



FOREST GOVERNANCE INDICATORS FOR SUSTAINABILITY: A THEORETICAL AND APPLIED REVIEW

**INDICADORES DE GOVERNANÇA FLORESTAL PARA A
SUSTENTABILIDADE: UMA REVISÃO TEÓRICO-APLICADA**

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ABSTRACT

This article discusses the state of the art regarding conceptual interactions among forest concessions, governance, and sustainability, focusing on identifying key indicators reflecting these interactions. For this purpose, a mixed methodological approach was adopted, combining systematic literature review with bibliometric and content analysis. Through screening publications from Web of Science and Scopus databases, 518 articles were initially identified, from which 50 were selected for qualitative analysis. The bibliometric analysis enabled the identification of the most influential authors, collaboration networks, and keyword co-occurrence patterns, as well as emerging themes in the field. The content analysis was structured into three thematic dimensions: (i) governance and forest policy, (ii) monitoring and evaluation, and (iii) management and implementation. The study presents indicators systematizing recurring main categories, such as transparency, legality, social participation, accountability, and institutional capacity. The results indicate that these elements are fundamental for the effectiveness of sustainable concessions. The research reinforces the need for integrated and adaptive approaches that align forest governance instruments with metrics sensitive to the ecological, social, and institutional contexts in which the concessions operate.

Keywords: Forest Governance; Sustainability. Forest Concessions. Assessment Indicators. Systematic Literature Review.

RESUMO

Este artigo discute o estado da arte das interações conceituais entre concessão florestal, governança e sustentabilidade, com foco na identificação dos principais indicadores que espelham essa interação. Para isso, adotou-se uma abordagem metodológica mista, combinando revisão sistemática da literatura com análise bibliométrica e análise de conteúdo. A partir da triagem de publicações nas bases *Web of Science* e *Scopus*, foram identificados 518 artigos, dos quais 50 foram selecionados para análise qualitativa. A análise bibliométrica permitiu identificar os autores mais influentes, as redes de colaboração e os padrões de coocorrência de palavras-chave, além de sinalizar os temas emergentes no campo. A análise de conteúdo foi organizada em três dimensões temáticas: (I) governança e política florestal; (II) monitoramento e avaliação; e (III) gestão e aplicação. O estudo apresenta indicadores, sistematizando as principais categorias recorrentes, como transparência, legalidade, participação social, *accountability* e capacidade institucional. Os resultados indicam que esses elementos são fundamentais para a efetividade das concessões sustentáveis. A pesquisa reforça a necessidade de abordagens integradas e adaptativas, que articulem os instrumentos de governança florestal com métricas sensíveis aos contextos ecológicos, sociais e institucionais nos quais as concessões estão inseridas.

Palavras-chave: Governança Florestal. Sustentabilidade. Concessões Florestais. Indicadores de Avaliação. Revisão Sistemática da Literatura.

INTRODUCTION

The intensification of climate change, environmental degradation and the growing global demand for sustainable solutions are reshaping the role of forests in the 21st century. They are no longer just home to rich biodiversity and regulating hydrological and climatic cycles but are also playing strategic roles in providing ecosystem goods and services essential to human life (MEA, 2005; FAO, 2015). In this context, models for the use and management of public forests assume a central role in sustainable development strategies, especially in countries with vast areas of tropical forests, such as Brazil. Examples such as community concessions in Guatemala, voluntary forestry agreements in Peru and national sustainable management programs in Indonesia illustrate different institutional arrangements aimed at reconciling conservation and economic use. In Brazil, the forest concession policy implemented in areas such as the Jamari National Forest (Rondônia) stands out, seeking to combine public governance instruments with the involvement of private companies and social participation, thus representing an important experience in environmental governance in countries with high biodiversity.



Forest concessions, as a public policy instrument, seek to reconcile the conservation of natural resources with economic and social development through the sustainable use of state-owned forests (Tegegne *et al.*, 2019; Bocci *et al.*, 2018). However, the effectiveness of these regimes depends directly on the quality of the governance implemented, as well as the institutional rules that regulate access, the different modalities of use of forest resources, and how different actors are included in the decision-making process (Arts; Buizer, 2009; Secco *et al.*, 2011). The articulation between forest concessions, governance and sustainability therefore constitutes a strategic field for understanding and improving contemporary models of environmental management for the sustainable use of forest resources.

The scientific literature on forest concessions has expanded significantly in recent decades, especially from experiences recorded in the context of Latin America, Africa and Southeast Asia. Studies such as those by Secco *et al.* (2011), Arts and Buizer (2009) and Linser *et al.* (2018) demonstrate that effective forest governance depends on institutional arrangements capable of guaranteeing transparency, public participation, accountability and legality in the decision-making process. Thus, social participation emerges as one of the pillars of good governance, since it enables the engagement of local communities, civil society organizations, and traditionally marginalized groups, promoting legitimacy and equity in decisions about the use of forest resources.

Furthermore, mechanisms for deliberation and social control, such as management councils and public consultations, strengthen the capacity of society to monitor concessionaires and public authorities. In parallel, sustainability has ceased to be an abstract normative concept and has become operationalized through specific indicators in the environmental, economic, and social dimensions, as advocated by Mendoza and Prabhu (2000a), D'Amato *et al.* (2020) and Hickey and Innes (2008).

Despite these advances, gaps persist in the integration between the three concepts – forest concession, governance, and sustainability – especially regarding the systematization of indicators that measurably translate the impacts of governance practices on sustainable outcomes. The literature reveals recurring challenges, such as the excessive standardization of criteria without adaptation to local contexts (Muhammed *et al.*, 2008; Hickey; Innes, 2008), the fragmentation of monitoring instruments (Irland, 2010) and the limited community participation in the planning, execution, and evaluation phases of concessions (Pokharel *et al.*, 2015; Jafari *et al.*, 2018).

In the study conducted by Pokharel *et al.* (2015) on community forests in Nepal, the authors observed that, despite the participatory rhetoric of forest policies, local communities remain marginally involved in defining sustainability criteria and strategic decision-making, which compromises the legitimacy and effectiveness of management. This finding aligns with other evidence found in Latin American and African contexts, where formal consultation mechanisms do not necessarily guarantee substantive engagement or equitable representation of local groups (Lucungu *et al.*, 2022; Nansikombi *et al.*, 2020).

It is also worth noting the existence of studies that frequently fail to consider interdisciplinary and comparative approaches that would allow for the evaluation of the effectiveness of institutional arrangements in distinct ecological and sociopolitical contexts (Kröger; Raitio, 2017; Lesniewska; McDermott, 2014). A deeper understanding of the interactions between these themes is particularly urgent in the current scenario, marked by new demands for traceability, accountability and multi-sectoral engagement promoted by frameworks such as the Sustainable Development Goals (SDGs) and the criteria of environmental, social and corporate governance (ESG) (Hartmann; Goodall, 2017; D'Amato *et al.*, 2020).

The SDGs, proposed by the United Nations (UN) 2030 Agenda, offer a global framework for addressing the main socio-environmental challenges of today. In the forestry sector, SDG 15 (Life on Land) aims to protect, restore and promote the sustainable use of terrestrial ecosystems and the sustainable management of forests and SDG 13 (Climate Action), which calls for land use practices aligned with climate mitigation and adaptation, stand out. In addition, targets such as SDG 16 (Peace, Justice and Strong Institutions) advocates for inclusive and accountable institutions at all levels and SDG 12 (Responsible Consumption and Production) promoting the sustainable use of natural resources, reinforcing the connection between governance, social justice and sustainability.

Similar studies as those by Begemann *et al.* (2021), Halonen *et al.* (2022) and D'Amato *et al.* (2020) point out that incorporating the SDGs into forest institutional arrangements broadens the legitimacy of public policies and strengthens the enlace between environmental conservation, social inclusion and economic viability. The integration between the SDGs and forest concession practices therefore represents an essential step to ensure not only environmental sustainability but also

intergenerational equity and the inclusion of multiple actors in decision-making processes.

ESG principles, in turn, are gaining increasing relevance as a normative and strategic guideline for public and private actors, influencing investments, regulations, and forestry practices, as evidenced in studies that address the integration between environmental sustainability, social justice and institutional performance (D'Amato *et al.*, 2020; Halonen *et al.*, 2022; Hayrinen *et al.*, 2016).

In the forestry sector, ESG criteria promote the integration of responsible management practices, socio-environmental justice and corporate governance, aligning with the notion of multi-scalar environmental governance. This, in turn, highlights the need for coordination between different levels of decision-making local, national and global - and between different sectors - public, private and community - as demonstrated by studies that emphasize governance as a relational and adaptive process, strongly dependent on local institutions, legal norms and collaborative practices (Secco *et al.*, 2011; Linser *et al.*, 2018).

In this sense, forest governance ceases to be seen merely as a technical or bureaucratic apparatus, assuming the role of a field of symbolic and political dispute, in which different narratives about development, conservation and justice shape the institutional frameworks and indicators used to measure sustainability (Arts; Buizer, 2009; Lesniewska; McDermott, 2014).

Considering this scenario, this paper discusses the state of the art of conceptual interactions between forest concessions, governance and sustainability, as well as it establishes as its main objective to identify the major criteria and indicators that reflect this interaction. The investigation was organized around the central question: What are the indicators that link forest governance to sustainability in concession contexts?

By systematizing the main findings of recent scientific literature, this study aims to contribute to the advancement of knowledge on the governance of public forests, supporting the formulation of public policies that are more aligned with the diverse socio-environmental contexts around the globe. The work is structured in five sections: after this introduction, the methodology used is presented; then, the results of the bibliometric and content analysis are presented; subsequently, the contributions of the identified thematic clusters are discussed and finally, the concluding remarks are presented, with theoretical and practical implications for the field.

STUDY METHODOLOGY

This study adopts a hybrid review methodological approach, combining bibliometric analysis and qualitative content analysis. This strategy is recommended for systematic reviews that simultaneously seek quantitative breadth and analytical depth, especially in interdisciplinary fields such as forest governance (Paul; Rialp, 2020).

Web of Science Core Collection (WoS) and Scopus (SCO) databases, both from Elsevier. These databases were chosen for their broad coverage of peer-reviewed journals and for concentrating on high-impact publications.

The search strategy combined the following descriptors: 'forest governance' AND 'indicators' OR 'forest concession' OR 'forest policy' AND 'sustainability' allowing us to retrieve studies focused on the intersection between governance, sustainability and forest concessions.

No chronological filter was established in the initial search phase since this study seeks to capture the trajectory and conceptual and methodological evolution of Forest Governance in its interface with Sustainability in forest concessions.

Considering that this is an interdisciplinary and constantly evolving field, especially regarding the use of indicators applied to public policies, a comprehensive approach was chosen. This choice made it possible to identify foundational milestones in the debate, such as Mendoza and Prabhu (2000a) who proposed a pioneering methodology for defining criteria and indicators of forest sustainability; and Arts and Buizer (2009), whose discursive-institutional analysis revealed forest governance as a field of normative and symbolic disputes. Moreover, it allowed for monitoring the most recent transformations driven by global agendas, such as the Sustainable Development Goals (SDGs), which have begun to guide new assessment instruments and policies focused on environmental governance.

The initial identification process resulted in 538 documents, 507 from the Web of Science database and 31 from Scopus. After removing 20 duplicates, the final corpus of the quantitative stage consisted of 518 documents, which were used in their entirety in the bibliometric analysis, conducted with the aid of the Bibliometrix package in the R software, version R (4.4.1).

Bibliometrics relies on metadata extracted from indexing databases and therefore requires a large and representative sample to map patterns of collaboration, scientific production and co-occurrence networks (Donthu *et al.*, 2021). This step aimed to understand the dynamics of the literature on the subject, allowing visualization of the connections between authors, keywords and the most influential journals, without the necessity of in-depth reading of each study.

Subsequently, a qualitative screening of the 518 records was carried out based on reading the titles, abstracts, and keywords resulting in the exclusion of 394 documents once they did not adhere to the previously defined descriptors or because they dealt with topics outside the scope of the research - such as, for example, studies focused on tree physiology, characterization of forest species, timber production in private plantations or isolated analyses on climate change unrelated to public policies, governance or forest concessions.

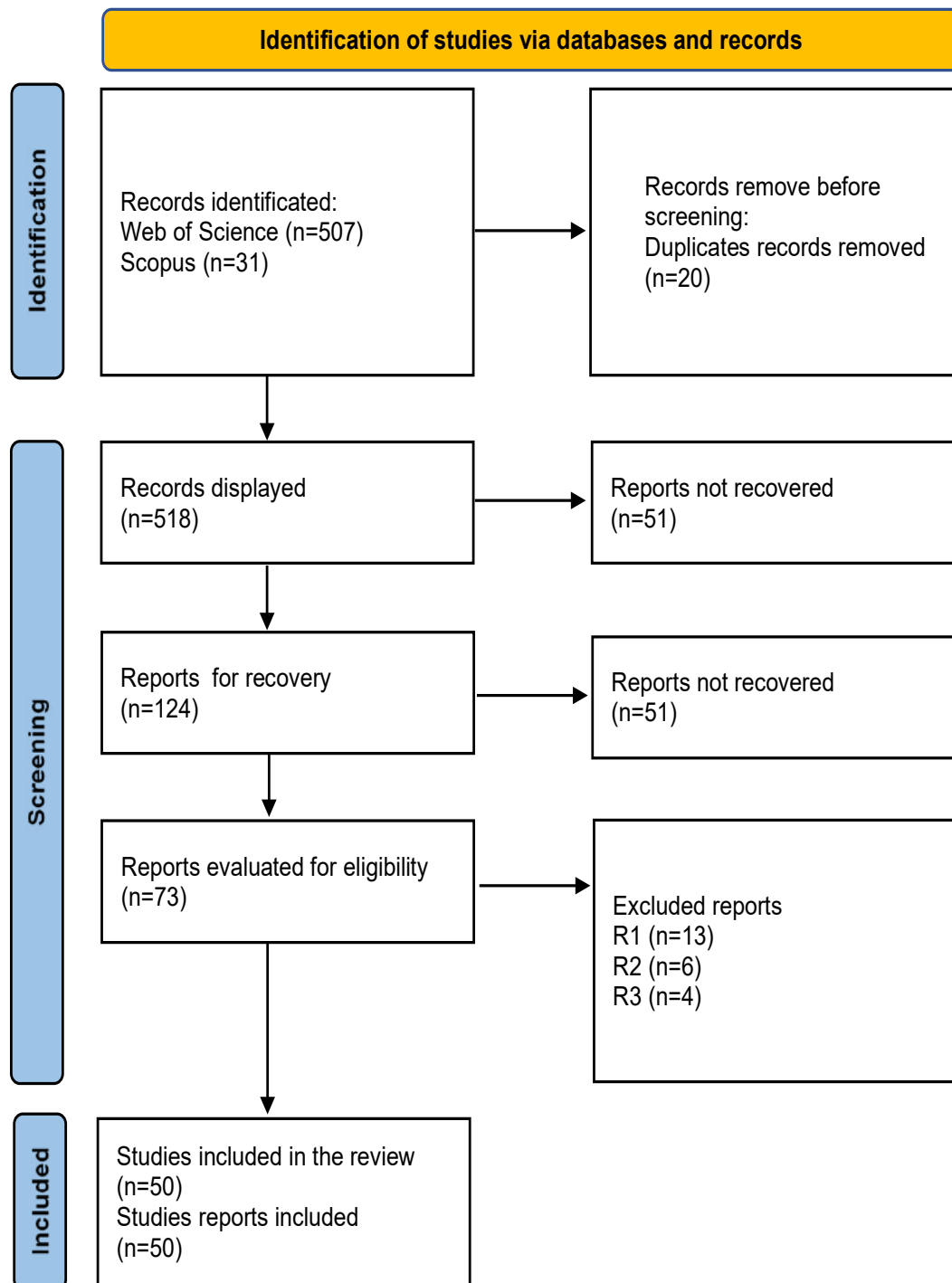
The remaining 124 papers underwent a preliminary reading, with 73 being read in full and assessed for eligibility for qualitative analysis. The exclusion of 23 studies at this stage was due to previously established criteria: thematic irrelevance ($n = 13$); absence of indicators or focus on governance ($n = 6$); or methodological weakness and analytical redundancy ($n = 4$). Thus, the final sample consisted of 50 papers, considered the most suitable to support the content analysis and answer the central research question.

This procedure is aligned with methodological guidelines that recommend systematic reviews with a minimum sample size of 40 documents (Paul; Rialp, 2020).

In order to explore the discussion pattern in the selected papers and to support the visualization and interpretation of thematic connections, the VOSviewer software (version 1.6.20) was used to identify and graphically represent the co-occurrence relationships between keywords, previously extracted and organized in the database.

Figure 1 shows the flowchart for the selection of papers according to the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Figure 1 | Flowchart for research papers included in this review based on PRISMA.



Source: Elaborated by the author.

INTEGRATED ANALYSIS OF THE RESULTS

BIBLIOMETRIC ANALYSIS

The bibliometric analysis aimed to evaluate the dynamics of scientific production in the field. To this end, metrics such as the average number of citations per document, the number of publications per author, the most productive authors, and the temporal evolution of their production were analyzed. Using data extracted from the Web of Science and Scopus databases, 518 papers were analyzed using the Cran tool in R/R Studio and its Bibliometrix package.

Table 1 | Database description

Key Information	Results
Period	1993-2023
Sources (Magazines)	111
Documents (Papers)	518
Annual Growth Rate %	9.45
Middle Ages of Documents	8.2
Average Citations per Document	21.66
References	27090
DOCUMENT CONTENT	
Keywords Plus (ID)	1253
Author Keywords (DE)	1835
AUTHORS	
Authors	1632
Authors of single-authored documents	54
AUTHORS' COLLABORATION	
Single-authored documents	58
Co-authors by Document	3.86
International Co-authorships %	44.59



Table 1 presents the final sample of the database of published papers. A total of 518 papers were produced by 1,632 authors, with an average of 3.86 co-authors per document. The volume of production in the period 1993–2023 indicates an average annual growth rate of 9.45%. The papers published in 111 scientific journals reveal the interdisciplinary nature of the field. The average of 21.66 citations per document and the total of 27,090 references indicate a consolidated field with a broad theoretical base and academic recognition. Authorship is markedly collaborative: of the 1,632 authors identified, the majority participated in co-authored productions, resulting in an average of 3.86 authors per paper and an international co-authorship rate of 44.59%, which highlights the presence of transnational research networks. Despite this, 58 documents were produced by a single author, also suggesting space for relevant individual contributions.

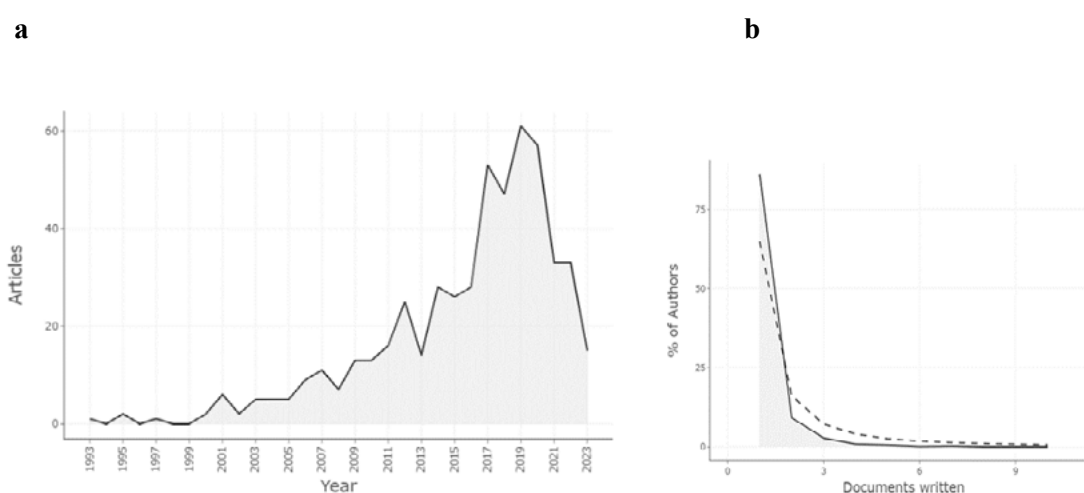
Scientific production showed significant expansion from 2010 onwards, with more pronounced growth between 2015 and 2020, culminating in a peak in publications in the latter year, as shown in Figure 2a. This growth coincides with the intensification of international sustainable development agendas, such as the SDGs and the growing concern with the bioeconomy and socio-environmental justice. However, the decline after 2021 may signal both an exhaustion of certain approaches and the need for methodological and empirical renewal, as well as being associated with the impact of the COVID-19 pandemic on publication cycles.

Figure 2b, in turn, illustrates an author distribution pattern that confirms Lotka's Law (1926), a principle according to which scientific production tends to concentrate among a few highly productive authors, while the majority contribute only one or two works. This behavior, common in consolidated fields, reveals that most authors in the sample appear infrequently, while names like Sotirov, Winkel and Arts (Figure 2a) concentrate a significant portion of the production. This pattern suggests a centralization of knowledge in specific academic centers, which may strengthen the conceptual consolidation of the field but also limit the diversity of perspectives.

Figure 2a reinforces this trend by showing the consistent productivity of key authors over time, indicating that recurring experts have deepened the debates. For example, the role of Arts (2009) in disseminating the discursive-institutional approach and of McGinley and Cubbage (2011) in the comparative analysis of forest public policies stands out.

The presence of authors linked to different geographical contexts, such as Azevedo-Ramos (Brazil) and Angelstam (Eastern Europe), further points to a process of internationalization of studies and to the recognition of the diversity of forest realities in the global debate on sustainability and governance.

Figure 2 | Scientific output **a** - Number of documents published per year and **b** - Productivity of authors according to studies included in the review

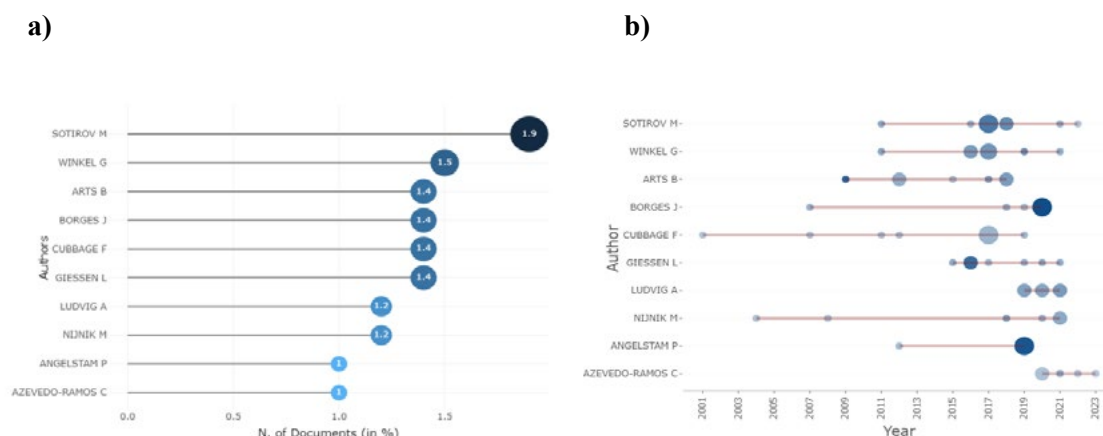


Source: Elaborated by the author.

Figure 3, composed of subfigures 3a and 3b, reveals relevant patterns in scientific production on Forest Governance and Sustainability. It is observed that authors such as Sotirov M., Winkel G. and Arts B. are among the most productive, not only in terms of the number of publications but also in the temporal consistency of their contributions. These authors focus their analyses on forest policies, environmental justice, and participatory governance instruments - themes aligned with recent transformations in the field. Authors such as Angelstam P. and Nijnik M., on the other hand, present more sporadic but significant publications, suggesting localized contributions and specific themes. The temporal analysis shows that production intensifies after 2010, coinciding with the expansion of international debates on the SDG and multi-scalar environmental governance, with the coordination of environmental policies between local and global levels. This heterogeneity of

trajectories highlights a theoretical and methodological diversity, while at the same time reinforcing the need for systematization and articulation between different perspectives and institutional contexts (Mendoza; Prabhu, 2000a; Linser *et al.*, 2018; Hickey; Innes, 2008; D'Amato *et al.*, 2020).

Figure 3 | Overview of the authors about scientific knowledge



Source: Elaborated by the author.

Note: **a)** Distribution of the proportion of papers considering the 10 most productive authors; **b)** Productivity of the 10 most productive authors over time, between 2001 and 2023 - the dot size represents the number of publications.

Table 2 highlights the 10 most cited papers from the analyzed sample, revealing the centrality of certain theoretical frameworks in consolidating the field of Forest Governance and Sustainability. Among them, the contributions of Arts and Buizer (2009) stand out, whose discursive-institutional approach has become a reference for understanding the power arrangements and discourses that shape forest policies. Also noteworthy is the work of Mendoza and Prabhu (2000a), a pioneer in the application of multi-criteria methodologies for evaluating forest sustainability, broadly influencing studies on indicators and decision-making in complex contexts.

The centrality of intergovernmental indicators and criteria, as instruments for standardization and comparative evaluation of forest policies, is reiterated by studies such as that of Linser *et al.* (2018), widely cited in the analyzed papers for its critical reflection on the trajectory of criteria and indicators (C&I) systems. Other authors, such as Hickey and Innes (2008), although less directly cited,

are frequently referenced indirectly in the literature as foundational contributions to the debate on sustainability assessment and the applicability of indicators in local contexts.

In turn, the paper by Lindenmayer *et al.* (2012) presents an ecological shift, proposing the forest retention model as a response to the limitations of traditional management.

The distribution of the most cited papers reveals a diversity of technical, institutional, ecological and participatory approaches, but reinforces that the most influential studies are those that address the challenges of measurement and governance. For example, the work of Mendoza and Prabhu (2000b) stood out for proposing a pioneering multi-criteria framework for evaluating forest sustainability, integrating social, economic and ecological aspects into a model applicable to different contexts. Arts and Buizer (2009) have broadly influenced the field by introducing the discursive-institutional perspective, revealing how discourses shape the formulation of forest policies. In the ecological field, Lindenmayer *et al.* (2012) contributed with the forest retention model, which offers more sustainable alternatives to traditional management. In turn, Hickey and Innes (2008) and Linser *et al.* (2018) consolidated the use of criteria and indicators as key tools for evaluating forest governance, especially in the intergovernmental context. These examples reveal that the most impactful studies not only propose robust analytical models but also directly address the tensions between standardization and local adaptation between technical efficiency and social legitimacy.

Therefore, the impact of these papers supports the theoretical frameworks analyzed in this study and guides future investigations into how governance practices can be monitored and evaluated based on robust evidence.

Table 2 | The 10 most cited papers

First author	DOI	Periodical	Year	TC*	TC per year	Theme
Lindenmayer DB	https://doi.org/10.1111/j.1755263X.2012.00257.x	Conservation Letters	2012	301	23.15	Forest conservation and management based on ecological retention.
Arts B	https://doi.org/10.1016/j.forpol.2008.10.004	Forest Policy and Economics	2009	254	15.88	Forest governance and institutional discourse analysis.
Mendoza GA	https://doi.org/10.1016/S0378-1127(99)00204-2	Forest Ecology and Management	2000	159	6.36	Multicriteria indicators for assessing forest sustainability.
D'amato D	https://doi.org/10.1016/j.forpol.2018.12.004	Forest Policy and Economics	2020	145	29	Bioeconomy and sustainability in forest policies.
Reed J	https://doi.org/10.1016/j.forpol.2017.01.012	Forest Policy and Economics	2017	132	16.5	Social participation in forestry decisions and governance.
Seeland K	https://doi.org/10.1016/j.forpol.2008.07.005	Forest Policy and Economics	2009	130	8.13	Cultural diversity and participatory governance in forest communities.
Persha L	https://doi.org/10.1016/j.gloenvcha.2013.12.005	Global Environmental Change	2014	128	11.64	Community-based forest management and conservation.
Cao S	https://doi.org/10.1016/j.landusepol.2009.02.006	Land Use Policy	2009	128	8	Deforestation and environmental degradation in China.
Yu D	https://doi.org/10.1007/s00267-011-9633-4	Environmental Management	2011	127	9.07	Evaluation of environmental policies with a focus on China.
Macdicken KG	https://doi.org/10.1016/j.foreco.2015.02.005	Forest Ecology and Management	2015	126	12.6	Global estimates of carbon and forest cover.

*TC = Total Citations

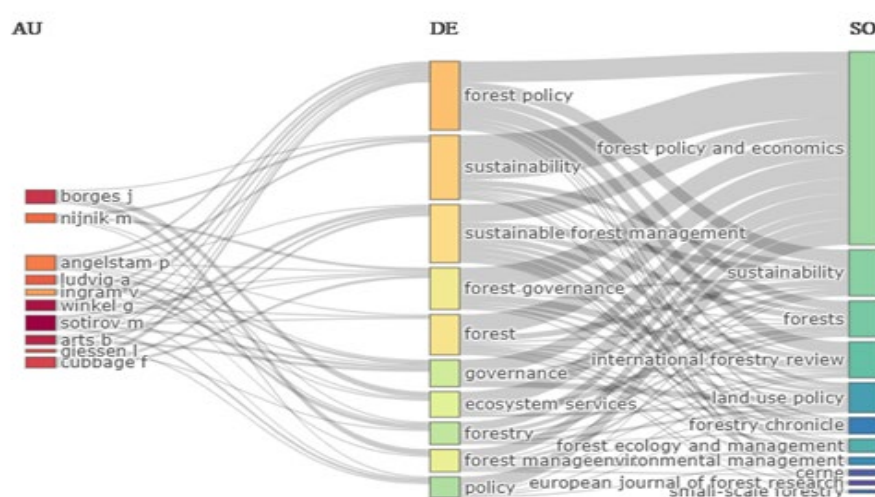
Source: Elaborated by the author.



Figure 4 provides an integrated visualization of the connections between the most productive authors, the main research themes, and the journals in which these productions are mostly published. It is noted that authors such as Borges J. and Nijnik M. are strongly linked to the field of forest policy, demonstrating the centrality of forest policy in contemporary discussions on sustainability. Other relevant authors, such as Angelstam P., Ludvig A., Winkel G. and Arts B. articulate their work around the terms forest governance, sustainability and ecosystem services, demonstrating an interdisciplinary approach that connects forest management, ecosystem services and governance instruments.

In the field of periodicals, 'Forest Policy and Economics' stands out as the main platform for disseminating these debates, followed by 'Sustainability - Impact Factors (IF) 2023: 3.9' (Q2 – Environmental Sciences), 'Forests - Impact Factors (IF) 2023: 2.9' (Q1 – Forestry), 'International Forestry Review - Impact Factors (IF) 2023: 1.5' (Q4 – Forestry) and 'Land Use Policy - Impact Factors (IF) 2023: 7.1' (Q1 – Environmental Studies and Planning & Development) demonstrating that scientific production is concentrated in periodicals that integrate the environmental, economic, and institutional dimensions of forest sustainability. This graphic representation reveals not only the flows of academic production but also the thematic convergence between governance, policy and sustainability, reaffirming the central axes addressed in this study.

Figure 4 | Three-field graph depicting the production of scientific knowledge.



Source: Elaborated by the author.

Note: The rectangles represent the main authors (a), keywords (b) and scientific journals (c).

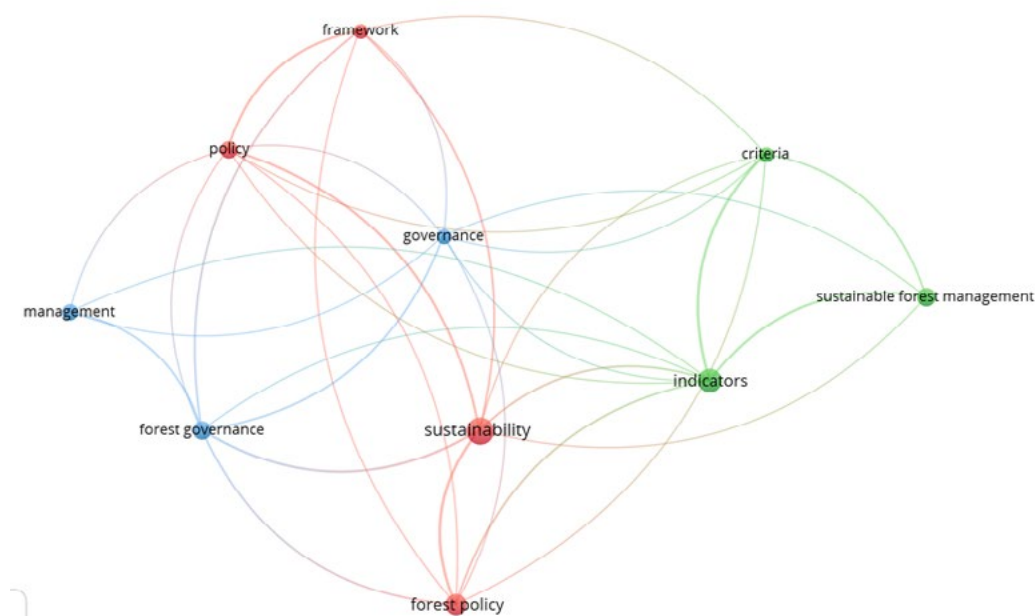


CONTENT ANALYSIS

Based on the thematic-analytical categorization procedure, an in-depth content analysis of the selected papers was carried out, seeking to identify patterns, conceptual divergences and structural recurrences in scientific discourse.

Figure 5 presents the keyword co-occurrence graph, created using VOSviewer software (version 1.6.20) based on 50 papers previously selected through a systematic review. The tool allowed visualization of the relationships between the most frequently used terms by the authors, resulting in a semantic network that reveals the main lines of discussion in the field of study. This network was automatically segmented into three clusters by similarity and frequency of co-occurrence, represented by different colors: red, green and blue. The visualization offers a graphical representation of the conceptual proximities between the themes discussed in the literature, allowing the identification of recurring thematic cores and cognitive structures of the field (van Eck; Waltman, 2010).

Figure 5 | Keyword Co-occurrence Network



Source: Elaborated by the author.

Cluster 1 (Red) 'Governance and Forest Policy Structures' is the most prominent in terms of term frequency and density of connections. It is composed of the following keywords: policy, forest policy, framework, governance and sustainability. The strong interconnection between these concepts suggests that the literature investigated focuses on the formulation and political-institutional framework. Policy and forest policy appear as central elements, acting as the foundation for governance and the pursuit of sustainability. The presence of framework indicates a discussion about the conceptual models and structures that guide decision-making and the implementation of sustainable forest policies.

Cluster 2 (Green) 'Monitoring and Evaluation of Forest Sustainability' is formed by the terms sustainable forest management, indicators and criteria. The proximity and strong links between these terms demonstrate a research focus on the practical and measurable dimension of forest management. The term sustainable forest management acts as the central concept, while criteria and indicators emerge as the main tools to operationalize and evaluate its progress and effectiveness. This cluster highlights the literature's concern with translating the concept of sustainability into concrete metrics for monitoring and accountability purposes.

Finally, Cluster 3 (Blue) 'Management and Application of Forest Governance' is composed of the terms management and forest governance and it also presents connections with policy and sustainability, which also belong to other clusters. This grouping suggests a line of research focused on practical application and implementation dynamics. Management is closely linked to forest governance, indicating that the literature examines how governance structures are applied and manifested in management practices at the operational level. The overlap of forest governance with Cluster 1 (governance) and of sustainability with Cluster 2 (sustainable forest management) reinforces the interconnected nature of the topic, where governance acts as a link between policy formulation and field management.

Cluster analysis demonstrates that the academic discussion on the interaction between forest concessions, governance, and sustainability is not restricted to a single domain, but unfolds along three main axes: the normative-political (Cluster 1), the operational-managerial (Cluster 3) and the evaluative-measurement (Cluster 2). The interconnection between the clusters, notably through terms such as sustainability and governance, highlights the multifaceted and integrated nature of the topic in the scientific literature.

CLUSTER 1 – FOREST GOVERNANCE AND POLICY (22 PAPERS)

Forest governance and policy, central themes of Cluster 1, are presented as a complex network of discursive and institutional interactions. Arts and Buizer (2009) and Nijnik *et al.* (2021) analyze how discourses and institutional structures are not neutral, but rather social constructs that shape how policies are formulated and implemented. The discussion extends to the role of participation and legitimacy, with Johansson (2016) examining how the process of a forestry program in Sweden benefited from the engagement of multiple actors, while Newing (2009) highlights the importance of incorporating traditional knowledge into international forest policy. These studies reinforce the idea that sustainable governance is fundamentally plural and socially constructed.

In a second phase, the discussion delves deeper into the practical application of policy in diverse national contexts. Papers such as those by Kroger and Raitio (2017) and Kotilainen and Rytteri (2011) in Finland illustrate how policy can evolve to align with the bioeconomy agenda, while Weiland (2010) and Soloviy and Cubbage (2007) explore policy transitions in Eastern European countries. This diversity of case studies demonstrates that there is no single 'recipe' for forest governance, but rather a need for adaptation to the socioeconomic and historical realities of each region.

Despite the importance of policy, this cluster also reveals the challenges and gaps between intention and practice. The reliability and integrity of statistical data, as per Pyzhev *et al.* (2021) in Russia, and the challenges in translating scientific knowledge into policy formulation (Zeigermann; Boecher, 2020) are recurring obstacles. This knowledge gap serves as a crucial point of connection with Cluster 2, in which measurement and evaluation become the tools to fill this gap. Still, the analysis by Anderson *et al.* (2019) in Peru does not find a clear association between sustainability commitments and deforestation reduction, casts doubt on the effectiveness of some policies, reinforcing the need for robust indicators for monitoring.

The interconnection between Cluster 1 and Cluster 3 is evident in how policies translate into practical governance mechanisms. Lesniewska and McDermott (2014) analyze the Voluntary Partnership Agreements (VPAs) for Forest Law Enforcement, Governance and Trade (FLEGT) as a policy that seeks to combat illegality, while Boer (2020) examines the power relations surrounding projects focused on Reducing Emissions from Deforestation and Forest Degradation, plus conservation,



sustainable management and carbon stock enhancement (REDD+). Both analyses demonstrate that policies, however well-intentioned, are subject to complex power dynamics and require effective enforcement and accountability mechanisms, themes that are central to Cluster 3.

Finally, this cluster highlights governance as a central and cross-cutting concept. Papers such as Roche's (2017) in New Zealand and Dekker *et al.* (2007) in Europe demonstrate that governance is not just the policy itself, but the way it is interpreted and implemented. Forest policy functions as the mechanism that translates the intention of sustainability into management actions, and the effectiveness of this translation depends on the strength of institutions, transparency and participation - elements that will be evaluated and monitored by the indicators discussed in the following clusters.

CLUSTER 2 – MONITORING AND EVALUATION OF FOREST SUSTAINABILITY (16 PAPERS)

Cluster 2 focuses primarily on instrumentalizing sustainability, providing the tools to measure the governance discussed in Cluster 1. The concept of Criteria and Indicators (C&I) is the backbone of this section, and its importance is contextualized within the evolution of intergovernmental processes (Linser *et al.*, 2018) and international reviews (Hickey; Innes, 2008), demonstrating its status as a globally recognized tool for forest management.

The discussion delves into the methodologies for applying C&I. Mendoza and Prabhu (2000a; 2000b), in two of their papers, are pioneers in introducing 'multi-criteria decision-making' approaches and 'Analytic Hierarchy Process' allow for the incorporation of social and environmental values into the decision-making process. Irland (2010) points to the need to fill data gaps in global assessments, while Diaz-Balteiro *et al.* (2018) further the methodological debate on measuring sustainability in natural systems. Research shows that assessment is a constantly evolving field, seeking increasingly sophisticated methods to capture the complexity of ecosystems.

The interconnection between this Cluster and Cluster 1 is clear in the discussion about market mechanisms, such as certification. Hansmann *et al.* (2006) and Muhammed *et al.* (2008) demonstrate how forest certification acts as a private governance system that complements public policies, offering sustainability guarantees to consumers. The study by Ningsih *et al.* (2020) on

certification and state regulation in Indonesia is a clear example of how these mechanisms coexist in plural governance arrangements.

The application of indicators at different scales and contexts is also a highlight. Pokharel *et al.* (2015) assess sustainability in a community forestry case in Nepal; Mrosek *et al.* (2006) test C&I in a private reserve in Canada; and Butler *et al.* (2022) evaluate family forests in the USA. This diversity of case studies shows that C&I are adaptable and can be used to assess sustainability in different realities, from local to national.

In summary, Cluster 2 provides the toolset for governance. The discussion of socio-environmental sustainability indicators, such as the approach of Lindenmayer *et al.* (2012) on tree retention and economic sustainability indicators (Hamunen *et al.*, 2019) allows the discussion on governance to move from the purely theoretical field and become measurable. The connections of this cluster with the other two are fundamental: it provides the necessary metrics so that the policies of Cluster 1 can be evaluated and implemented effectively in the real world, as will be detailed in Cluster 3.

CLUSTER 3 – MANAGEMENT AND APPLICATION OF FOREST GOVERNANCE (12 PAPERS)

Cluster 3 acts as the practical application of the two previous clusters, demonstrating how governance policies and sustainability indicators manifest themselves in concrete actions and results. The focus is on management mechanisms, such as forest concessions, which serve as a laboratory for policy implementation, improvement of monitoring procedures, and verification of results in light of the proposed indicators. Papers such as those by Rocha *et al.* (2006) and Willem *et al.* (2019) analyze the economic viability of concessions in the Amazon, while Bocci *et al.* (2018) evaluate the social impact, such as income generation in communities, demonstrating the multidimensionality of governance outcomes.

The connection to Cluster 2 is direct and explicit since this cluster uses and enhances indicators for monitoring. Secco *et al.* (2011) propose a framework for evaluating governance at the project level, providing an essential methodological basis. Tegegne *et al.* (2014) create a framework of specific indicators to monitor the impact of the FLEGT's AVP, a policy discussed in Cluster 1. This

integration shows that research is moving towards a more holistic approach, in which policymaking, indicator definition, and impact assessment are parts of the same system.

The social dimension of governance, introduced in Cluster 1, receives in-depth analysis here. Community perception and attitude are central elements, with Lucungu *et al.* (2022) and Nansikombi *et al.* (2020) exploring how local communities in Africa engage with and perceive governance projects. These studies reinforce that the success of governance cannot be measured solely by economic or environmental metrics, but also by legitimacy and social acceptance.

Cluster 3 also addresses the environmental performance of policies and programs. Song *et al.* (2014) analyze the sustainability of a reforestation program in China, while McGinley and Cubbage (2017) examine forest governance in the US through the Montreal Process, which are the S&I discussed in Cluster 2. The relationship between forest management and new agendas such as the bioeconomy and circular economy (D'Amato *et al.*, 2020; Patari *et al.*, 2016) shows that sustainable forest governance is a dynamic concept that adapts to new global challenges and opportunities.

The interconnection of this cluster with the others is key to understanding sustainable governance. Cluster 3 demonstrates that effective governance requires more than good policies (Cluster 1) and good indicators (Cluster 2); it demands practical application, continuous monitoring and consideration of social, economic, and environmental impacts to achieve sustainable results.

As shown in Table 3, with the main indicators that emerge from this analysis, categorized by thematic dimensions, with references to the authors of each cluster, the analysis of the papers reveals that forest governance is sustainable when it is multidimensional, being composed of a complex interaction of elements. The clusters, although organized independently, demonstrate themes that interconnect and reinforce each other.

Table 3 | Indicators for Sustainable Forest Governance

Indicator	What does the Indicator represent?	Reference Authors
Dimension: Governance and Decision-Making Processes		
Existence of an Institutional and Legal Framework	The presence of national laws, policies (such as the FLEGT-VPAs) and programs that formalize forest management and conservation.	Tegegne <i>et al.</i> (2014) - Cluster 3; Kroger and Raitio (2017) - Cluster 1; Lucungu <i>et al.</i> (2022) - Cluster 3; Secco <i>et al.</i> (2014) - Cluster 1; Dekker <i>et al.</i> (2007) - Cluster 1; Weiland (2010) - Cluster 1
Participation and Dialogue with Stakeholders	The degree to which local communities, indigenous peoples, NGOs, and other actors are involved in the formulation and implementation of policies and projects.	Mendoza and Prabhu (2000) - Cluster 2; Nansikombi <i>et al.</i> (2020) - Cluster 3; Lucungu <i>et al.</i> (2022) - Cluster 3; Secco <i>et al.</i> (2011) - Cluster 3; Johansson (2016) - Cluster 1; Nijnik <i>et al.</i> (2021) - Cluster 1
Transparency and Access to Information	The availability of information on decision-making processes , statistical data, and resource allocation.	Pyzhev <i>et al.</i> (2021) - Cluster 1; Secco <i>et al.</i> (2011) - Cluster 3; Tegegne <i>et al.</i> (2014) - Cluster 3; Boer (2020) - Cluster 1
Dimension: Evaluation and Monitoring		
Use of Criteria and Indicators (C&I)	The application of science and innovation (S&I) systems , such as those of the Montreal Process, to measure the performance of forest management.	Linser <i>et al.</i> (2018) - Cluster 2; Hickey and Innes (2008) - Cluster 2; McGinley and Cubbage (2017) - Cluster 3; Jafari <i>et al.</i> (2018) - Cluster 2; Ireland (2010) - Cluster 2; Butler <i>et al.</i> (2022) - Cluster 2
Existence of Certification Systems	The adoption of certifications such as FSC and PEFC , or mechanisms of legality, which provide guarantees of sustainability and access to markets.	Hansmann <i>et al.</i> (2006) - Cluster 2; Muhammad <i>et al.</i> (2008) - Cluster 2; Lesniewska and McDermott (2014) - Cluster 1; Anderson <i>et al.</i> (2019) - Cluster 1; Ningsih <i>et al.</i> (2020) - Cluster 1
Indicators of Economic Sustainability	Metrics for evaluating the financial viability and economic impact of concessions or businesses based on forest products.	Rocha <i>et al.</i> (2006) - Cluster 3; Willem <i>et al.</i> (2019) - Cluster 3; D'Amato <i>et al.</i> (2020) - Cluster 3; Hamunen <i>et al.</i> (2019) - Cluster 2; Patari <i>et al.</i> (2016) - Cluster 3
Socio-environmental Sustainability Indicators	Metrics for evaluating the social impact on local communities (income, quality of life) and environmental performance (deforestation rates, biodiversity conservation).	Anderson <i>et al.</i> (2019) - Cluster 1; Bocci <i>et al.</i> (2018) - Cluster 3; Pokharel <i>et al.</i> (2015) - Cluster 2; Song <i>et al.</i> (2014) - Cluster 3; Lindenmayer <i>et al.</i> (2012) - Cluster 2; Hayrinen <i>et al.</i> (2016) - Cluster 2; Linser and Lier (2020) - Cluster 2

Dimension : Application and Results		
Effectiveness and Implementation Capacity of Policies	The ability to translate scientific knowledge into governance actions and to implement policies effectively.	Zeigermann and Boecher (2020) - Cluster 1; Roche (2017) - Cluster 1; Secco <i>et al.</i> (2011) - Cluster 3; Vogelpohl and Aggestam (2012) - Cluster 1; Halonen <i>et al.</i> (2022) - Cluster 1
Accountability Mechanisms	The existence of formal and informal processes that ensure decision-makers are accountable for their actions and outcomes.	Secco <i>et al.</i> (2011) - Cluster 3; Teegne <i>et al.</i> (2014) - Cluster 3; Arts and Buizer (2009) - Cluster 1
Community Perception and Attitude	A qualitative assessment of how local communities view and engage with forest management policies and projects.	Lucungu <i>et al.</i> (2022) - Cluster 3; Nansikombi <i>et al.</i> (2020) - Cluster 3; Mrosek <i>et al.</i> (2006) - Cluster 2; Biswas and Choudhury (2007) - Cluster 1

Source: Elaborated by the author.

Cluster analysis demonstrates that the academic discussion on the interaction between forest concessions, governance and sustainability is not restricted to a single domain but unfolds along three main axes: the normative-political (Cluster 1); the operational-managerial (Cluster 3) and the evaluative-measurement (Cluster 2). The interconnection between the clusters, notably through terms such as sustainability and governance, highlights the multifaceted and integrated nature of the topic in the scientific literature.

To synthesize and translate this complex network of conceptual interactions into a practical tool, Table 3 consolidates the indicators that emerge from the in-depth analysis of the 50 selected papers. The table, entitled 'Indicators for Sustainable Forest Governance', organizes these findings into three dimensions that reflect the complete governance cycle: (i) 'Governance and Decision-Making Processes' which corresponds to the political and institutional framework of Cluster 1; (ii) 'Evaluation and Monitoring' aligns with the measurement tools of Cluster 2 and (iii) 'Application and Results' reflects the practical implementation and impacts of Cluster 3.

This structuring allows for a holistic understanding of how the different elements of forest governance are articulated to achieve sustainability. The table not only systematizes the main recurring categories, such as transparency, legality, social participation, accountability, and institutional capacity, but also links them to the reference authors who discussed them in each of the dimensions. In this way, the indicator framework serves as a central contribution of this study, providing a robust basis for empirical research and for the formulation of public policies that are more aligned with the diverse global socio-environmental contexts.

DISCUSSION

This research, based on bibliometric and content analysis, revealed that sustainable governance in forests is an inherently multidimensional and dynamic concept that cannot be understood in isolation. Structuring the literature into three distinct clusters - (1) Forest Governance and Policy, (2) Monitoring and Evaluation and (3) Management and Application - demonstrated that field research does not follow a single path, but operates in a continuous cycle of theoretical formulation, methodological instrumentalization, and practical application. The main contribution of this study is the identification of a set of indicators that, by integrating the findings of these three axes, provide a concise and interconnected framework for evaluating sustainable governance in forests.

The interconnection between the clusters is an important aspect of our analysis. Cluster 1, with its focus on institutional and power dynamics (Arts; Buizer, 2009; Nijnik *et al.*, 2021), establishes the theoretical and political basis for governance. However, it alone is not sufficient to guarantee sustainability. The analysis reveals that sustainability policies and commitments may not translate into concrete results, as observed by Anderson *et al.* (2019). It is at this point that Cluster 2, focused on measurement and Criteria and Indicators (C&I), becomes crucial. Research on C&I, by authors such as Linser *et al.* (2018) and Mendoza and Prabhu (2000a; 2000b), offers the methodological tools so that the political aspirations of Cluster 1 can be objectively evaluated. This relationship of mutual dependence between politics and measurement is the driving force behind the discussion and demonstrates that research in the area is evolving from a conceptual debate to a practical and quantifiable challenge.

The applicability of these concepts and tools is realized in Cluster 3, which acts as the final link in the cycle. The management of forest concessions (Rocha *et al.*, 2006; Willem *et al.*, 2019) and reforestation programs (Song *et al.*, 2014) serve as a laboratory for the implementation of policies. Here, the importance of indicators becomes tangible: they are used to monitor the economic (Bocci *et al.*, 2018) , environmental, and social impacts of projects, bridging the gap between what is theorized and what is done. The research by Secco *et al.* (2011) and Tegegne *et al.* (2014), which proposes frameworks of indicators for evaluating governance at the project level, is a notable example of this bridge, integrating the discussions of the three clusters.

It is within this context of integration that global sustainability agendas, such as the Sustainable Development Goals (SDGs) and environmental, social, and corporate governance (ESG) criteria, gain a new dimension. Forest governance emerges as the main mechanism that allows nations and companies to achieve goals such as SDG 15 (Life on Land) and SDG 13 (Climate Action) but also other social and institutional objectives, such as SDG 16 (Peace, Justice and Strong Institutions). Similarly, the indicators identified in this study, such as legality, transparency and community engagement, align directly with ESG criteria. They become robust metrics for accountability, allowing companies and governments to demonstrate responsibility for their forest management practices, especially in a scenario of increasing demands for traceability and accountability. (Grab Hartmann; Goodall, 2017).

Our analysis, therefore, shows that the field of forest governance is moving from a theoretical discussion to a practice that requires integrated tools and frameworks. The proposal of a framework of indicators that reflects this interaction directly contributes to this evolution, showing that governance is not just a bureaucratic apparatus, but a field of dispute where different narratives (Arts; Buizer, 2009) and new frameworks, such as the SDGs and ESG, shape the rules and criteria for measuring sustainability.

Forest governance emerges as the central and cross-cutting concept that ties all these elements together. It is the mechanism by which policies (Cluster 1) are translated into management actions, which are evaluated through indicators (Cluster 2) to achieve sustainable results in practice (Cluster 3). The framework of indicators we present reflects this dynamic, grouping the contributions of authors from all clusters into thematic dimensions that permeate the entire discussion. It

demonstrates that governance is sustainable when it is legally sound and transparent (Cluster 1), measurable and certifiable (Cluster 2) and effective in its application and in considering community perceptions (Cluster 3).

Despite advances in the literature, the analysis also points to important research gaps. Although participation is widely discussed, its qualitative measurement and the real impact of community perceptions on different types of concessions and governance arrangements still need further investigation. Additionally, the integration of bioeconomy and circular economy indicators, although incipient (D'Amato *et al.*, 2020), suggests a promising trend for future research. The study of forest governance, therefore, remains a fertile field, requiring increasingly interdisciplinary and comparative approaches so that sustainability indicators can be adapted and effectively applied in different global and local contexts.

FINAL CONSIDERATIONS

An integrated analysis of the scientific literature allowed us to achieve the central objective of this study: to identify and analyze the indicators that link Forest Governance to Sustainability, focusing on forest concessions. The main results, derived from a systematic literature review of 50 papers, demonstrate that this relationship is multifaceted and strongly context-dependent. The findings reveal that the most effective indicators transcend technical metrics, incorporating essential elements such as transparency, legality, social participation, accountability and institutional capacity. These elements, systematized into three analytical dimensions, form a robust framework that validates the need for integrated and adaptive approaches to forest governance.

The main academic contribution of this work lies in the theoretical synthesis of a dispersed literature. By organizing the findings into three thematic clusters - (i) governance and forest policy, (ii) monitoring and evaluation and (iii) management and application - the study offers an analytical model that organizes the research field and fills the gap regarding the lack of an integrated vision. The proposal of a typology of indicators that connects these three dimensions advances the topic by providing a concrete tool for empirical research, policy formulation, and the evaluation of governance quality in concessions.



Beyond its academic contributions, this research offers significant practical and social implications. For the managerial and private sectors, the indicator framework can serve as a guideline for monitoring and reporting governance and sustainability practices, aligning with ESG criteria. Socially, the emphasis on community participation and engagement reinforces the need for fairer and more equitable policies. The results of the study also align directly with the SDGs, positioning forest governance as a fundamental pillar for achieving sustainable development goals at a global level.

Finally, it is important to acknowledge the limitations of this study, which, being a literature review, is based exclusively on existing literature and does not include primary data. However, the systematized indicators comprise the analytical matrix that underpins an ongoing empirical investigation on forest governance for sustainability in Amazonian forests. Due to its structure anchored in three dimensions (governance and decision-making processes; evaluation and monitoring; application and results), this matrix is considered relevant for guiding similar investigations in other geographical contexts, with the necessary adaptations. Furthermore, the incorporation of these indicators into legal, financial and environmental performance evaluation instruments represents a relevant development to be explored in specific research.

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