A bibliometric analysis of transnational environmental governance studies

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Abstract

The field of transnational environmental governance is broadly said to examine how non-state and sub-state actors from different countries tackle global, regional, and local environmental challenges together; however, there has been no dedicated effort to quantitatively conceptualize the knowledge structure of this burgeoning research area. Therefore, this study undertook a bibliometric analysis of transnational environmental governance studies from 1997 to 2023 using comprehensive data sources (authors, journals, keywords, and references) and multiple methods (co-citation networks, co-occurrence networks, and collaboration networks) to identify the field's key contributors and conceptual, intellectual, and social structures. The results provide a detailed overview of the transnational environmental governance research landscape, and call attention to an overemphasis on Western perspectives and a lack of attention to the Global South. We call for more inclusive analyses that better account for the diverse actors shaping transnational environmental governance around the world.

Keywords: transnational environmental governance; bibliometric analysis; key contributors; knowledge structures

1. Introduction

Cross-border collaboration is essential for solving environmental challenges in an increasingly globalized world [1–3]. Global environmental issues such as climate change and biodiversity loss necessitate a concerted global effort [4]. Regional nature and human-made systems such as forests, rivers, and energy are more effectively managed through cross-border collaboration [5,6]. Furthermore, North–North, North–South, and South–South cooperation can stimulate learning and innovation, enable faster technological transfer, and contribute to improved environmental governance [7].

Early studies tend to focus more on state-driven multilateral mechanisms such as UNFCCC and the Stockholm Convention. By the late 1990s, driven by the "governance turn" in the social sciences, scholars began to examine how non-state (e.g., NGOs, private corporations, and civil

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society groups) and sub-state (e.g., local governments) actors interacted across borders and political jurisdictions to tackle environmental challenges [8,9]. These pioneering studies gave rise to the new field of transnational environmental governance, which actively engages with the transnational as a distinct sphere of environmental politics.

Transnational environmental governance involves a diverse array of stakeholders. NGOs contributed valuable scientific and technical support to regimes like the Montreal Protocol and the Convention on Biological Diversity. Businesses have also spearheaded private certification projects and voluntary standards that supplement state regulations. Furthermore, sub-state actors implement climate action faster than national efforts, as they have more direct control over key issues like urban planning and transportation [10]. Ambitious climate initiatives in progressive cities also pave the way for national governments to implement more stringent regulations [11].

Previous literature reviews have analyzed the shifting global governance frameworks towards transnational environmental governance and the field's key research themes [8]. A more recent review focused on the conditions that foster transnational environmental governance initiatives, their relationships with state-centered cooperation and intergovernmental institutions, their legitimacy and accountability, and the political implications of their expansion [12]. Nevertheless, the increasing volume of studies on transnational environmental governance necessitates a quantitative literature analysis to better understand the current state of the field and its future directions.

This study employed bibliometric analysis methods to examine the field of transnational environmental governance and map its research trends. Bibliometric analyses summarize large amounts of bibliometric data to provide a comprehensive overview of the knowledge structure, identify research hotspots and knowledge gaps, and offer suggestions and inspiration for future research. They are particularly useful when the scope is broad or when the dataset is too large for manual review [13]. Several bibliometric software tools (e.g., CiteSpace, VOSviewer, and SciVal) help researchers conduct advanced quantitative literature analysis and visualization to trace the development of academic disciplines.

2. The rise of transnational environmental governance

Non-state and sub-state actors' engagement in transnational environmental governance was motivated by conventional state-driven cooperation's perceived limitations in addressing complex cross-border environmental challenges like climate change [8]. Formal inter-state regimes are slow to make decisions, weak in implementation and enforcement, and have questionable legal efficacy. This leaves room for transnational actors to offer irreplaceable specialist expertise, steer public opinion, and form partnerships in a more flexible manner, leading to a "hollowing out" of the nation-state [12].

The heightened involvement of transnational actors has given rise to new forms of cooperation, institutions, and governance mechanisms that cut across traditional jurisdictional boundaries set by national borders [12]. New concepts like epistemic communities [14] and global civil society [15] were developed to capture the diversity of transnational governing dynamics. Another key topic is transnational municipal networks [16, 17], voluntary associations of local governments that collaborate on environmental issues across national boundaries [18]. These networks (e.g., C40 and ICLEI) facilitate knowledge sharing, capacity building, and policy diffusion among member cities [19]. They mobilize local action and promote innovation via peer learning [20]. However, they are limited by a lack of resources, weak enforcement mechanisms, and the voluntary nature of the commitments [21].

Transnational public-private partnerships involve cross-border collaboration between government agencies and private sector actors [22]. They can take various forms, including joint projects,

voluntary agreements, and co-regulation schemes [23], but always aim to leverage the complementary strengths of public and private entities for a more effective and legitimate outcome [24]. Nevertheless, partnerships may be hindered by power asymmetries, limited accountability, and potential greenwashing, which can undermine their credibility and impact [23].

Under the orchestration model, an actor (the orchestrator) enlists and supports intermediary actors to influence the behavior of target actors in pursuit of a common goal [25]. International organizations and states typically employ indirect governance tools (e.g., funding, convening, and persuasion) to orchestrate non-state actors [26]. Orchestration can effectively mobilize a diverse array of actors and resources toward a common objective while allowing for autonomy and flexibility [27]. However, it may be constrained by the orchestrator's limited authority over target actors and misalignments between orchestrators and the intermediaries [28].

Transnational private governance refers to rules and standards developed and implemented by non-state actors, such as corporations, NGOs, and multi-stakeholder initiatives, to govern transnational economic activities and their environmental impacts [29]. It is grounded in the concept of private authority and the notion of civil regulation. These tactics use market and stakeholder pressures to improve environmental outcomes when state regulation falls short [30]. Transnational private governance often manifests as voluntary certification schemes, industry codes of conduct, and reporting standards [31]. However, these tools suffer concerns over legitimacy, accountability, and the commercial dilution of standards [32].

3. Methods

3.1. Software

Bibliometrix is a new, open-source bibliometric tool, supported by the R programming language, tailored for bibliometric analysis and literature visualization. It helps researchers identify research trends, assess the influence of specific academic journals, map knowledge structures and collaboration networks, and illustrate the evolution of research themes. Bibliometrix has several advantages over other bibliometric tools: notably, it covers a wide range of bibliometric indicators and quantitative analytical methods and offers multiple algorithm options to ensure precision and reliability. Bibliometrix has been widely adopted by researchers conducting systematic reviews in the field of environmental studies [33,34].

3.2. Data collection

The data for this study were derived from the Core Collection of Web of Science, a comprehensive database of scholarly literature that is widely used for bibliometric analyses across disciplines. The data collection process proceeded in two parts (Figure 1). The first part focused on transnational governance initiatives targeted toward specific environmental issues, including climate change, water, and forests. We searched for these different types of transnational environmental governance initiatives using quotation marks to ensure accurate search results. In the second phase, we captured looser matches by removing the quotation marks around "transnational governance." To ensure that the literature gathered in the second step was relevant to transnational environmental governance, we restricted the Web of Science categories to "environmental sciences" and "environmental studies." The search, conducted on April 15, 2023, generated 582 records.

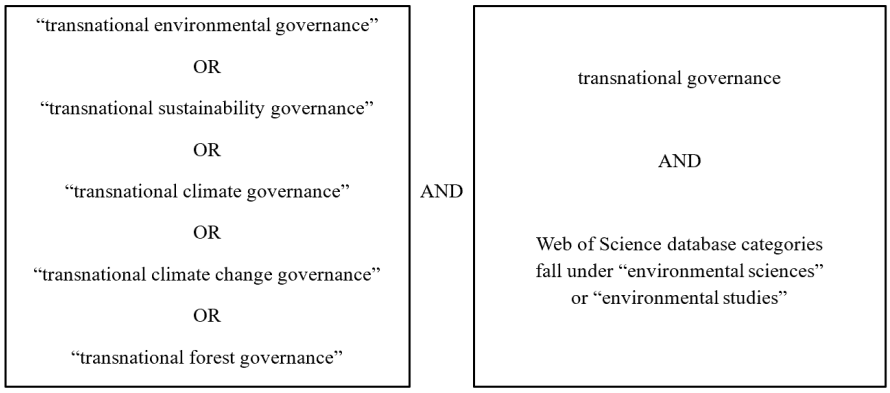

Figure 1: *Search terms, Boolean operators, and their logical relationship*

3.2.1 Data analysis

The data analysis phase was also divided into two stages. We first identified the key contributors—both key authors and key sources (i.e., the most influential scholars and journals). Table 1 illustrates the specifications for the key contributor analysis.

Table 1: *Specifications for the key contributor analysis*

Level of Analysis	Metrics	Unit of Analysis	Bibliometric Technique	Statistical Technique
Authors	Most relevant authors	Authors	N/A	Production analysis
	Authors' production over time	Authors	N/A	Production analysis
	Co-citation network	Authors	Co-citation analysis	Network analysis
Source	Most relevant sources	Journal	N/A	Production analysis
	Source's production over time	Journal	N/A	Production analysis
	Co-citation network	Journals	Co-citation analysis	Network analysis

The second stage analyzed the field's knowledge structure at three distinct levels: conceptual structure (the evolution of popular topics), intellectual structure (high-impact papers, defined as both a broad impact and a sustained impact), and social structure (researchers' social attributes and their cooperative networks) (Table 2).

Table 2: *Specifications for the knowledge structure analysis*

Level of Analysis	Metrics	Unit of Analysis	Bibliometric Technique	Statistical Technique
Conceptual structure	Co-occurrence network	Keywords	Co-occurrence analysis	Network analysis
	Thematic evolution	Keywords	Co-occurrence analysis	Network analysis
Intellectual structure	Co-citation network	References	Co-citation analysis	Network analysis
	Historiography	References	Co-citation analysis	N/A
Social structure	Countries' scientific production	Country	N/A	Productivity analysis
	Countries' collaboration world map	Country	Collaboration analysis	Collaboration network

This study's bibliometric methods included co-citation analysis, collaboration analysis, and co-occurrence analysis. These bibliometric methods were applied to analyze data on authors, journals, references, and keywords. Co-citation analysis examined the frequency with which two papers were cited together by other papers [35], to ascertain their relatedness and place in the research network. Collaboration analysis investigated co-authorship to generate social networks among researchers [36], revealing inter-country, inter-institutional, and individual collaborations.

Co-occurrence analysis explored the co-occurrence of keywords to uncover development trends across different research topics [37]. The parameters for generating co-citation, collaboration, and co-occurrence networks at each level of analysis are detailed in Table 3. The Walktrap and Leiden clustering algorithms were utilized to manage a small and large number of nodes, respectively.

Table 3: *Method Parameters for Making the Knowledge Structure Analysis*

Network	Co-citation			Collaboration		Co-occurrence
	Authors	**Source**	**Reference**	**Country**	**Authors**	**Keywords**
Clustering algorithm	Walktrap	Walktrap	Walktrap	N/A	Walktrap	Leiden
Number of nodes	50	50	50	N/A	100	1858
Repulsion force	0.1	0.1	0.1	N/A	0.1	0.2
Min.edge	2	2	2	2	1	3
Normalization	N/A	N/A	N/A	N/A	Association	Association

We mapped the thematic evolution of transnational environmental governance research into five distinct sub-periods: 1997–2014, 2015–2017, 2018–2019, 2020–2021, and 2022–2023. While most bibliometric studies divide the literature into equal time spans, we elected for the unequal sub-periods used here (17 years, 3 years, followed by spans of 2 years each) to reflect the substantial variations in publication output over time. The parameters established to map the thematic evolution are listed in Table 4.

Table 4: *Method parameters for mapping thematic evolution*

Parameter	Value
Number of words	1858
Minimum cluster frequency	5
Weight index	Inclusion index weighted by word-occurrences
Minimum weight index	0.1

4. Results

4.1. Key contributors

4.1.1 Authors

The most relevant researchers (i.e., those actively publishing) in the field of transnational environmental governance were initially identified based on their scientific output, measured by the number of publications. However, the most relevant researchers are not always the most influential. Therefore, we examined scholars' output over time, research trajectories, and co-citation networks to identify the most influential authors. Author productivity was assessed using scores for both individual production and fractionalized production (i.e., assigning a fraction of authorship production for co-authored papers). Individual production was the primary criterion for ranking authors, while fractionalized production scores were used to differentiate authors with identical individual production scores. Table 5 lists the top 16 relevant researchers in transnational environmental governance.

An analysis of these 16 researchers' trajectories revealed that interest in transnational environmental governance significantly increased after 2013, with five active researchers publishing that year. The field peaked in 2019, when nine active researchers collectively published 13 papers. Graeme Auld was a notably early contributor and had the most sustained research trajectory. Philipp Pattberg and Frank Biermann were also early entrants who devoted considerable time to

Table 5: *Top 16 relevant researchers*

Rank	Author	Institute	Individual Production	Fractionalized Production
1	Philipp Pattberg	VU University of Amsterdam	10	4.61
2	Sander Chan	Radboud University	7	1.60
3	Thomas Hickmann	Lund University	5	2.80
4	Joana Setzer	London School of Economics and Political Science	5	2.70
5	Yixian Sun	University of Bath	5	2.38
6	Graeme Auld	Carleton University	5	2.00
7	Marielle Papin	MacEwan University	4	3.00
8	Paul Foley	Grenfell Campus	4	2.50
9	Richard Perkins	London School of Economics and Political Science	4	2.50
10	Lukas Hermwille	Wuppertal Institute for Climate	4	2.38
11	Caleb Gallemore	Lafayette College	4	2.03
12	Frank Biermann	Utrecht University	4	2.00
13	Aarti Gupta	Wageningen University	4	1.79
14	Harriet Bulkeley	Durham University	4	1.74
15	Stefano Ponte	Copenhagen Business School	4	1.67
=15	Hamish van der Ven	University of British Columbia	4	1.67

the field. Some researchers, like Sander Chan and Thomas Hickmann, entered the field relatively late; however, they have emerged as some of the most active contributors in recent years.

Figure 2 illustrates the author co-citation network. Each node represents a researcher, with the size of the node indicating the number of times a researcher has been co-cited. The degree of the node reflects how many other researchers have been co-cited alongside them. A larger node and a higher degree signify greater influence.

The author co-citation network included three main clusters (Figure 3: cluster 1 = red, cluster 2 = blue, cluster 3 = green). Cluster 1 features contributions from various intergovernmental organizations, such as the World Bank, OECD, United Nations, FAO, and European Commission. Reports from these agencies provide researchers with case studies and fundamental insights. Cluster 2 has influential scholars in environmental politics, such as Harriet Bulkeley, Kenneth W. Abbott, Liliana Andonova, Frank Biermann, Karin Bäckstrand, Michele Betsill, Philipp Pattberg, Thomas Hale, Jessica F. Green, and Sander Chan. Their research primarily examines the governance roles of non-state actors and transnational governance mechanisms. Political economy and international relations scholars in this cluster offer alternative theoretical perspectives; for example, Ostrom [38] introduced the concept of polycentric governance, and Keohane and Victor [39] proposed the regime complex in transnational environmental governance. Cluster 3 includes three political geographers—Neil Brenner, David Harvey, and Jamie Peck—who emphasize the perspective of scale [40], suggesting that national, international, and local actors play crucial roles in transnational environmental governance. Their insights into neoliberalism also offer a theoretical basis for analyzing emergent conditions, governance mechanisms, and the limitations of transnational environmental governance [41].

4.1.2 Journals

The most relevant and active journals in the field were identified using the number of papers published on transnational environmental governance, while accounting for their annual publication counts, and creating a journal co-citation network map (Figure 3). The top ten most active journals in the field of transnational environmental governance (based on the cumulative number of papers published since 1997) are listed in Table 6. The top three publications were Global Environmental Politics, Environment and Planning A: Economy and Space, and Sustainability, accounting for 14.11%, 11.69%, and 10.89% of all published papers in the field, respectively. The three journals

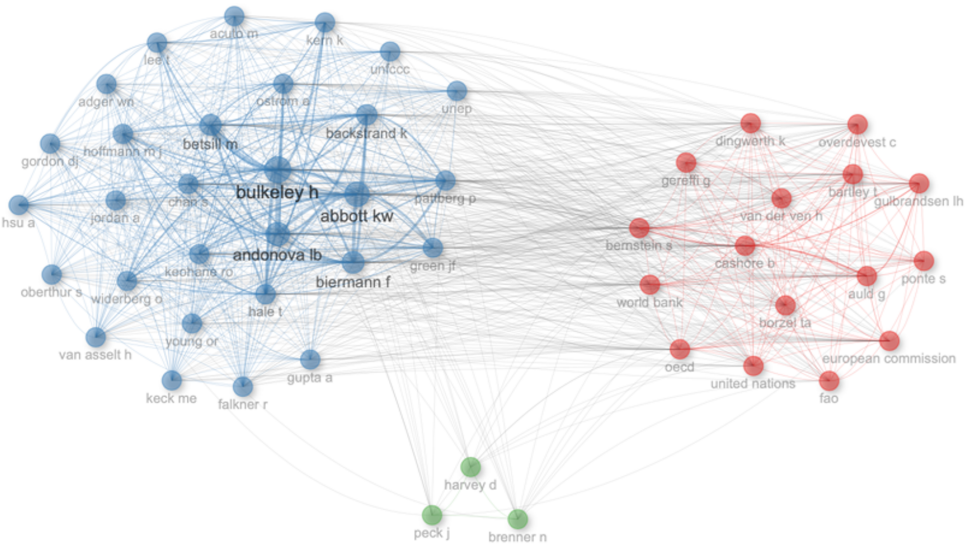

Figure 2: *Author co-citation network*

with the highest overall citations are Global Environmental Politics, Global Environmental Change: Human and Policy Dimensions, and Environment and Planning A: Economy and Space. The three journals with the highest average number of citations per paper were Global Environmental Change: Human and Policy Dimensions, Global Environmental Politics, and Environment and Planning C: Politics and Space.

Table 6: *Top 10 relevant journals*

Journal	Production	Total Citation	Citation per Paper
Global Environmental Politics	35	1246	35.60
Environment and Planning A: Economy and Space	29	874	30.13
Sustainability	27	256	9.48
Wiley Interdisciplinary Reviews - Climate Change	26	474	18.23
Environmental Politics	25	736	29.44
Environment and Planning C: Politics and Space	24	763	31.79
Transnational Environmental Law	24	357	14.87
International Environmental Agreements: Politics, Law and Economics	22	469	21.32
Global Environmental Change: Human and Policy Dimensions	21	935	44.52
Environmental Policy and Governance	15	228	15.20

Some of the earliest journals to publish on transnational environmental governance research were Environment and Planning C: Politics and Space, Environment and Planning A: Economy and Space, and Environmental Politics. Other journals began to publish research in this area after 2005. For instance, Sustainability and Wiley Interdisciplinary Reviews: Climate Change have an impressive publication output, despite only starting to publish on transnational environmental governance in 2015. As of May 2023, their total number of publications on transnational environmental governance ranked third and fourth, respectively.

Figure 3 depicts the three clusters of the journal co-citation network (cluster 1 = red, cluster 2 = blue, cluster 3 = green). Cluster 1 includes journals that examine transnational environmental governance through a political science lens. These journals focus on governance mechanisms [42], the governance function and legitimacy of non-state actors [43,44], and the governance function of sub-state actors [20]. Cluster 2 encompasses journals that provide geographical perspectives

on transnational environmental governance studies. Research published in these journals often integrates scalar politics and network politics to construct a new spatial grammar for understanding emerging forms of transnational environmental governance [45,46]. Cluster 3 features journals that offer transnational environmental governance insights from the Global South [47–49].

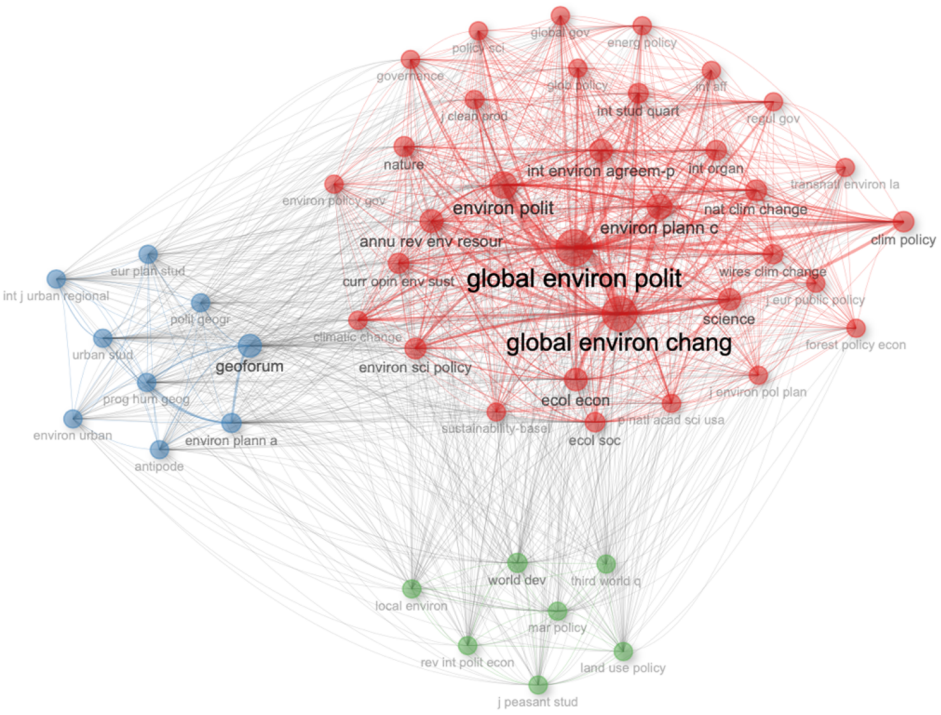

Figure 3: *Journal co-citation network*

4.2. Knowledge structure

4.2.1 Conceptual structure

To analyze the conceptual structure of the field, we identified the prominent research topics and then selected key topics for closer longitudinal examination (from 1997 to 2023). Figure 4 organizes the main research themes in transnational environmental studies into four clusters using a keyword co-occurrence network (cluster 1 = red, cluster 2 = blue, cluster 3 = green, cluster 4 = purple). Cluster 1 focuses on key attributes, such as legitimacy, accountability, and transparency of governance initiatives. These studies examine 'typical' cross-border environmental governance issues, such as biodiversity [50,51], illegal logging and forest protection [52,53], and fisheries and aquaculture management [54,55].

The nodes in cluster 2 are centered on transnational climate governance—the issue that receives the most attention from researchers. Widely discussed frameworks and perspectives include multi-level governance [56], transnational municipal networks [10], orchestration [26], and transnational regime complex [57]. Cluster 3 considers policy learning, such as micro-step mechanisms for changing transnational environmental governance [58,59]. It encompasses agricultural trade, often arguing that trade can both exacerbate and mitigate climate change [60,61].

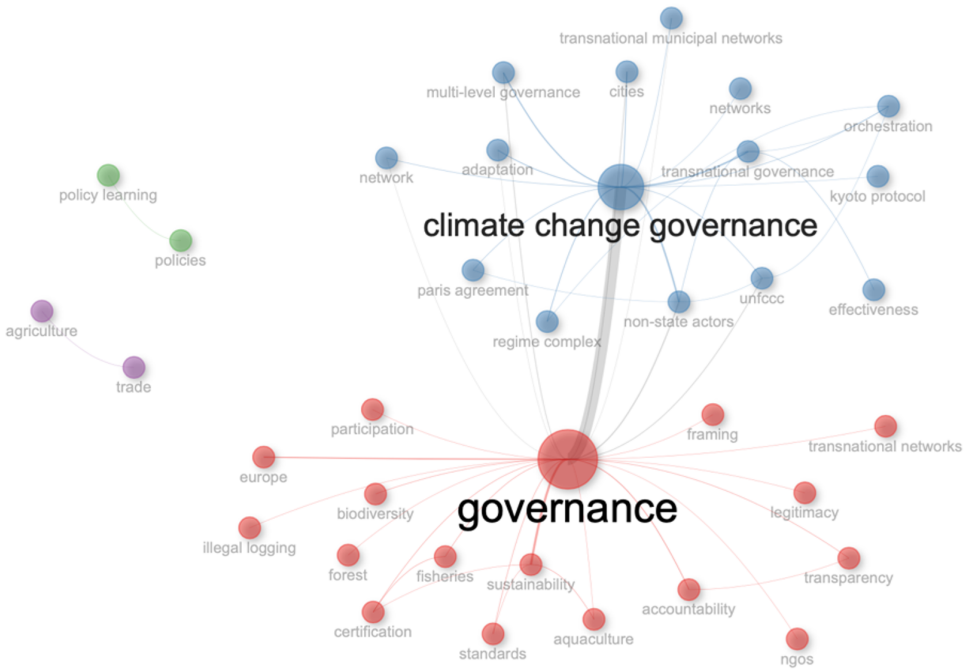

Figure 4: *Co-occurrence network of keywords*

Figure 5 illustrates the evolution of research topics using streamlines that represent the convergence or divergence of topics over time. "Climate governance" is the only keyword that appears in all five time slices, affirming its prominent position in the field of transnational environmental governance. From 1997 to 2014, climate governance research examined the gridlock of international climate negotiations and the emergence of innovative climate policies, such as the REDD mechanism [[62, 63]. During this period, researchers began exploring modes of climate governance beyond state-led approaches, including public-private partnerships and the involvement of sub-state actors [22]. Between 2015 and 2017, studies on transnational climate governance drew on various theoretical frameworks and governance mechanisms [64, 65], and took significant interest in the accountability of climate governance schemes [66].

In 2018-2019, this theme began to diverge; some research centered sub-state actors (e.g., quantitative studies on the effectiveness of municipal networks [67]) while others focused on non-state actions, such as corporate certifications and private climate governance [68]. The years 2020 and 2021 were milestones for global environmental governance. Some scholars proposed formally integrating transnational climate governance into the Paris Agreement collaboration system to enhance global cooperation in mitigating and adapting to climate change [69]. From 2022 to 2023, researchers conducted more detailed studies on the impact of city networks based on previous research outcomes [70].

The topics of "fisheries" and "aquaculture" were also of significant interest in transnational environmental governance research, particularly the role of certification and global civil society in transnational fisheries governance [71]. In recent years, transnational biodiversity conservation has attracted increasing attention. Other (non-climate change) environmental issues have received less sustained attention. While the keywords "forest" and "river" appeared in the dataset, they did not show a sustained research trend or trigger significant hotspots in any time slice.

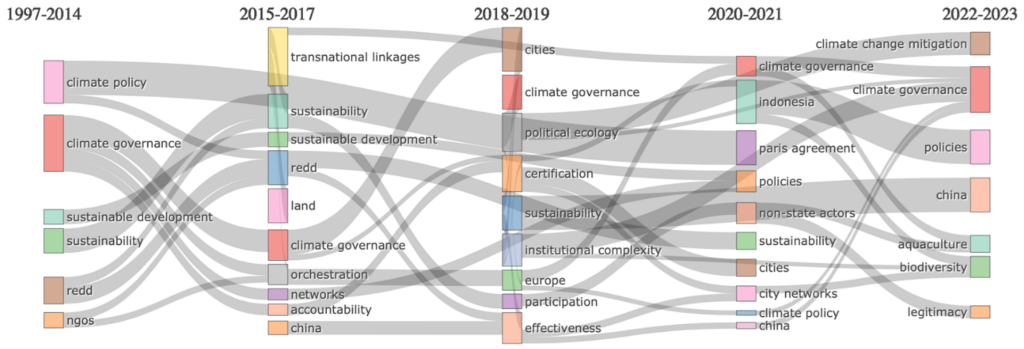

Figure 5: *Thematic evolution*

4.2.2 Intellectual structure

The reference co-citation network was mapped to identify "cornerstone" papers that propose foundational concepts and represent consensus in the field of transnational environmental governance research. A historiographic map was then produced to identify "milestone" papers from 1997 to the present, which have directly influenced the research direction of subsequent publications.

Figure 6 splits the reference co-citation network into three clusters (cluster 1 = red, cluster 2 = blue, cluster 3 = green). Research in cluster 1 includes "cornerstone" papers that propose definitions, theoretical foundations, and analytical frameworks for transnational environmental governance. The most influential paper in this cluster is Andonova and Betsill's "Transnational Climate Governance," which provided a precise definition of transnational environmental governance and established a systematic classification framework [9]. Ostrom's paper [38] addressed shortcomings in traditional collective action theory and introduced a new perspective on transnational environmental governance. Hoffmann proposed holistic, multidimensional perspectives and in-depth analytical tools for diagnosing climate change problems [72]. Bulkeley et al. [73] constructed a database of 60 transnational climate governance initiatives to empirically explore their characteristics. Finally, Hale and Roger explored interactions between conventional actors (states and international organizations) and emerging actors (non-state and sub-state actors) to redefine orchestration in global politics in "Orchestration and Transnational Climate Governance" [26].

Core literature in cluster 2 elucidates how non-state actors promote market-based transnational governance mechanisms (e.g., "Governing Through Markets: Forest Certification and the Emergence of Non-State Authority" [74]). Its most influential studies also address concerns about the proliferation of non-state actors in transnational environmental governance and the interactions between fragmented governance schemes [75]. Key research in cluster 3 examines how sub-state actors construct transnational networks to address environmental problems, particularly climate change (e.g., "Transnational Networks and Global Environmental Governance: The Cities for Climate Protection Program and Cities" and "Europeanization, and Multi-Level Governance: Governing Climate Change through Transnational Municipal Networks").

While this reference co-citation network visualizes the influence of "cornerstone" papers, it does not capture how key research affects subsequent studies over time. Therefore, Figure 7 presents a historiographic map, illustrating how "milestone" research shapes the direction of subsequent studies. In the field of transnational environmental governance, research topics generally begin by introducing concepts before exploring governance mechanisms and, eventually, evaluating governance outcomes. Qualitative research often lays the groundwork for subsequent

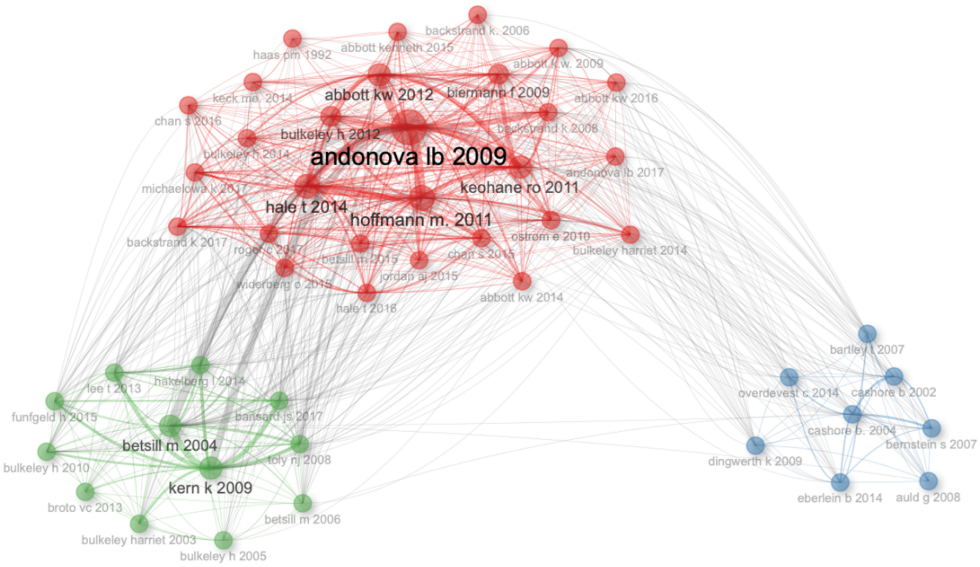

Figure 6: *Reference co-citation network*

quantitative research.

The research line on transnational municipal network studies (the purple nodes) illustrates this progression well. Giest and Howlett's [21] foundational review, "Comparative Climate Change Governance Lessons from European Transnational Municipal Network Management Efforts," reviewed types and roles of city networks in climate change governance and set the stage for subsequent empirical research. Busch et al. [76] then used qualitative surveys and interviews in German cities to demonstrate how city networks significantly influence city-level government policymaking on climate change issues. This finding paved the way for Heikkinen et al. [77] to conduct large-sample statistical analyses of the relationship between network membership and progress in adaptation planning. This progression—beginning with a desktop review, progressing to qualitative case studies, and culminating in quantitative analyses—was observed in many other lines of inquiry.

Another type of progression is illustrated by the nodes on the transnational governance of illegal logging (the brown nodes). Overdevest and Zeitlin [78] initiated this research line by analyzing the architecture, achievements, and challenges of a transnational timber legality assurance system. Nathan et al. [79] subsequently identified the various challenges Chinese timber corporations faced when implementing this system. Their findings were corroborated by similar research on Cambodian forestry [80]. These two empirical studies on the system's limitations paved the way for van der Ven et al. [44] to propose a framework for Global South engagement in sustainable commodities governance. This research line progressed from the design of innovative governance instruments through their actual implementation and limitations.

4.2.3 Social structure

Figure 8 maps the international scientific cooperation network in the field of transnational environmental governance studies. Darker shades indicate higher levels of scientific production, with the highest number of publications coming from the United States (316), the United Kingdom (255), Germany (205), the Netherlands (197), Canada (123), and Australia (103). The collaboration

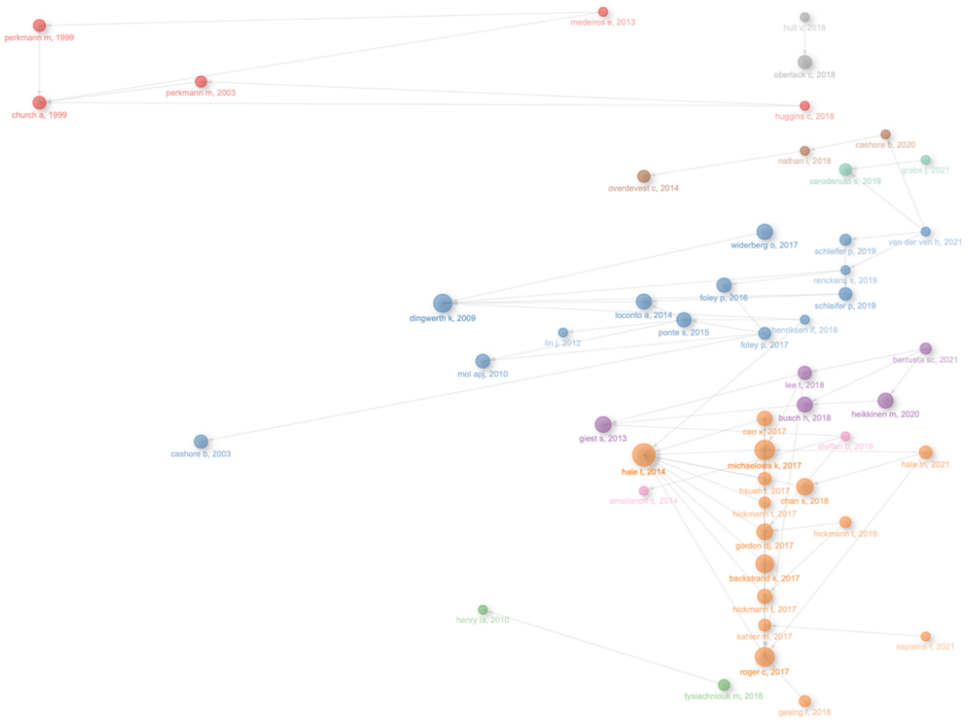

Figure 7: *Historiographic map*

network's hubs are primarily located in Europe (notably the Netherlands, the United Kingdom, Germany, and Sweden). The United States serves as another important hub for cooperation.

Figure 9 depicts an author collaboration network that illustrates interactions between individual researchers. The six networks (of fifteen) consisting of three or more researchers were selected for more detailed analysis. Researchers within collaborative networks typically share commonalities (e.g., highly consistent research interests or they originate from the same region, country, or institution).

Researchers in cluster 1 focus on the modes and mechanisms of transnational environmental governance, with a particular emphasis on constructing theoretical frameworks. Those in the second collaborative network are concerned with the governance roles of non-state and sub-state actors in transnational environmental governance, and tend to engage in more empirical research than their counterparts in cluster 1. Cluster 3 primarily comprises researchers from Dutch institutions (the PBL Netherlands Environmental Assessment Agency, Wageningen University, and Utrecht University) who work on the Sustainable Development Goals and biodiversity. Cluster 4 focuses on market-driven transnational environmental governance, including transnational private governance regimes, international trade, and international economics. Cluster 5 is composed of geographers who study the systemic integration of global sustainability and human-environment interactions. The sixth collaborative network is the only group that practices Global North-South cooperation and studies environmental issues in developing countries (Ghent University is a central hub for this cluster, as most of its researchers have studied or taught there).

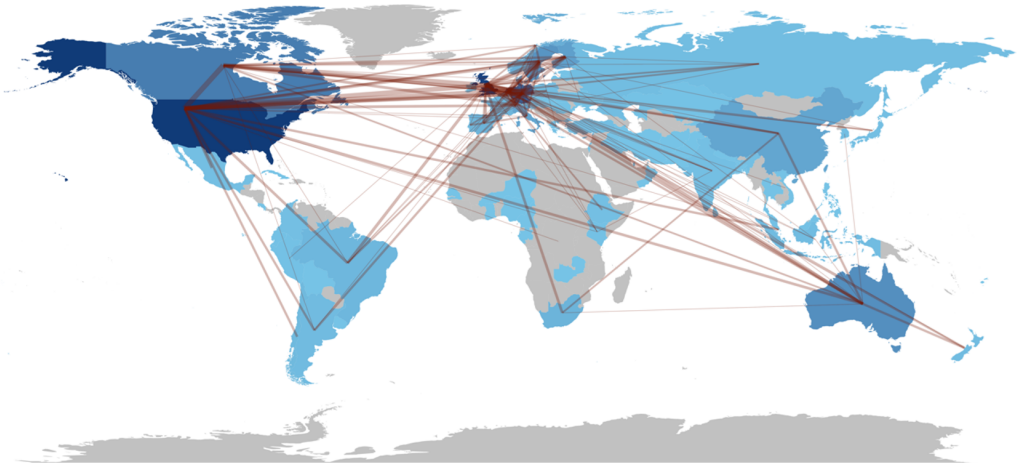

Figure 8: *Collaboration map*

5. Conclusions

This paper employed multiple bibliometric methods (co-citation networks, co-occurrence networks, and collaboration networks) to quantitatively analyze scientific production (authors, journals, keywords, and references) in the field of transnational environmental governance. The results provide a detailed overview of the transnational environmental governance research landscape. The field has become interdisciplinary, attracting scholars from disciplines like politics, international relations, and geography, and finding homes in publishing outlets traditionally focused on environmental studies, political science, and geography. The field's analytical frameworks and theoretical perspectives include legitimacy, accountability, transparency, multi-level governance, transnational municipal networks, orchestration, transnational regime complex, policy learning, and trade. Its research topics are highly varied, with a strong focus on climate governance.

Nevertheless, several research gaps persist. Firstly, most studies are conducted by Western scholars, primarily from Western research institutes and on Western contexts. This likely obscures non-Western issues and the full complexity of transnational environmental governance [81]. Analytical frameworks developed in European contexts (e.g., multi-level governance and transnational municipal networks) may not be fully applicable to projects outside these regions [82]. Transnational non-state actors also work in and/or from the Global South, where governance systems are closely intertwined with international interventions [83, 84]. Numerous countries share borders in Asia and Africa, and the rise of emerging powers such as China brings in new actors and mechanisms in transnational environmental governance [85]. As such, scholars should urgently incorporate insights from the Global South, especially the logic of post-colonialism, into transnational environmental governance research.

Another issue is that most work focuses on individual governing projects, their emergence conditions, governance mechanisms, and effectiveness, legitimacy, and accountability. Few studies explore interactions between multiple governance schemes, address challenges posed by regime complexes, or offer holistic perspectives on interactions and coupling mechanisms. Therefore, future research should develop an integrative theoretical framework to understand how different models interact, evolve, and converge in diverse contexts.

Finally, new methodologies and perspectives are needed to assess the long-term impacts and effectiveness of transnational environmental governance, particularly its social justice implica-

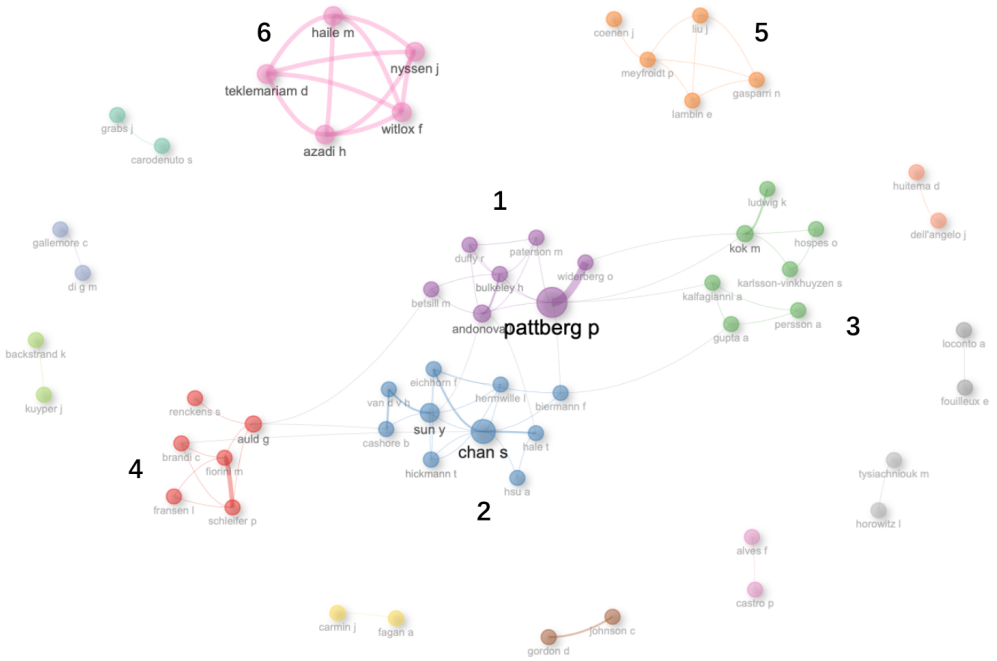

Figure 9: *Author collaboration network*

tions. Little work has interrogated how governance processes affect vulnerable and marginalized communities, especially from the perspectives of distributional, procedural, and recognitional justice [86,87]. Marginalized or underrepresented groups from the Global South may not have access to the forums where key governance decisions are made [86]. There are significant justice concerns surrounding transnational environmental governance's distributive impacts (i.e., the unequal allocation of environmental benefits and burdens across regions, countries, and communities) and procedural impacts (i.e., decision-making processes that lack transparency, inclusivity, and genuine participation) [88,89]. Furthermore, recognitional justice is frequently overlooked—the values, identities, and knowledge systems of Indigenous peoples, local communities, and culturally distinct groups are often marginalized or misunderstood in dominant governance frameworks [90,91]. Exploring these dimensions will deepen our understanding of who benefits, who bears the costs, and whose voices are ignored in transnational environmental decision-making [92–94].

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