowledge on forest rehabilitation and biodiversity has developed, disseminated, and become interconnected within the international scientific community.

RESULTS AND DISCUSSION

In this part of the study, link strength is used to examine the intensity of relationships within the scientific landscape, including scientific production, authorship, country collaboration, and thematic structures.

Descriptive bibliometric analysis

Table 1 summarizes the main characteristics of the dataset and shows that research on forest rehabilitation and biodiversity has grown steadily from 2002 to 2026, with an annual growth rate of 6.94%. A total of 562 documents published in 160 sources indicate that the field is supported by a broad range of journals. The involvement of 3,049 authors, with an average of 5.95 co-authors per paper, and an international co-authorship rate of 46.26% demonstrate the high level of collaboration and global engagement in this research area. Only 13 single-authored papers highlight the dominance of team-based research. The large number of author keywords (2,163) reflects thematic diversity, while 4,699 cited references indicate a well-established knowledge base. The average document age of 4.85 years shows that the literature is relatively recent.

Table 1. Main information

Description	Results
Timespan	2000-2026
Sources	160
Document	562
Annual Growth	6.94%
Authors	3049
Author of single-authored document	13
International Co-Authorship	46.26%
Co-Author per Doc	5.95
Author’s Keywords (DE)	2163
References	4699
Document Average Age	4.85
Average citations per doc	23.43

The overall information presented in Table 1 is discussed in detail in the following headlines of the study.

Annual scientific production

Overall, the annual scientific production on forest rehabilitation and biodiversity shows a steady upward trend from 2000 to 2026 (Figure 2). A noticeable increase appears shortly after 2005, coinciding with the entry into force of the Kyoto Protocol, which strengthened global commitments to carbon mitigation and stimulated interest in forest-based climate solutions (Ge & Lin, 2021). Publication output rises more substantially after 2015, aligning with the adoption of the Paris Agreement and the Sustainable Development Goals (SDGs), both of which emphasized forest rehabilitation, carbon sequestration, and biodiversity conservation as global priorities. These policy shifts appear to have catalyzed intensified research activity, leading to a marked surge in publications from 2018 onward. The sharp peak in 2024 reflects the culmination of growing international attention toward restoration initiatives under the UN Decade on Ecosystem Restoration (2021–2030). Collectively, these trends suggest that major global environmental agreements have played an important role in shaping and accelerating scientific output in this field.

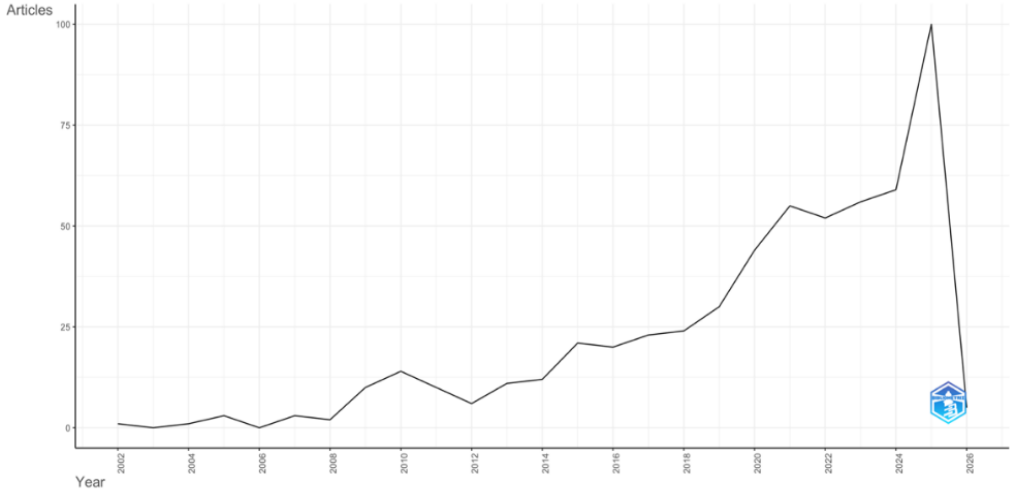


Figure 2. Annual scientific production
(Source: visualize using Biblioshiny)

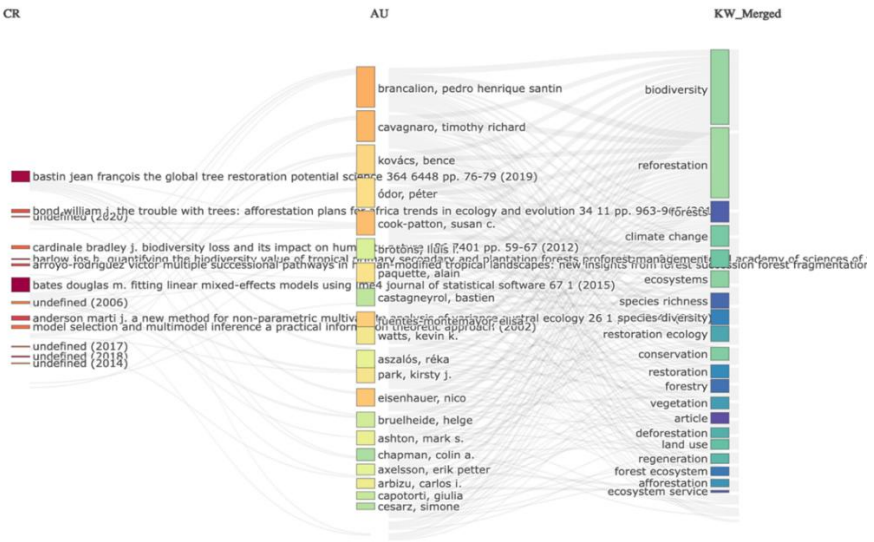


Figure 3. Sankey diagram that visualizes relationships among article key scientific references, authors, and research themes (Source: visualize using Biblioshiny).

The diagram (Figure 3) shows how key scientific references, authors, and research themes are interconnected within a body of environmental and ecological literature. Several influential papers often related to global tree restoration potential, biodiversity loss, afforestation, and statistical or ecological methodology link to a diverse group of authors working across fields such as reforestation, conservation, forestry, climate change, and ecosystem services. The authors occupy the central position in the visualization, illustrating how their work bridges foundational references and major thematic areas. On the right, the merged keywords highlight the dominant topics in this research landscape: *biodiversity, reforestation, ecosystem functioning, species richness, restoration ecology*, and *land use*. Overall, the pattern of flows suggests a research domain strongly centered on ecological restoration and biodiversity, supported by widely cited studies and spanning multiple interconnected subfields.

Authorship

Authorship identification enables a clear understanding of who produces knowledge, how scientific contributions are distributed, and how influence is structured within a research field. By accurately identifying authors, bibliometric analysis can assess research productivity and impact, identify influential scholars, and map co-authorship networks that reveal collaboration patterns across institutions and countries. This information helps trace the diffusion of ideas, highlights key knowledge brokers, and ensure the reliability of performance indicators such as publication counts and citation metrics. Moreover, proper authorship identification reduces errors caused by name variations or ambiguities, thereby improving the validity of the analysis and supporting strategic decisions related to collaboration, funding, and future research directions.

The research trend on forest rehabilitation and biodiversity shows the distribution of authors based on the number of documents they have contributed. Brancalion, Pedro Henrique Santin is the most prolific author with seven documents. Cavagnaro, Timothy Richard; Cook-Patton, Susan C.; and Eisenhauer, Nico each contributed five documents. Several other authors –namely Fuentes-Montemayor, Elisa; Kovács, Bence; Paquette, Alain; Park, Kirsty J.; Watts, Kevin K.; and Ódor, Péter –each contributed four documents, indicating a relatively balanced level of productivity among this group of authors.

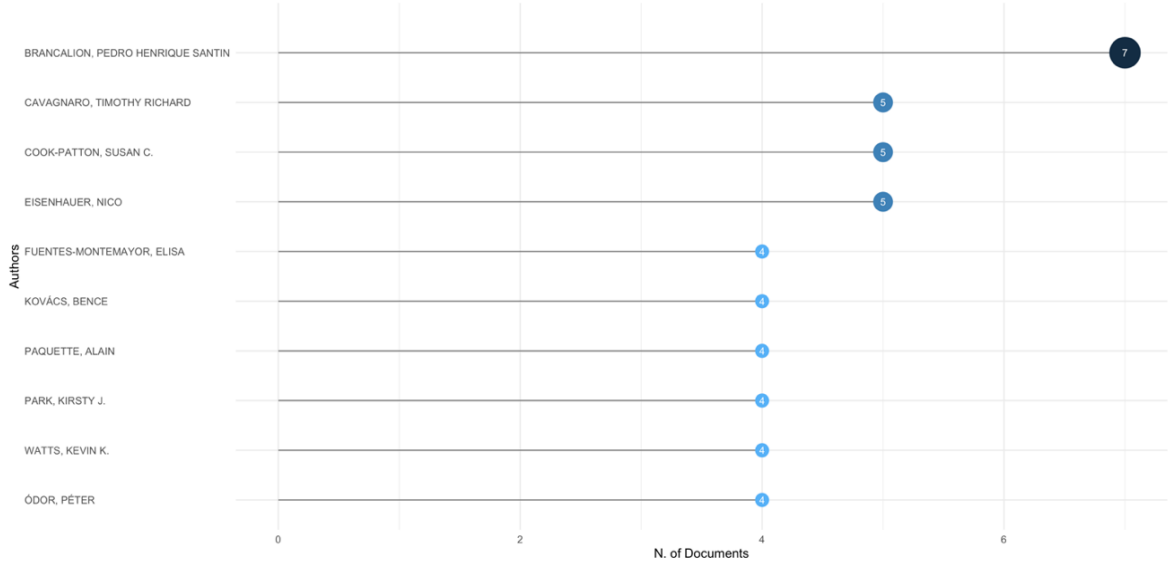


Figure 4. Most relevant authors
(Source: Visualize using Biblioshiny)

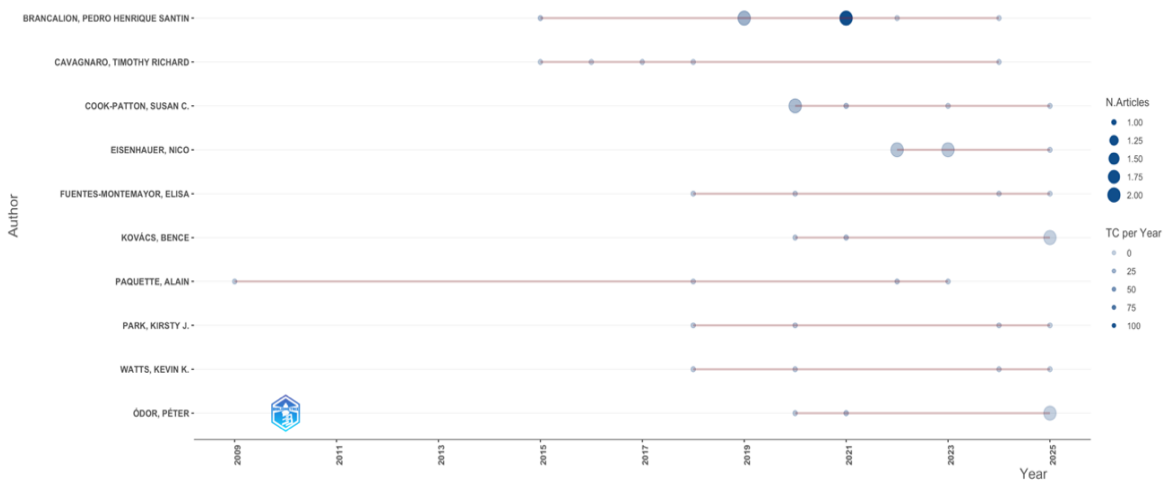


Figure 5. Authors' production overtime
(Source: Visualize using Biblioshiny)

Based on the most relevant authors and authors' production overtime figures, Brancalion, Pedro Henrique Santin is the most prolific author publishing articles on forest restoration (N = 7). In 2015, he published one article; in 2019, two articles; in 2021, two articles; in 2022, one article; and in 2024, one article (Figure 5). Detailed information on the article titles, journals, and keywords is presented in Table 2.

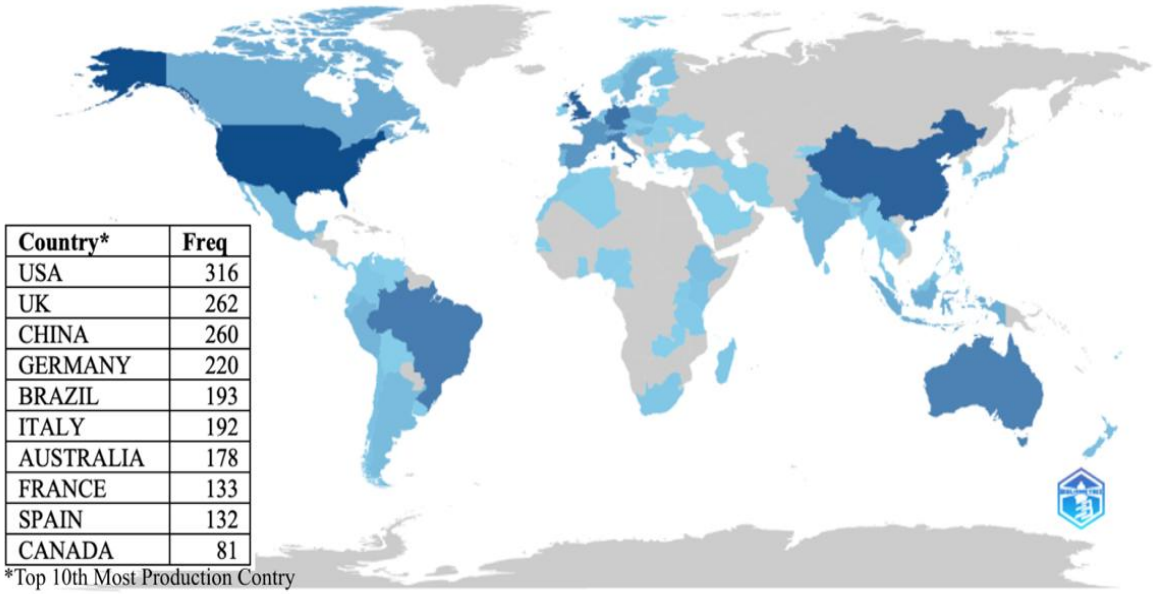
Table 2. Paper detail authored by Brancalion, et al.

No.	Title	Year	Journal	Keywords
1	Land-use patterns and fungal bioaerosols in the Brazilian Atlantic Forest biome (Mantoani et al., 2024)	2024	Discover Environment	Coffea arabica; Eucalyptus; Fungal spores; Ice nucleation; Maize; Restoration
2	Natural forest regrowth under different land use intensities and landscape configurations in the Brazilian Atlantic Forest (Schweizer et al., 2022)	2022	Forest Ecology and Management	Aboveground biomass; Dynamic model; Forest and landscape restoration; Forest dynamics; Forest management
3	Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits (Di Sacco et al., 2021)	2021	Global Change Biology	afforestation; biodiversity; carbon sequestration; climate change; livelihood; reforestation; regeneration; restoration ecology
4	Transformative governance for linking forest and landscape restoration to human well-being in Latin America (Aguiar et al., 2021)	2021	Ecosystems and People	climate change; governance approach; land tenure; land use; landscape ecology; reforestation; restoration ecology; Latin America
5	The effectiveness of lidar remote sensing for monitoring forest cover attributes and landscape restoration (Almeida et al., 2019)	2019	Forest Ecology	Biodiversity; Cost effectiveness; Land reclamation; Optical radar; Reforestation; Remote sensing; Restoration
6	Intensive silviculture enhances biomass accumulation and tree diversity recovery in tropical forest restoration (Brancalion et al., 2019)	2019	Ecological Applications	abundance; anthropogenic effect; biodiversity; biomass; conservation status; forest management; forestry; plantation forestry; reforestation
7	Creating space for large-scale restoration in tropical agricultural landscapes (Latawiec et al., 2015)	2015	Frontiers in Ecology and the Environment	agricultural land; biodiversity; ecosystem service; exploitation; income; productivity; reforestation; restoration ecology; risk assessment; timber

These papers together paint a coherent narrative about how forest rehabilitation can successfully restore biodiversity and ecosystem function when ecological, technological, and social dimensions are integrated. They show that forests are shaped not only by the trees that grow in them but also by the microorganisms such as fungal bioaerosols (Mantoani et al., 2024), technology (Almeida et al., 2019), and human decisions that influence their recovery (Aguiar et al., 2021).

Country map

An analysis of the country's distribution of research can help to comprehend a county's capacity and explore capacity differences among various countries (Huang et al., 2016). Academic collaboration among different countries may assume a guiding role in promoting the dissemination of knowledge and academic exchange (Chen et al., 2020). The collaboration world map shows the authors' country-based affiliation. The color on the map shows the intensity level of the publications (light colors indicate week intensity and dark color indicates strong intensity (Figure 6).



Country*	Freq
USA	316
UK	262
CHINA	260
GERMANY	220
BRAZIL	193
ITALY	192
AUSTRALIA	178
FRANCE	133
SPAIN	132
CANADA	81

*Top 10th Most Production Contry

Figure 6. Country scientific production
(Source: visualize using Biblioshiny)

Based on the visualization, United States of America (316 publications), followed by the United Kingdom (262) and China (260) (Figure 6), reflecting strong research capacity, funding, and policy prioritization in these countries. The high output from the USA and UK is closely linked to long-standing investments in ecological restoration, ecosystem services, and interdisciplinary approaches, often supported by extensive international collaboration. Meanwhile, China's growing contribution highlights increasing national attention to land degradation, biodiversity loss, and large-scale ecological restoration programs. Overall, the distribution of scientific production indicates that this research field remains largely led by developed countries, underscoring the need to strengthen research capacity and collaboration in developing regions where land degradation and biodiversity loss are most pronounced.

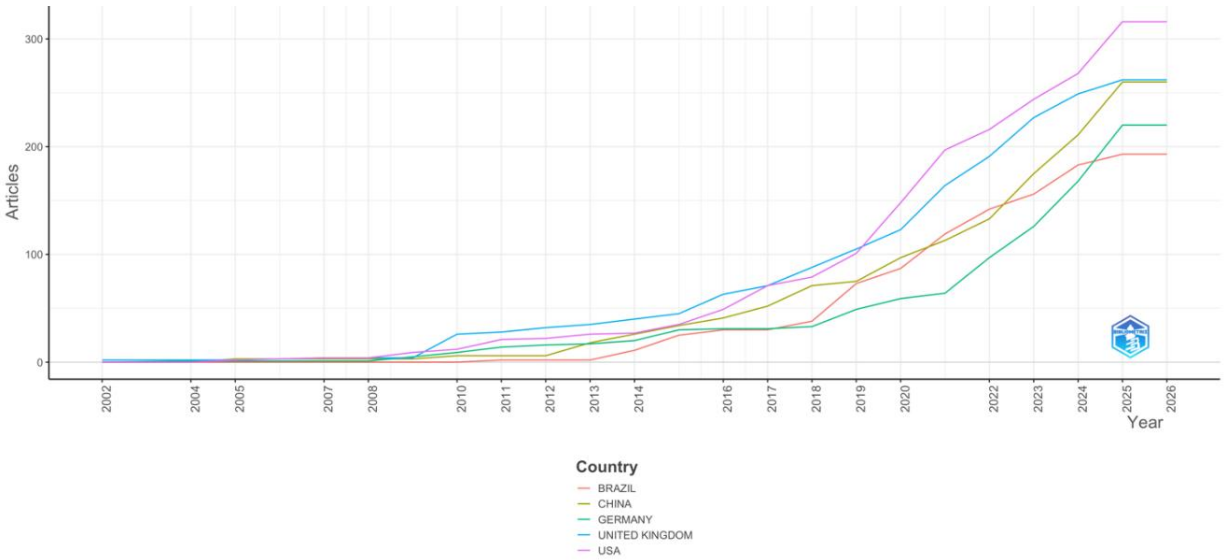


Figure 7. Country production over time
(Source: visualize using Biblioshiny)

Meanwhile, Figure 7 shows a clear upward trend in scientific production on forest rehabilitation and biodiversity across all countries over time, with a marked acceleration after the mid-2010s. The USA exhibits the steepest and most consistent growth, maintaining its leadership throughout the period, followed closely by the United Kingdom and China, both of which show rapid increases in publication output in recent years. Germany and Brazil also demonstrate steady growth, although at a comparatively lower scale. Overall, the temporal pattern indicates a growing global research interest in forest rehabilitation and biodiversity, likely driven by increasing concerns over land degradation, biodiversity loss, and climate change, as well as the expansion of national and international restoration initiatives.

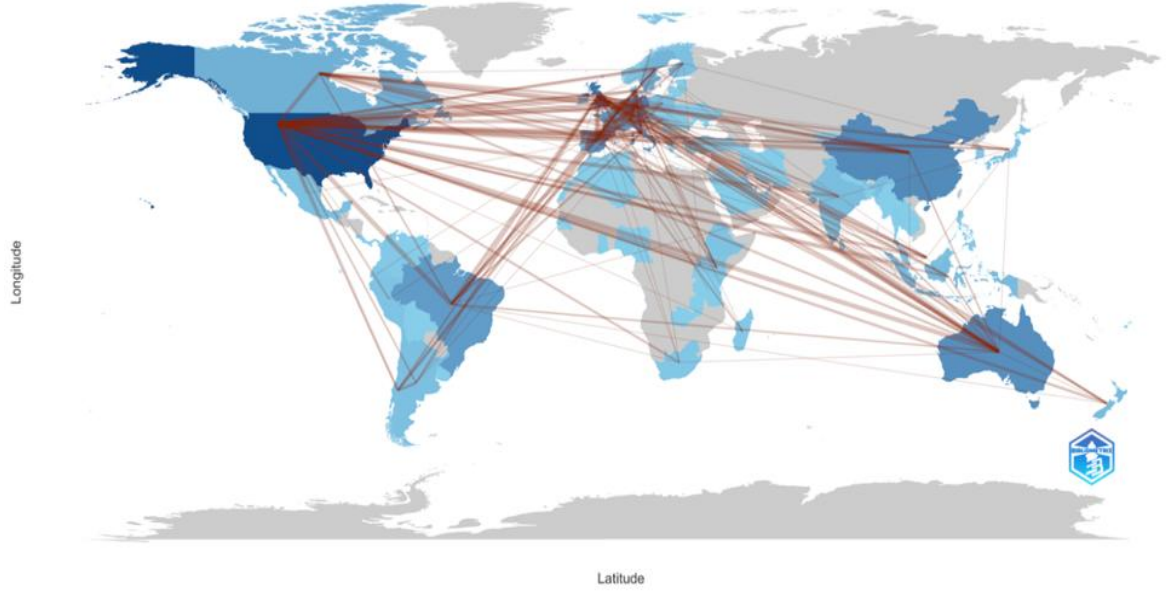


Figure 8. Country collaboration map
(Source: visualize using Biblioshiny)

Figure 8 illustrates the global collaboration network in research on forest rehabilitation and biodiversity, revealing a highly interconnected pattern dominated by a small number of central countries. The United States**,** United Kingdom, China, Germany, and

Australia emerge as major collaboration hubs, as indicated by the dense network of international links extending across Europe, Asia, the Americas, and Oceania. The strong transcontinental connections suggest that research in this field is largely driven by international partnerships, particularly between developed countries and regions rich in biodiversity. However, collaboration intensity remains uneven, with many countries in the Global South participating mainly as peripheral partners. This pattern highlights the importance of strengthening equitable and reciprocal international collaborations to enhance knowledge exchange and context-specific solutions for forest rehabilitation and biodiversity conservation.

Theme

The diversity of themes in research trends on forest rehabilitation and biodiversity reveals the dynamic and interdisciplinary nature of the field, reflecting a transition from narrowly focused ecological restoration toward integrated approaches that combine biodiversity conservation, reforestation, land-use management, ecosystem services, and climate change mitigation. This thematic diversity indicates growing recognition that forest rehabilitation is a complex socio-ecological process, requiring the integration of ecological science, spatial technologies, and sustainability-oriented management strategies to address global environmental challenges (Guzman-Molina et al., 2025).

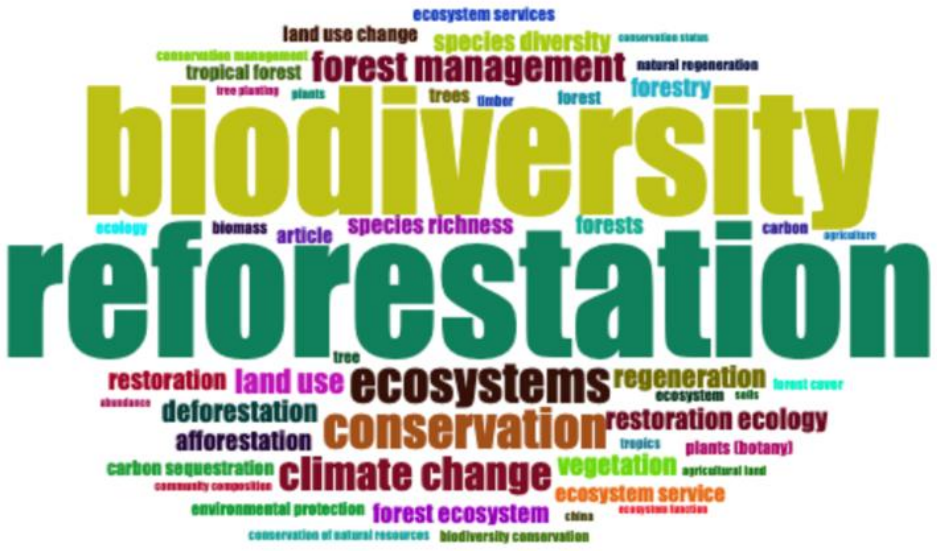


Figure 9. Cloud word of research trend on forest rehabilitation and biodiversity
(Source: Visualize using Biblioshiny)

Figure 9 presents a keyword co-occurrence word cloud highlighting the dominant themes in research on forest rehabilitation and biodiversity. The most prominent terms biodiversity, reforestation, ecosystems, and conservation indicate that the literature strongly emphasizes forest-based rehabilitation and ecosystem-level approaches to biodiversity recovery. Frequently appearing keywords such as forest management, restoration ecology, land use, and ecosystem services reflect an integrative perspective that links ecological restoration with sustainable land management and human benefits. The presence of terms like climate change, carbon sequestration, and regeneration further suggests that forest rehabilitation research is increasingly framed within the context of climate change mitigation and ecosystem resilience (Kundariati et al., 2024). Overall, the keyword distribution demonstrates a convergence of biodiversity conservation, forest restoration, and climate-related objectives within this research field.

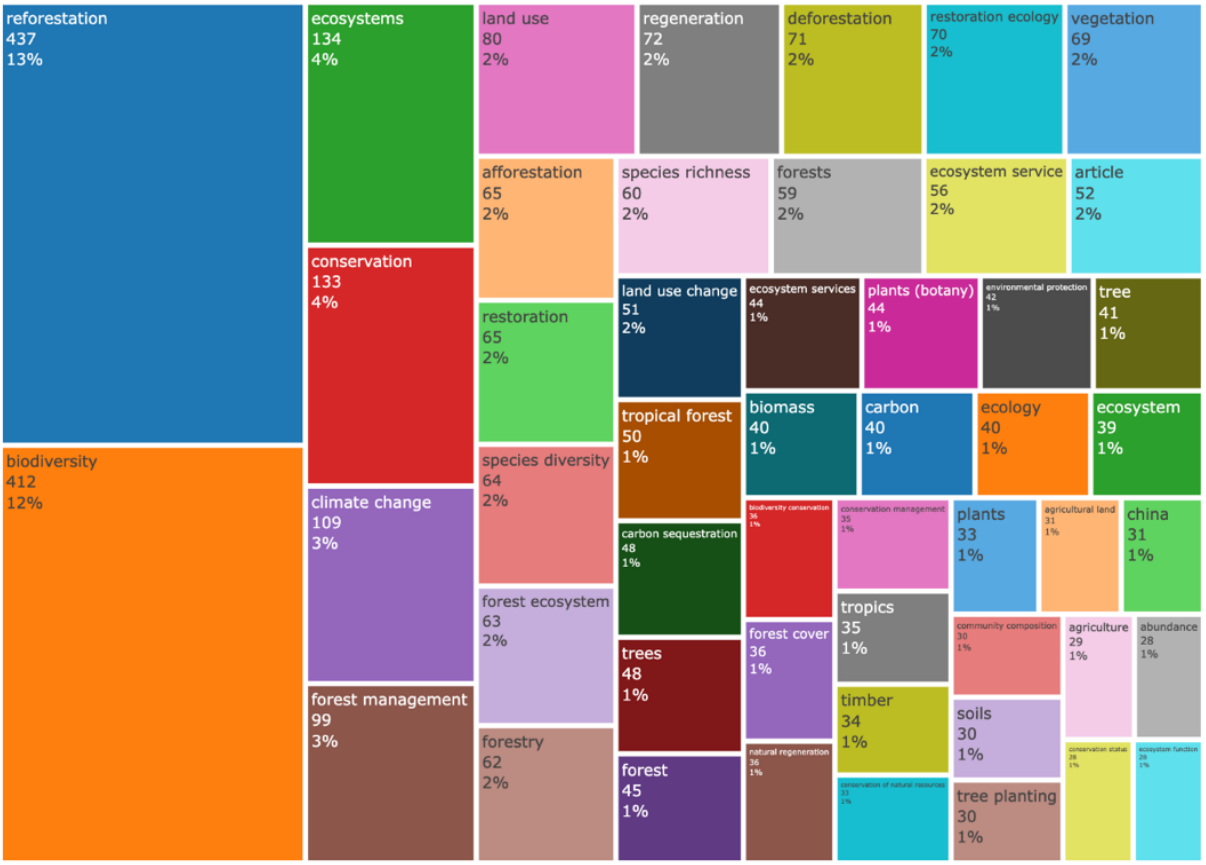


Figure 10. Tree map of research trend on forest rehabilitation and biodiversity (Source: Visualize using biblioshiny)

Figure 10 illustrates a thematic tree map of keyword frequencies in research on forest rehabilitation and biodiversity**.** The largest nodes are reforestation (437 occurrences, 13%) and biodiversity (412, 12%), indicating that forest-based restoration and biodiversity recovery are the central focus of the literature. Other prominent themes include ecosystems (134, 4%), conservation (133, 4%), climate change (109, 3%), and forest management (99, 3%), highlighting the integration of ecological restoration with climate-related concerns and sustainable management practices. Medium- and smaller-sized themes such as land use**,** afforestation**,** species richness**,** restoration ecology, and carbon sequestration reflect more specific ecological processes and management strategies. Overall, the tree map shows a research landscape dominated by forest and biodiversity-centered rehabilitation, with increasing attention to climate change mitigation, ecosystem services, and land-use dynamics.

The evolution of trend topics in forest rehabilitation and biodiversity research over time. Early studies (around 2007–2012) focused mainly on species identification, habitat types, and forest structure, reflecting a descriptive and taxonomy-oriented phase. From the mid-2010s onward, research expanded toward forest management, ecosystem management, restoration, and land-use change, indicating a shift to applied and management-oriented approaches. In recent years (2019–2024), dominant topics include biodiversity, reforestation, ecosystem services**,** climate change, and remote sensing, highlighting an increasing emphasis on large-scale restoration, climate-related challenges, and the use of advanced spatial technologies. Overall, the trend analysis demonstrates a clear transition from localized ecological assessments to integrated, technology-supported, and climate-oriented forest rehabilitation research.

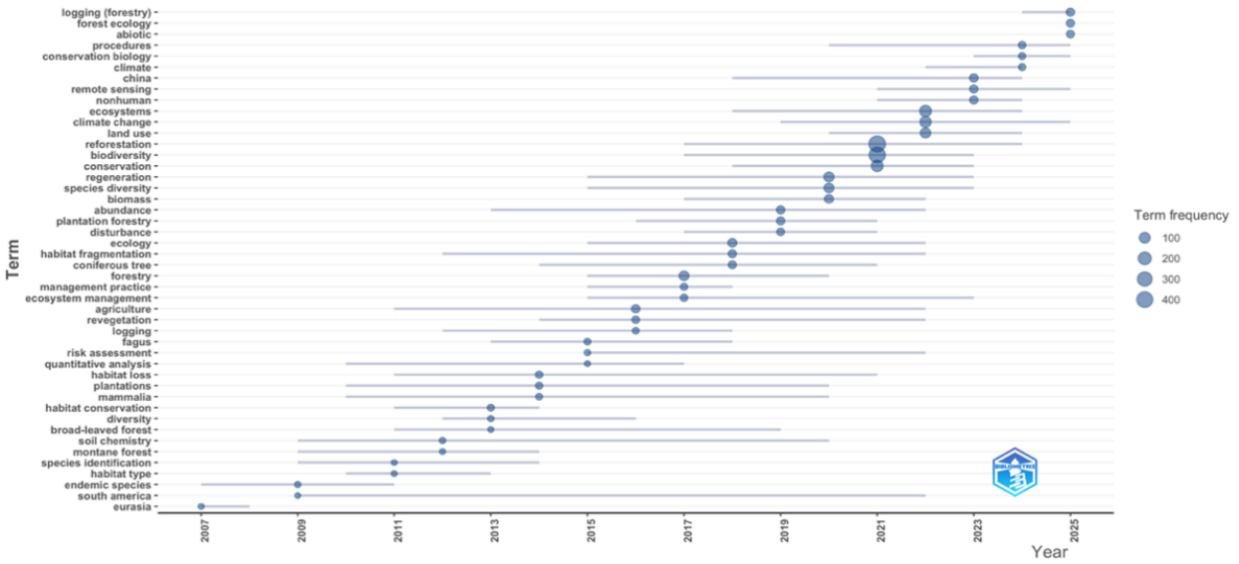


Figure 11. Trend topic on forest rehabilitation and biodiversity research trend (Source: Visualize using Biblioshiny)

Scientific mapping techniques consist of thematic maps that depict the conceptual structure of a particular research domain (Figure 12). The thematic map consists of a network analysis of word occurance to explain what science is saying in a field, key themes, and patterns (Jain et al., 2022). Density is used to measure consistency between nodes and centrality is used to measure the degree of correlation among different subjects (Jelvehgaran Esfahani et al., 2019).

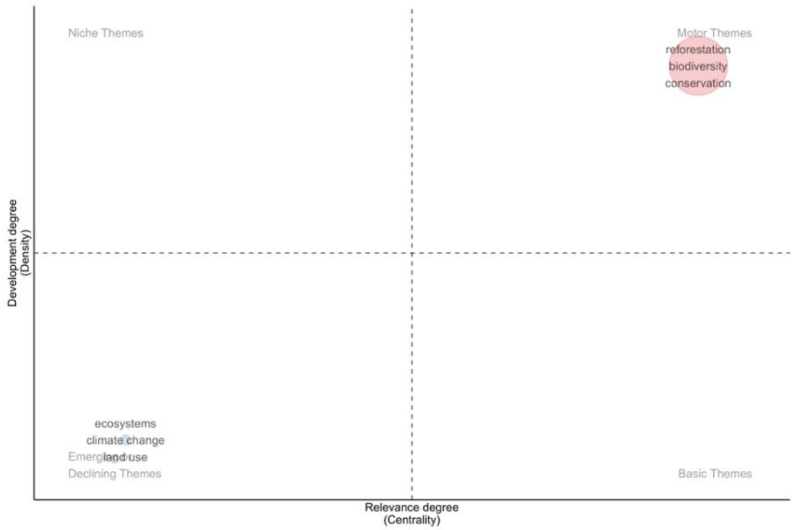


Figure 12. Keywords with the strongest citation burst on forest rehabilitation and biodiversity research trend (Source: Visualize using Biblioshiny)

Figure 12 contains the keywords with the strongest citation burst. The blue line represents the time interval, whereas the black line stands for the time it was detected that a keyword has a burst. The thematic map of forest rehabilitation and biodiversity research based on relevance (centrality) and development (density). Reforestation, biodiversity, and conservation are positioned in the motor themes quadrant, indicating that these topics are both highly developed and central to the field, and thus drive current research agendas. In contrast, ecosystems, climate change, and land use appear in the emerging or declining themes quadrant, suggesting that while these topics are relevant, they are either still consolidating conceptually or

receiving comparatively less focused development within this literature. Overall, the thematic structure highlights forest-based biodiversity restoration as the core and most mature research stream, while broader system-level and climate-related themes represent areas with potential for further integration and growth.

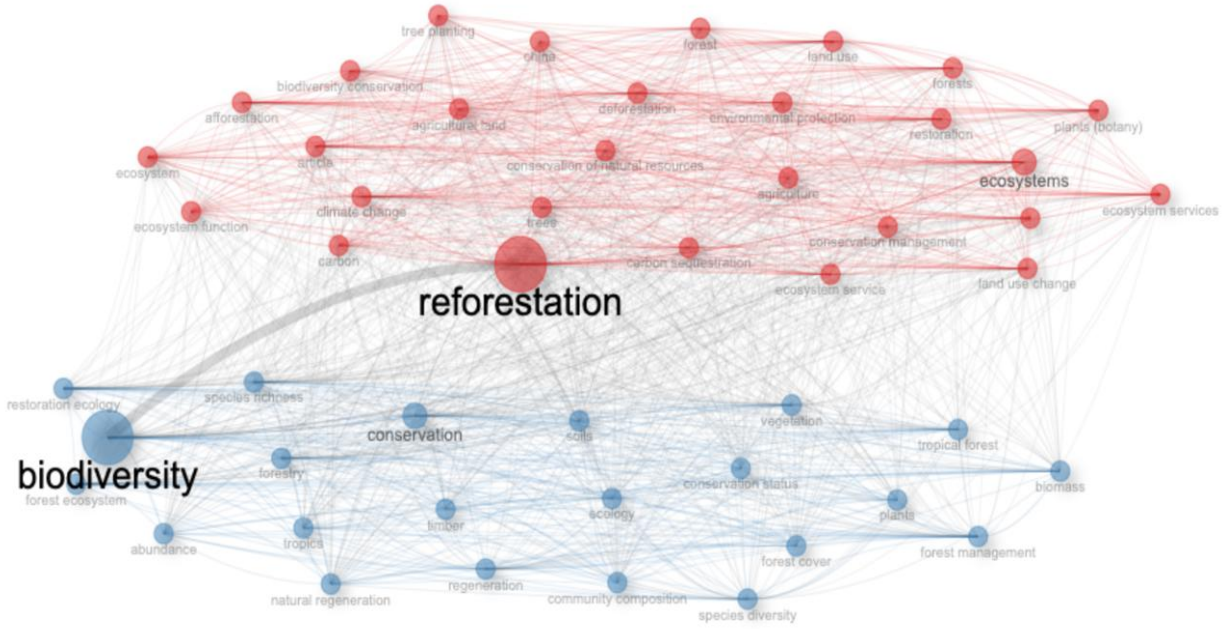


Figure 13. Co-occurrence network
(Source: Visualize using Biblioshiny)

Figure 13 shows a keyword co-occurrence network in forest rehabilitation and biodiversity research, revealing two strongly connected thematic clusters. The first cluster, centered on reforestation, is closely linked to terms such as land use, ecosystems, ecosystem services, carbon sequestration, and climate change, highlighting a focus on research focus on forest-based restoration as a strategy for ecosystem recovery and climate mitigation. The second cluster is dominated by biodiversity, which connects with keywords including species richness, species diversity, forest ecosystem, and conservation, reflecting ecological outcomes and biodiversity responses to rehabilitation efforts. The dense interconnections between the two clusters indicate that reforestation and biodiversity are highly integrated research themes, emphasizing that forest restoration is widely studied both as a land management intervention and as a driver of biodiversity conservation.

These findings are particularly relevant to Indonesia, one of the world's mega biodiversity countries facing substantial forest degradation and land-use change challenges (Adinugroho et al., 2022). The increasing global emphasis on ecosystem restoration and biodiversity conservation aligns with Indonesia's national forest rehabilitation programs and climate mitigation commitments (Adiwinata et al., 2022). However, the bibliometric findings also indicate that contributions from developing tropical countries remain relatively limited, suggesting the need to strengthen Indonesian research capacity, international collaboration, and long-term restoration monitoring initiatives.

CONCLUSION

This bibliometric analysis provides a comprehensive overview of the development of research on forest rehabilitation and biodiversity during the 2000–2026 period. First, regarding publication trends and research performance, the results indicate a substantial

increase in scientific output over the past two decades, reflecting growing global concern over forest degradation, biodiversity loss, climate change mitigation, and ecosystem resilience. The increasing number of publications and citations demonstrate that forest rehabilitation has become an important and expanding area of environmental research.

Second, concerning collaboration patterns and scientific contributions, the analysis reveals strong international collaboration networks involving authors, institutions, and countries. Developed countries play a dominant role in shaping the scientific landscape, particularly through high publication productivity and influential citation performance. At the same time, collaboration among institutions has contributed to the interdisciplinary development of the field and the dissemination of restoration-related knowledge across regions.

Third, with respect to thematic evolution and research focus, the findings show that major research themes are concentrated on reforestation, biodiversity recovery, ecosystem services, and climate change. Recent thematic developments also indicate a shift toward more integrated and technology-oriented restoration approaches, including the use of remote sensing, spatial analysis, and data-driven environmental monitoring. These emerging themes suggest that forest rehabilitation research is increasingly linked to sustainable development and climate adaptation agendas.

Based on the bibliometric findings, several directions for future research are recommended. First, greater attention should be given to biodiversity-rich developing regions, which remain underrepresented in scientific literature despite their ecological importance and vulnerability to forest degradation. Second, more equitable international collaboration should be encouraged to strengthen research capacity, knowledge exchange, and inclusive scientific participation across regions.

In addition, future studies should integrate socio-economic, governance, and community-based perspectives alongside ecological and technological approaches, as these aspects appear less dominant in the current research landscape. Long-term monitoring studies and comparative cross-regional analyses are also needed to better evaluate restoration effectiveness under different environmental and socio-political contexts. Finally, the broader application of advanced technologies, such as remote sensing, big data analytics, and participatory monitoring methods, may improve evidence-based decision-making for sustainable forest rehabilitation and biodiversity conservation.

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