



A Bibliometric Analysis on Public-Private Partnerships in Forest Management Using Bibliometrix R-Studio

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Received December 13, 2024/Accepted July 10, 2025

Abstract

The paper thereby joins the discussion on the fast-changing research landscape of public-private partnerships (PPPs) in forest management, providing a comprehensive bibliometric analysis. A dataset of 241 documents is retrieved from the Scopus database, whose analyses are done using advanced bibliometric tools available within the Bibliometrix package in R Studio. The study maps the intellectual structure of the field, identifies its key themes, and traces their evolution from 1987 to 2024. The bibliometric approach allows for the identification of core authors, influential journals, leading institutions, and geographical distribution of contributions, thereby painting a clear picture of the knowledge dynamics within the domain. The findings underline the central place PPP holds in the face of such global challenges as climate change, preservation of biodiversity, and sustainable development but bring into sharper focus the governance and institutional frameworks that underpin these partnerships. Special attention is paid to the policy discourses and academic debates surrounding PPP arrangements, especially in developing countries where forest governance is often contested. This paper identifies major emerging trends in future research, in particular, the integration of cutting-edge technologies like machine learning. It fills this critical gap with a holistic overview of the current state of the art in forest management PPPs, thus offering useful insights for researchers, policymakers, and practitioners who want to enhance the effectiveness of such partnerships in achieving sustainable environmental outcomes.

Keywords: public private partnerships, forest management, bibliometrix

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Introduction

Public-private partnerships (PPPs) are widely recognized as innovative approaches in forest conservation, particularly in addressing limited funding (Chisika & Yeom, 2021; Mishenina & Dvorak, 2022). Their applications include forest conservation, afforestation, value addition, and bioenergy, with the establishment of private timber development agencies identified as a key enabler (Widman, 2015). These partnerships offer financial benefits, support local economic empowerment, and enhance tourism outcomes (Ngwakwe & Mokgalong, 2016; Litheko, 2022). They also play a role in agricultural sustainability and global food security by bridging the capabilities of public and private sectors (Mangeni, 2019; Agarwal et al., 2023).

Empirical insights from Kenya suggest that PPPs can enhance forest governance by building trust between stakeholders (Chisika & Yeom, 2021), while in South Africa, they have contributed to conservation and job creation through local enterprises (Ngwakwe & Mokgalong, 2016). Conversely, the experience in China reveals risks of

renegotiation and inefficiency, underscoring the importance of strategic decision-making (Liang et al., 2019).

Despite their promise, it is important to note that they are not beyond criticism. Some scholars brought out risks, inefficiencies, and conflicts inherent in the implementation of PPPs (Papajohn et al., 2011; Siddiquee, 2011). In Sweden, institutional discretion affects landowner participation in conservation agreements (Widman, 2015). Stakeholder conflicts, especially those between economic actors and public interest users, continue to turn up in the forest management outcome (Eyvindson et al., 2019; Jakobsson et al., 2021; Termizi et al., 2023).

The growing interest of private-sector entities through PPPs is therefore a natural trend toward leveraging private investment, innovation, and efficiency for the achievement of public environmental goals. What is rather surprising, though, is that despite the growing popularity of PPPs in forest management, there seems to be very little scholarship in terms of a systematic understanding of how these partnerships really work across different contexts, what

results are being achieved, and what problems they commonly face. While various case studies and theoretical discussions have been included, comprehensive and large-scale analyses of mappings of the evolution of research in this area, identification of key themes, and emerging trends are still lacking. Furthermore, the heterogeneous use of terms within the literature, for example, in terms of spelling and conceptualization of "public-private partnerships", is likely to add to the complexity and potentially diminish the coherence and comparability of the results. Through this paper, an effort is made to bridge these gaps with an all-inclusive bibliometric analysis on the research into public-private partnerships in forest management. The aim of this paper is to map the intellectual landscape of the field, identify key themes of research, and trace their evolution over time. This analytical research effort tries to bring forth the current nuances in research on PPPs in forest management, highlighting the critical gaps and suggesting directions for future inquiry. This research contributes to the wider debate on how best to manage forests in a manner that generates insights useful for both academic research and practical policy decisions. The findings are thus expected to have value for researchers, policymakers, and practitioners concerned with improving the effectiveness of PPPs in tackling some of the most urgent environmental challenges of our times.

Methods

This work applied a strict bibliometric approach in analyzing the landscape of research relevant to PPPs in forest management, following previous studies (Ibrahim & Kumar, 2023; Kumar et al., 2023; Sajida & Kusumasari, 2023a; 2023b). Data collection began with a comprehensive search of the Scopus database, chosen for its excellent coverage of publications of a scholarly nature across all subject areas. The query used was TITLE-ABS-KEY (forest* AND "public-private partnership"), set to retrieve all documents that brought out relevance and contained these terms in the title, abstract, or keywords. The asterisk symbol (*) after the keyword "forest" included such terms as "forests," "forestry," and "forest management" to guarantee the greatest possible scope in the search. This produced an initial return of 245 documents. The application of a language filter limited documents to those published in English. This step was taken to ensure uniformity in the linguistic framework because much of the literature in scholarship across the world is often drafted using the English language, which aids in cross-comparative studies. This led to a dataset of 241 documents, which was used as the input for the next steps in analysis.

Bibliometric analysis in this study was supported by the Bibliometrix package in R Studio, which is a very powerful tool designed for quantitative research on bibliometrics. In this research, Bibliometrix was used to extract, analyze, and plot a wide range of bibliometric indicators that contributed to a better understanding of the dataset. The analysis proceeded along a few lines, including annual scientific production, to find out the trends in publication output over time and thereby obtain information about the important periods of activity concerning research and probable changes

in the focus of the field. Then, through thematic maps and Sankey diagrams, it was possible to trace the evolution of the main themes of research carried out to outline how the focus of the research has changed over time and what topics seem currently to be areas of interest. The study has also analyzed the most highly cited documents and key topics represented in the dataset, providing insight into foundational works and current research priorities within the chosen field. Then, factorial analyses were done to reveal how different research themes relate with each other, giving nuanced insight into exactly how different topics interrelate and the relative importance of these topics in the field. Ambitiously, the analyses map the intellectual structure and dynamics of research into PPPs in forest management, hence giving insight into its development, present situation, and way forward in this very important area of study.

Results

The scientometric analysis of PPPs in forest management demonstrates the development and the engagement of scholarship in the period between 1987 and 2024. From the data, it can be noted that 241 documents have been published by 165 sources, with the latest publications by Marandu et al. (2024). An annual growth rate of 6.12% indicates a steady rise in scholarly interest in PPPs in forest management.

The field involves 917 authors, with high collaboration indicated by an average of 3.93 co-authors per article and nearly 30% international co-authorship. With 836 keywords and over 11,000 citations across documents, the field shows both thematic diversity and strong academic integration (average 16.84 citations/document). Here, the bibliometric data described in Figure 1 show that it is a very dynamic area, which is well covered by solid academic collaboration, in addition to a quickly growing body of influential and more internationally linked literature. In such a way, this analysis underlines critical areas of PPPs in forest management, which will have both significant scholarly interest and significant real-world implications.

The yearly scientific production on PPPs in forest management, as observed in Figure 2, shows a wave-like increasing trend from 1987 to 2024. From 1987 to 1996, minimal activities had been noted, with just a few publications. After minimal activity before 2006, research in PPPs surged notably from 2012, peaking in 2019, likely due to growing global environmental concerns. This peak thus infers increased scholarly attention, probably triggered by global environmental challenges and increased recognition of PPPs as plausible strategies toward sustainable forest management. One of the interesting topics, the proposed model in transnational public-private partnership (TPPP), consists of four categories of social responsibility factors; these include economic, environmental, social, and people-oriented factors by Chen et al. (2019).

The number of publications peaked in 2013 and then declined to as low as 9 articles by the year 2024. The reduction could speak to several factors that include potential shifts in funding for research, a change of priorities in the academic community, maturation of the field, or consolidation of knowledge instead of rapid growth. The annual scientific production trajectory basically describes



Figure 1 Document output.

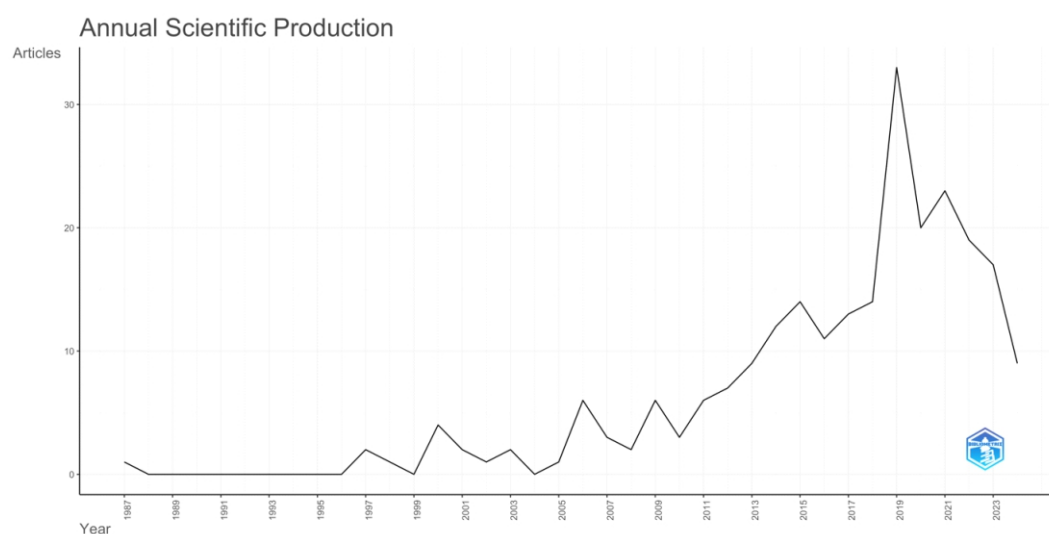


Figure 2 Annual scientific production.

dynamic interest in PPPs within forest management: it comprises rapid growth periods followed by stabilization. In 2019, the increase means some kind of critical moment of emergence or breakthrough of the field, while the subsequent decrease could be a transition phase in which the research community is digesting and building upon the extensive works produced in peak years.

This is highlighted by the average number of citations per annum for publications in the field of PPPs in forest management between the years 1987 and 2024, illustrated by the use of Figure 3. The trends in these numbers of citations reflect a range of milestone phases in the development of academic impact and dissemination for the research within this field. Citation impact remained low until the 2000s, with peaks in 2007, 2018, and 2021. A drop after 2019 suggests a consolidation phase in the field.

On the contrary, for 2019, there is clearly a strong decline in average citations per year, which is coincident with some general drop in yearly publications. Such a decrease might signal the beginning of a period of consolidation of the field with relatively fewer works of a breakthrough nature being produced, or it might signal the beginning of a change in the focus of the scholarly work being put out. In a nutshell, this context reflects the episodic nature of the scholarly impact of PPPs in the field of forest management. Peaks of high

influence are followed by phases of lower citation activity. Peaks in citation averages signal moments of paramount scholarly contribution, while the global constant downward trend of the most recent years may signal either the need for a new research focus or a need for innovation in approaches to restore the scholarly impact of the field.

Table 1 shows the top sources for PPP in forest management research according to the number of documents published. IOP Conference Series: Earth and Environmental Science tops the list with 13 publications, leading as the venue where research findings in this area have been shared (Zinovyeva et al., 2019). This conference would likely be a key platform for the presentation of new research and discussion related to all topics on environmental science, including forest management PPPs. The next important sources include Environmental Management, Forest Policy and Economics, and Sustainability; these three journals have a total of seven publications. Key sources include IOP Conference Series (13 articles), Environmental Management, Forest Policy and Economics, and Sustainability, reflecting both specialization and interdisciplinary appeal.

In other words, the placement of articles on PPPs in forest management across these sources indicates the interdisciplinary nature of the research. On the one hand, some of the publications are contained within specialized

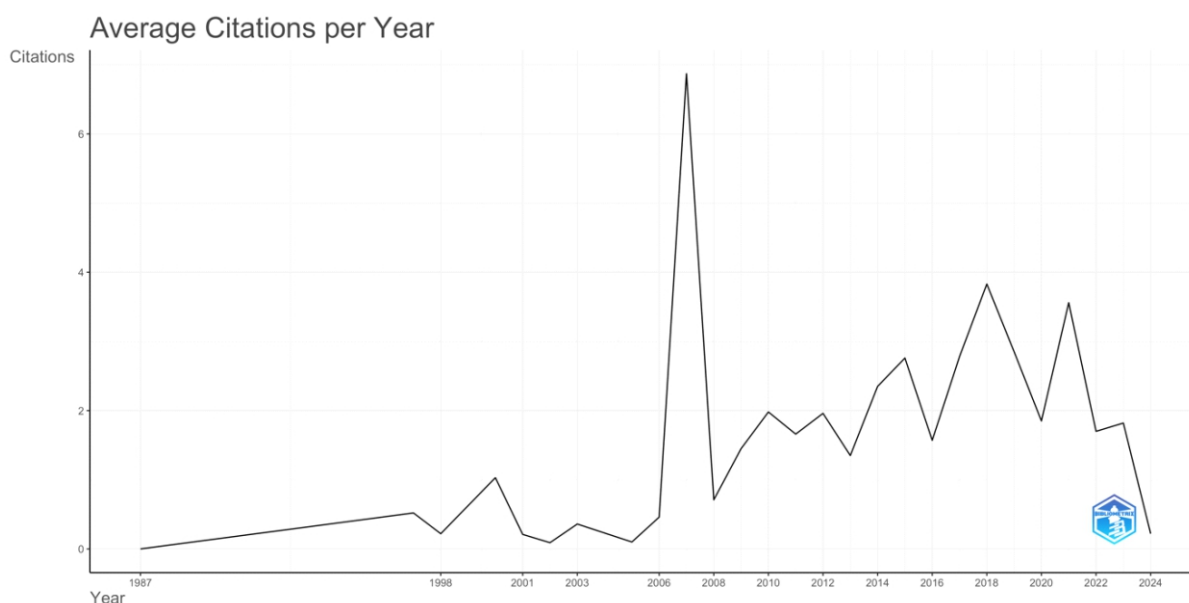


Figure 3 Average citations per year.

Table 1 Most relevant sources

| Sources | Articles |
|--|----------|
| IOP Conference Series: Earth and Environmental Science | 13 |
| Environmental Management | 7 |
| Forest Policy and Economics | 7 |
| Sustainability (Switzerland) | 7 |
| International Forestry Review | 6 |
| Journal of Environmental Management | 5 |
| Land Use Policy | 5 |
| Environmental Science and Policy | 4 |
| Forests | 4 |
| Trees, Forests and People | 4 |

forestry journals, and others are spread through more generalized environmental science and policy outlets, reflecting the complex, multifaceted, and cross-disciplinary approaches needed to discuss the issues of forest management through public-private partnerships.

The data displayed in Figure 4, therefore, represent a timeline of the production of the research outputs of the core authors of the PPPs in the forest management field, including the total citations and citations per year for that unit of publication. This visualization shows when authors publish and how their work's impact changes over time.

The most eminent authors in the field of PPP and forest management include Chirwa PW and Jamnadass R, both of whom have made substantial scholarly footprints. Chirwa has been stable in publication from 2009 to 2022, with a notable peak in citation in 2009 (TCpY of 6), which has long-term relevance. In 2019, a high-impact output was featured by Jamnadass with 70 citations and a TCpY of 11.67 (Chirwa & Odhiambo, 2020; Syampungani et al., 2009; Tshidzumba et al., 2018; Tshidzumba & Chirwa, 2022). Likewise, Keane peaked in productivity in 2019 with 2 papers totaling 58 citations (TCpY of 9.67). Bjärstig leads in total output over the past decade and maintains a consistent presence in research, although the effects of citations vary widely

(Bjärstig & Kvastegård, 2016; Bjärstig, 2017). Such trends paint a picture of differing kinds of bibliometric effects from authors who combine a mostly enduring scholarly presence with short bursts of high-impact contributions. However, it should be noted that the papers are much fewer in total but with a high average impact, with a total category per year of 4.5 for papers published in 2017. That means the work produced, despite a lower frequency of publications, has been of significant influence. Conversely, new entries from users like Chen in 2023 and 2024 haven't been cited currently, as most recent publications are getting indexed by the academic community. Evidently, some authors have a sustained and impactful presence over time, while others have a relatively short but very influential period of research activity. The actual differences in citation counts or TCpY for different years clearly indicate that research impacts are not static; some works are outlined as particularly influential only for short periods, corresponding to dynamic focus and developments in PPPs in forest management.

Table 2 shows some of the most cited documents internationally on the subject of PPPs in forest management, signifying that their topic remains relevant and that the debate on the natural environment, along with policies, is still current. The assessment provides some clues regarding the impact and the dissemination of this critical set of publications.

The most successful document was titled "Increasing Rice Production in Sub-Saharan Africa: Challenges and Opportunities" by Balasubramanian et al. (2007), published in *Advances in Agronomy* in the year 2007 with 282 citations. This significant number of citations, with a mean average of 15.67 per year, indicates that the publication has been very instrumental in the discourse on agricultural and environmental challenges in sub-Saharan Africa. It most likely addressed critical issues related to food security and sustainable land use.

The article by He et al. (2019), titled "Co-Benefits Approach: Opportunities for Implementing Sponge City and

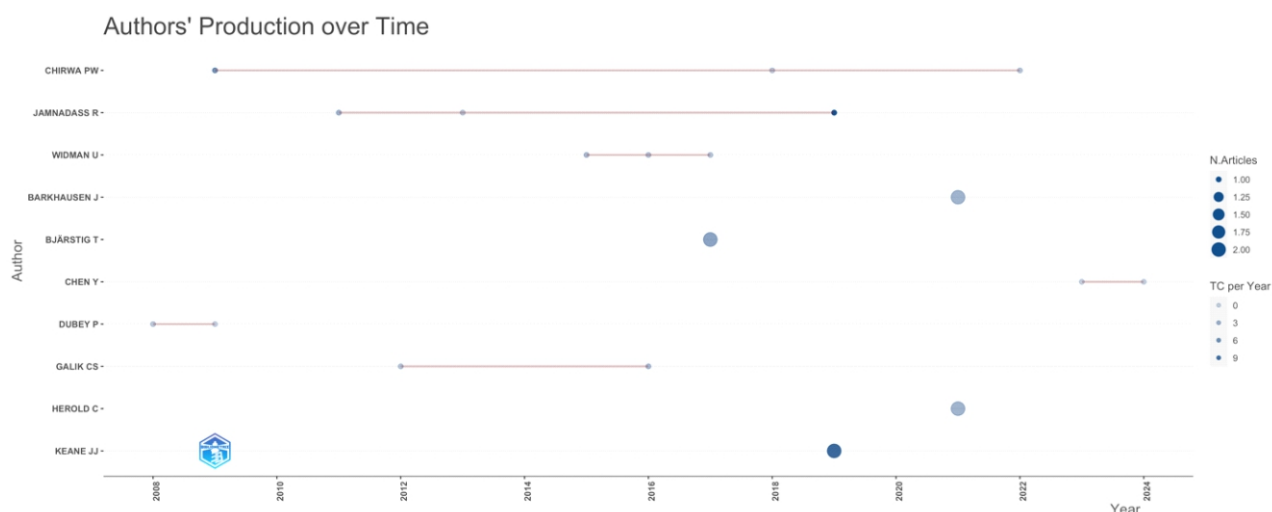


Figure 4 Authors production over time.

Table 2 Most global cited documents

| Document title | Authors, Year | Source | Citations | TC per year | Normalized TC |
|--|--------------------------------|---|-----------|-------------|---------------|
| Increasing rice production in Sub-Saharan Africa: Challenges and opportunities | (Balasubramanian et al., 2007) | Advances in Agronomy, 94, pp. 55–133 | 282 | 15.67 | 2.28 |
| Co-benefits approach: Opportunities for implementing sponge city and urban heat island mitigation | (He et al., 2019) | Land Use Policy, 86, pp. 147–157 | 178 | 29.67 | 10.41 |
| Risk and cooperation: Managing hazardous fuel in mixed ownership landscapes | (Fischer & Charnley, 2012) | Environmental Management, 49(6), pp. 1192–1207 | 98 | 7.54 | 3.85 |
| Cross-border malaria: A major obstacle for malaria elimination | (Wangdi et al., 2015) | Advances in Parasitology, 89, pp. 79–107 | 97 | 9.70 | 3.52 |
| The Miombo woodlands at the crossroads: Potential threats, sustainable livelihoods, policy gaps, and challenges | (Syampungani et al., 2009) | Natural Resources Forum, 33(2), pp. 150–159 | 96 | 6.00 | 4.14 |
| Historical assessment of Chinese and Japanese flood management policies and implications for managing future floods | (Luo et al., 2015) | Environmental Science and Policy, 48, pp. 265–277 | 88 | 8.80 | 3.19 |
| Developing a sustainable and circular bio-based economy in EU: By partnering across sectors, upscaling and using new knowledge faster, and for the benefit of climate, environment & biodiversity, and people & business | (Lange et al., 2021) | Frontiers in Bioengineering and Biotechnology, 8, 619066 | 84 | 21.00 | 5.91 |
| Transparency in global environmental governance: Critical perspectives | (Gupta & Mason, 2014) | Transparency in Global Environmental Governance: Critical Perspectives, pp. 1–339 | 83 | 7.55 | 3.21 |
| Spanish strategy on bioeconomy: Towards a knowledge-based sustainable innovation | (Lainez et al., 2018) | New Biotechnology, 40, pp. 87–95 | 82 | 11.71 | 3.06 |
| The political context of REDD+ in Indonesia: Constituencies for change | (Luttrell et al., 2014) | Environmental Science and Policy, 35, pp. 67–75 | 79 | 7.18 | 3.06 |

"Urban Heat Island Mitigation", published in *Land Use Policy*, has garnered significant attention, receiving 178 citations. The large number of citations, in fact, 29.67 per year, points to this document's relevance to contemporary urban planning and environmental policy reflections in the context of long-horizon climate adaptation and sustainable city planning. The Fischer and Charnley 2012 paper, "Risk and cooperation: managing hazardous fuel in mixed ownership landscapes," published in *Environmental Management*, has accrued 98 citations, which, by any standard, places it in a position of strong significance within the field of environmental

management. It is a landmark paper for understanding the intricacies associated with managing forest landscapes within different ownerships. With an average cited frequency of 7.54 times per year, the interest in and relevance of this work is evidently sustained over time. Other prominent publications are Wangdi et al. (2015)'s article, "Cross-Border Malaria: A Major Obstacle for Malaria Elimination" in *Advances in Parasitology*, and Syampungani et al. (2009)'s article on the "Miombo woodlands" in *Natural Resources Forum*, each with 97 and 96 citations, respectively, further enhancing transparency and knowledge about cross-border health

predicaments and sustainable management of crucial ecosystems, like the Miombo woodlands.

Noticeably, the 2021 publication in *Frontiers in Bioengineering and Biotechnology* by Lange et al. (2021), "Developing a Sustainable and Circular Bio-Based Economy in EU," has accumulated a total of 84 citations over a very short period, leading to an outstanding average of 21 citations per year. High numbers like this represent the great importance and the growing urgency gained by the bioeconomy and the concept of its circularity within the discussion on contemporary environmental policies.

Also, from Luttrell et al. (2014), the document "The political context of REDD+ in Indonesia," published in the previous year in *Environmental Science and Policy* with 79 citations, makes a strong contribution by presenting the critical evaluation of REDD+ in Indonesia as a fundamental area of interest of the environmental governance framework and the implementation of policies on the environment. Here, the most globally cited documents in the data set underline the diversity and breadth of the research issues that meet PPPs in forest management, ranging from agricultural problems and problems in urban design to the control of malaria, bioeconomy, and international environmental governance. These documents stimulate not just academic knowledge but also policy formation and practical approaches to sustainable development.

Figure 5 illustrates the relative distribution of key themes and topics of research on PPP in forest management. Each rectangle's size corresponds to the frequency or relative prominence of the respective term or concept within the dataset, thus giving a graphic overview of the points this field is more intensively working on. The most prominent themes are "public-private partnership" and "public-private partnership," occupying the largest spaces in the treemap with 17% and 15%, respectively. This visualization easily gives an indication that the concept of PPPs is really at the core of the research, providing the basic foundation on which various discussions and studies with respect to forest

management are pinned. The slight variation in spelling of the term again suggests a lack of standardization in terminology across the literature. The topics "climate change" and "biodiversity" represent 5% each of the general themes, thus showing that both are majorly important in PPP discourses (Ternell et al., 2020). Attention towards "climate change" proves the urgent necessity with which sustainability in forest management needs to be practiced to enable both mitigation and adaptation. In contrast, "biodiversity" represents the core concerns of the conservation of species and ecosystems within PPPs in forest management. Both "REDD+" and "sustainability" each represent 5% of the themes, making them highly relevant to the research. Attention toward "REDD+" follows the global trend of combating deforestation through the use of incentives and partnerships, while "sustainability" refers to the broader goal of balancing the environmental, economic, and social objectives of forest management.

The terms "forest management" and "conservation," each accounting for 3%, also highlight the characteristic operating and strategic features of forest resource management (Morkovina et al., 2019; Chisika & Yeom, 2021). These terms likely embrace all activities, from policy implementation to on-the-ground conservation efforts, within the PPP framework. Other themes of note are "governance" and "deforestation," both at 3%. "Governance" refers to the formulation of appropriate institutional frameworks within which PPPs can become effective, with regulatory environments supportive of such partnerships in line with public policy. "Deforestation" is a significant challenge that PPPs would be addressing, especially in countries where forest loss is a serious matter (Furumo & Lambin, 2020). The terms "reforestation," "forest policy," and "protected areas" all account for 3% each, pointing to the restoration efforts, formulation of policy regarding these areas, and protection of the forests as part of the PPP agenda.

Geographical terms such as "India," "China," "Amazon," and "Canada" indicate that some of the studies come from a

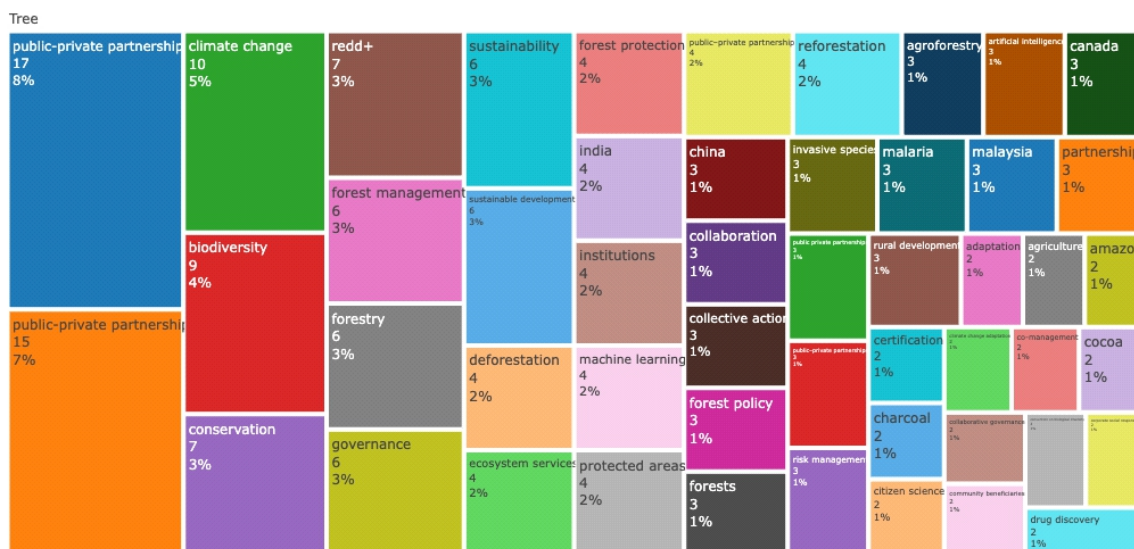


Figure 5 Tree-map.

regional perspective, with the diversity indicating the global applicability of PPPs in various forest management contexts. The presence of countries like "Malaysia," "Brazil," and "Indonesia" also shows the importance of the tropical forest and special challenges and opportunities that such regions present to PPPs. Emerging topics like "machine learning," "big discovery," and "charcoal" may reflect that this research is also using some new approaches and focused issues within the broader PPP framework. The mentioning of "machine learning" confirms the involvement of advanced technologies in forest management, probably within data analysis, monitoring, or even decision-making processes. In other words, the treemap provides an overview and a very expressive look at the general themes from this research on PPPs in forest management. The dominance of terms related to climate change, biodiversity, governance, and sustainability reflects the field's ambitions in solving the most critical global challenges by joining forces. Geographic diversity and new themes brought forward testify to its breadth, but it is also a forward-looking process in search of constructing innovative solutions for the sustainable management of forests worldwide.

Figure 6 demonstrates the evolution of key research topics within the PPP in forest management. The graph illustrates how the attention levels of different subjects under study have surged at different points in time, showing changes of focus according to emerging trends.

The frequency of moderate keywords such as "risk management" and "agroforestry", spans from 2006 to 2012, indicating that these may be among the first topics of interest in the broader context of PPPs. The interest in "risk management" is likely to denote concerns over mitigation of environmental and economic risks associated with forest management, while "agroforestry" is very much about the close integration between agriculture and forestry practice, central in the context of sustainable land use. Moving into the period from 2013 to 2015, we have issues such as

"institutions," "REDD+," and "malaria." Above all, the theme "institutions" implies a need for creating reliable institutional frameworks to ensure effective PPP management. At this juncture, from 2013 to 2015, the issue relating to "REDD+" is found in this international debate that calls for concerted efforts to manage climate change through the incentivization of forest retention. The mention of "malaria" gives away the implication of an interdisciplinary approach where the implications of forest management on public health are considered. The frequency of core terms from 2014 to 2020, such as "public-private partnerships," "governance," "conservation," and "forestry," fairly increases. This period represents significant growth in research evidenced by in-depths studies on the contribution of PPPs to effective governance and conservation of forests, which naturally bring out recurrence. This is the recurrence that is identifying topics that reflect a maturation of the field by looking into basic concepts in much depth.

Between 2016 and 2020, "protected areas," "reforestation," "ecosystem services," and "climate change" emerge as increasingly hot topics. These topics reflect growing concerns about protecting and restoring forest ecosystems, which play multifunctional roles of carbon and biodiversity reservoirs while regulating water in the broader context of climate change mitigation. In the 2020s, entirely new topics that are likely to come into focus include "machine learning," "artificial intelligence," "biodiversity," and "sustainable development." This means that the emergence of "Machine Learning" and "Artificial Intelligence" could lead to increased applications of advanced technologies in forest management practices, particularly in monitoring, decision-making, and optimization of PPPs. Sustained attention to topics such as "biodiversity" and "sustainable development" is an illustration of the persistence of these issues in relation to rising global environmental challenges.

The addition of fixed countries recently, such as "Canada," "India," and "China," means that regional studies

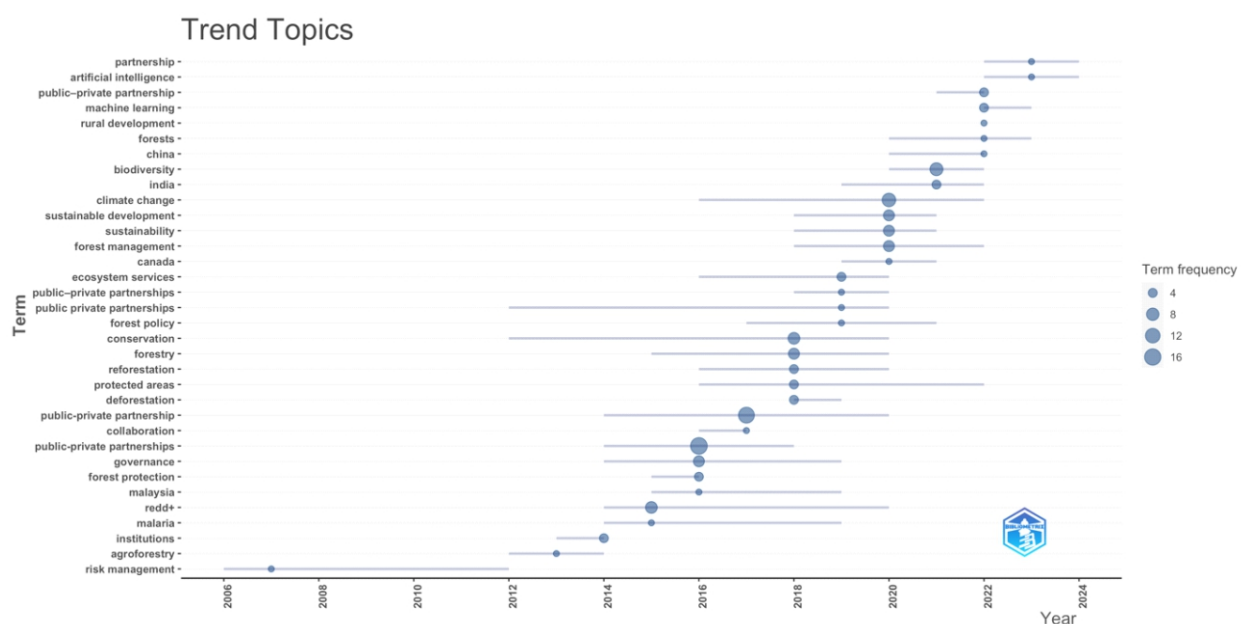


Figure 6 Trend topics.

and case-specific studies apparently do contribute to a global understanding of how PPPs are tailored according to geographical and socio-political contexts.

In synthesis, the data on trending topics present the evolution of this PPP field, which has undergone a shift from the most basic questions of risk management to much more integrated issues: that of climate change, biodiversity, and use of advanced technologies. It may thus be concluded that the field reacts to global environmental challenges and the supreme necessity for innovative, sustainable solutions in forest management.

The thematic map on Figure 7 above is a strategic landscape of the area of research on PPP in forest management; it shows motor themes distributed across the 2D space regarding their centrality and density. This will let us realize the maturity, importance, and specificity of different research topics in this domain.

Themes of the motor quadrant are fully developed and central to the field. They are integral to domain actions and propel research. It identifies the more prominently featured topics in literature: "public-private partnerships," "forestry," "governance," "REDD+," and "deforestation." The prominence of these themes in the study situates current research at its core, primary focusing on how PPPs are expected to address troubling issues like deforestation and forest governance. The co-presence of "ecosystem services" and "collective action" within the themes indicates that the contribution of collective efforts and ecosystem services provision makes forest practice also sustainable.

On the lower-right quadrant are the basic themes. They are as prevalent but more foundational and less complex. These themes include, for example, "biodiversity," "sustainability," "conservation," and "public-private partnership." The placement of "sustainable development" and "climate change" in this quadrant emphasizes that,

although they are fundamental, these topics serve as the foundation for the broader discussion on forest issues. However, these issues are also so 'basic' that they consist of the backbone topics for other more applied or advanced studies. It is evident that these themes are still relevant, for the research into them has remained steady; therefore, they provide the necessary framework for further studies.

The themes within the lower-left quadrant have lower centrality and density and are therefore emerging or decaying. These themes include "machine learning," "artificial intelligence," and "drug discovery." The presence of "social network analysis" in this quadrant indicates that these topics are not yet in the mainstream but are picking up. "Machine learning" and "artificial intelligence" probably describe what, at the current date, is the leading edge of technology use in forest management. These are likely becoming topical because they are technologies starting to be examined as mechanisms for transforming the field. Their position in this quadrant indicates that they are topics where new interest is being generated, but they might shift from that position once they become widely applicable, or they might not.

Niche themes, which are very specialized but of lower centrality for the whole landscape, are the last to be placed in the upper-left quadrant. These are "environmental justice", "urban forestry", "community forestry", "rural development". Important in particular contexts but less diffuse across the board, like the motor themes. The underpinning of these niche areas in "social innovation" and "sustainable livelihoods," therefore, suggests that these two themes are critical in the targeted interventions and specialized studies that articulate specific challenges facing forest management. There is a well-laid-out depiction of the state in which the research in forest management PPPs is right now. The driving motor themes are heavily based on governance, defores-

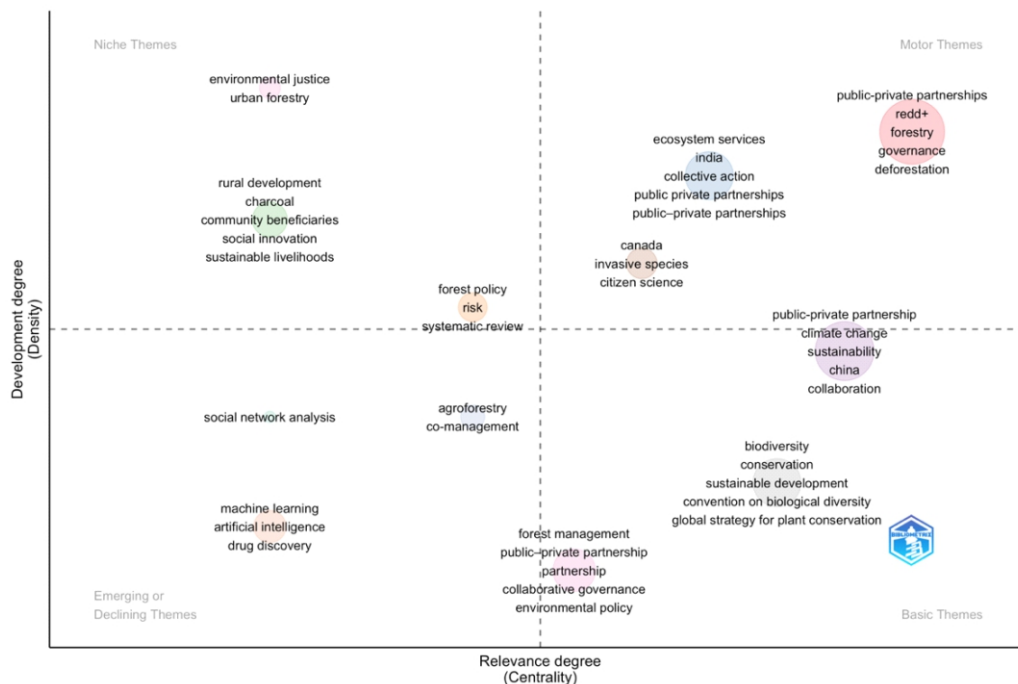


Figure 7 Thematic map.

tation, and ecosystem services. Basic themes continue to provide the bedrock of knowledge and frame-works that so many others will be built upon, while emerging themes like machine learning and artificial intelligence have the kind of disruptive potential to reshape the field. Niche themes, on the other hand, occupy deep, specialized insights and cater to the specific context within the broader domain. This typology suggests activity, in which there are areas of strength contrasted with excitement about innovation in the emerging ones.

The thematic evolution in Figure 8 shows the trends in research on PPPs in forest management across three time frames: 1987–2015, 2016–2020, and 2021–2024. In the first period, the main keywords were "public-private partnerships," "institutions," "conservation," and "climate change." These keywords aimed to enhance the understanding of institutional arrangements for conservation and climate mitigation. The inconsistent hyphenation of "public-private partnership" reflects an early stage of conceptual development.

The 2016–2020 period marks an expansion of research themes. "Public-private partnerships" remain central, joined by "REDD+," "collective action," "forest management," and "sustainable development." The emergence of "REDD+" signals growing attention to global environmental policy, while "collective action" underscores interest in resource governance dynamics. The continued prominence of "forest management" and "sustainable development" indicates the increasing integration of PPPs into broader sustainability concerns.

From 2021 to 2024, the field both consolidates and diversifies. Core themes "public-private partnerships," "forest management," "sustainability," and "climate change" persist, while new emphases emerge on "protected areas" and "biodiversity," reflecting a heightened focus on ecosystem preservation and biological diversity. This evolution shows the transition from foundational and institutional themes to

presence of "climate change" and "sustainability" across all periods illustrates their centrality to forest management discourse. Here, the thematic trajectory highlights increasing specificity and sophistication in PPP research as it adapts to global challenges related to environmental governance and sustainable resource use.

The multi-dimensional scaling of factorial analysis (Figure 9) has produced a bipartite division of important themes in forest management within PPP research. The bigger blue cluster reflects the multidimensional and interdisciplinary nature of this field whereby recurring jargon such as "public-private partnerships", "sustainability", "biodiversity", "climate change", "ecosystem services" is found. Themes under that cluster include risk management, forest management, reforestation, and invasive species. This grouping shows the strong intersection made by economic- and social-oriented PPPs with efforts for restoration and challenges of the ecosystem. The inclusion of "machine learning" and "malaria" strengthens the argument for the connection between technology and public health, thereby suggesting a comprehensive and multifaceted research perspective.

This smaller red cluster has more focused themes such as "collective action," "institutions," "governance," and "protected areas." These themes talk about structural and organizational-level dimensions of PPP which are needed for successful implementation, especially regarding roles of institutional strength and adaptive governance in the management of critical ecosystems.

In totality, these have been cast within two clusters, cluster of current PPP research that has come with two emphasis: the first bring an extensive scope for integration within environmental, technological, and social concerns; the second strategic to consider the institutional framework and stakeholder coordination. It shows how they are being conceived: as collaborative and policy-driven vehicles towards the multifarious challenges of sustainable forest

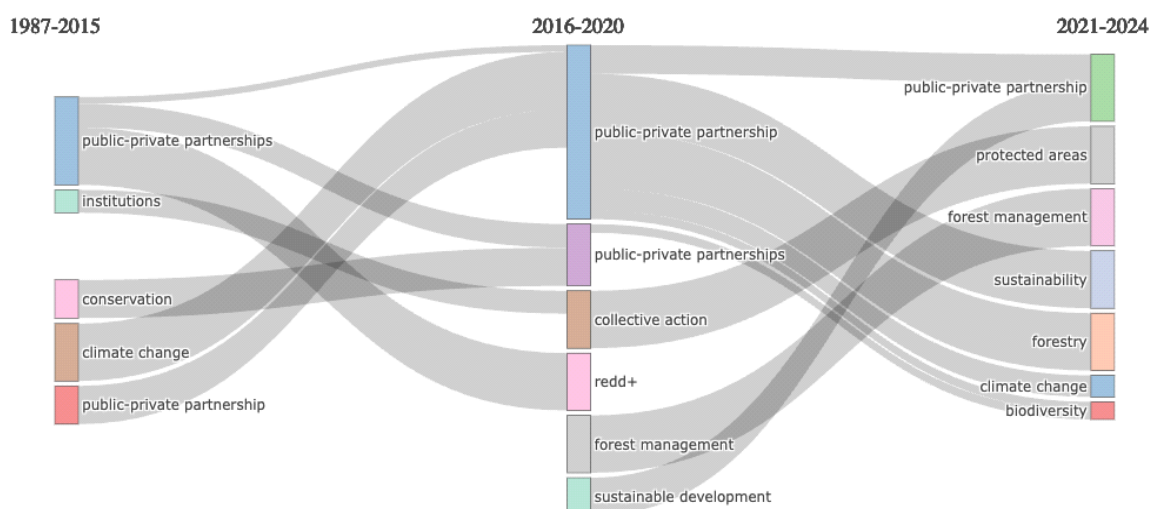


Figure 8 Thematic evolution.

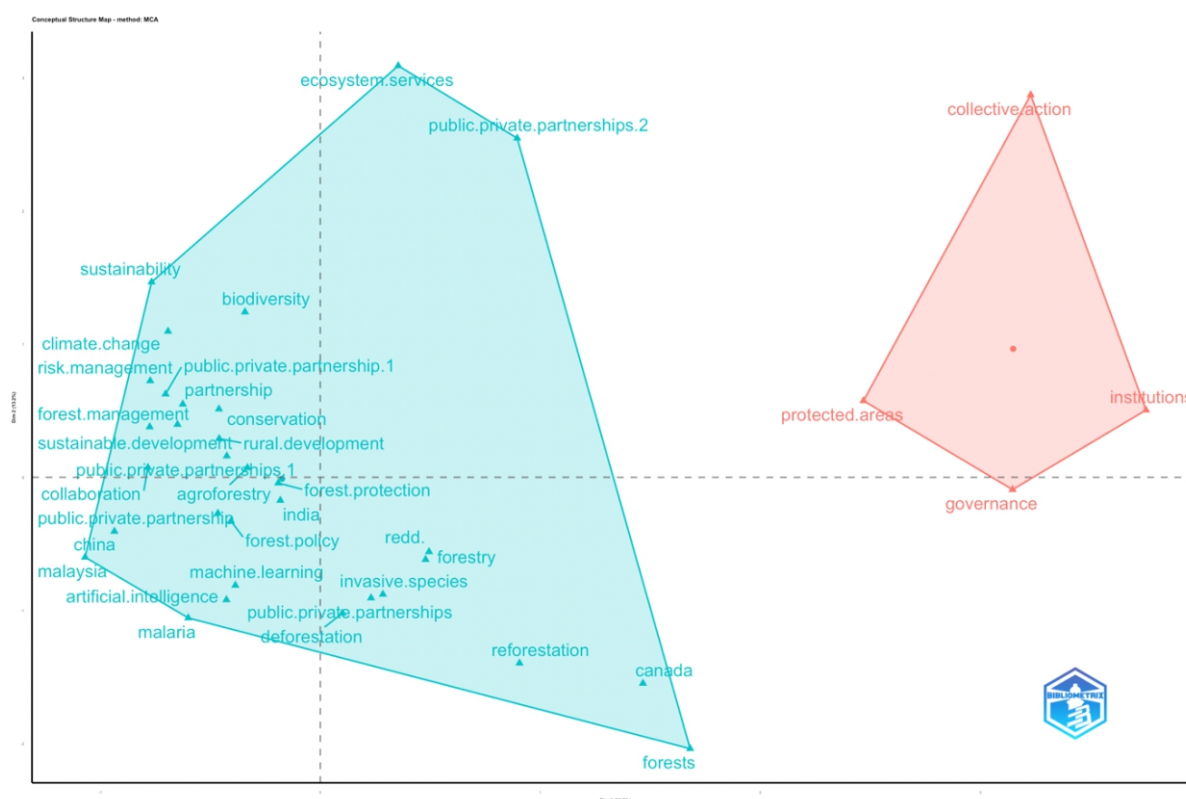


Figure 9 Factorial analyses.

Discussion

The dynamics in the changing research landscape on PPPs should be captured by the results provided through several scientometric analyses on forest management. As an example, the results highlight the increasing complexity and interdisciplinarity of the field, indicating that PPPs have emerged as central solutions to address both environmental and socio-economic challenges in forest management. A key result is that PPPs were a basic theme consistently over different periods. From the factorial analysis (Figure 9), the centrality of PPPs has persisted, evolving from a focus on basic explorations of institutional frameworks to more sophisticated analyses regarding their role in sustainability, good governance, and environmental protection. In this respect, the growth of PPPs has moved the concepts from being theoretical ideas to applied concepts as PPPs are increasingly harnessed to apply global environmental governance mechanisms like those established under the aegis of REDD+ for climate change mitigation and biodiversity conservation. The thematic map presented in Figure 7 highlights the dual nature of research focus within PPPs; though broad, integrative themes seemed prevalent, such as sustainability and climate change, there is also a critical need to examine the specific governance and institutional frameworks underpinning these partnerships. The thematic map identifies niche themes such as environmental justice and urban forestry, which would suggest that, while the core research is being broadened, there are still niche areas within which issues require more focused attention. Niche themes come out as very important

in the context of dealing with the peculiar problems of marginalized communities and urban areas where hitherto classical PPP models may need to be readapted or re-envisioned. Figure 6 depicts a review of trend topics, adding to the perspective of how research priorities have evolved over time. Recent years have shown an increasing interest in the possibilities of using advanced technologies, among which are machine learning and artificial intelligence, for the optimization of forest management practices to bring about better PPP outcomes. This comports with wider global shifts to data-driven decision-making in environmental management.

The thematic clusters and keyword analyses point to regional concentrations of studies in the Global North, despite the global relevance of the dataset. This bibliometric mapping reveals a lack of empirical studies from Southeast Asia and other Global South contexts, where there is increasing interest in governance innovations with respect to PPPs in forest management. For instance, Indonesia's REDD+ implementation of multi-stakeholder partnerships in forest conservation and community forestry shows rapidly evolving PPP models that remain nearly undocumented in the indexed literature. This gap creates a very valid opportunity for future research to analyze the model of the localization and institutionalization of PPPs in different ecological and political contexts. As Laaksonen-Craig (2004) notes, despite possessing abundant forest resources and considerable potential in the forest industry, developing countries have often failed to attract substantial investment or foster effective partnerships due to institutional weak-

nesses and regulatory uncertainties. Other studies show that the majority of land reform projects in South Africa failed due to the structural design of the partnership and the poor socioeconomic status of community beneficiaries" (Tshidzumba & Chirwa, 2022). This observation aligns with the lack of documented PPP models from these regions and further underscores the need to explore forest-sector PPPs in Global South contexts as both empirical and theoretical contributions to the evolving discourse. Nevertheless, such insights into thematic evolution, intellectual structure, and research dynamics are generally offset by constraints or limitations of the bibliometric approach. The analysis is heavily dependent on metadata and citation patterns and may, therefore, fail to capture the theoretical depth, contextual reality, or tangible efficacy of PPPs in forest management. There is also the possibility of excluding relevant studies because of the use of only one database (Scopus) and an emphasis on English publications, especially with regard to areas where PPP practices are documented locally in other languages. These limitations indicate that future research may need to draw on qualitative or case-based approaches alongside bibliometric studies to better appreciate how PPPs operate across different governance terrains.

Conclusion

The current study aims to conduct a comprehensive bibliometric analysis of research on PPPs in forest management, providing valuable insights into the field's evolution, current status, and potential future growth. Findings highlight the essence of PPPs in dealing with urgent global environmental problems of climate change, biodiversity conservation, and sustainable development. After such an analysis, one can observe the development of PPPs from basic concepts and institutional frameworks to more sophisticated, in recent times, integrated approaches that underline governance, collective action, and advanced technologies in design and implementation. Although PPPs have significantly contributed to forest management, major limitations and challenges still exist; therefore, this indicates a substantial opportunity for future research to address these gaps. However, the limitation in this article relies on the scope of the bibliometric analysis itself, as it was broadly tailored to identify only trends, sustained themes, and influential works in this particular field. Bibliometric analyses inherently count and describe patterns, but they lack the ability to explore detailed aspects of research content, such as underlying methodologies, theoretical frameworks, or socio-political contexts that influence how PPPs are delivered. In the future, these findings could be complemented with in-depth qualitative analysis through case studies and field research to more fully illuminate how PPPs work in different settings and what kinds of challenges they are likely to face.

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