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Mapping Green Finance Pathways for Low-Carbon Transition and Sustainable Development: A Global Bibliometric Analysis

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ABSTRACT: Green finance has grown from an environmental lending system into a full-fledged financial system to facilitate low-carbon transitions, climate mitigation, and sustainable development. Although the literature on green finance, carbon emissions, and sustainable development is growing quickly, there is a lack of comprehensive literature that covers the development history, intellectual structure, thematic development, and new research fields of green finance and carbon emissions. This study aims to overcome this lack by performing a detailed bibliometric analysis of 565 publications from Scopus that were published between 2004 and 2025. The study employs co-word analysis, co-citation analysis, bibliographic coupling, thematical mapping and collaboration network analysis, using the R package Bibliometrix and VOSviewer, to explore the knowledge structure in the field. The result show that three stages of evolution have occurred; environmental responsibility, making carbon markets and the introduction of environmental, social governance (ESG) investment, and the recent arrival of green bonds, sustainable financing tools and climate risks management. Since 2019, the research output has grown significantly, with carbon emission reduction, green bonds, green finance, blended finance and carbon pricing being new and emerging research field. This study is based on historical evolution and knowledge mapping, creating a new research framework and research roadmap to help improve green financial mechanism, enhance low carbon transition and promote sustainable development in different national and economic contexts.

KEYWORDS: Green finance, Low carbon emission, SDGs, Net zero policy, Green fintech

JEL classification: O44, Q53, Q54, Q56

1. INTRODUCTION

Green finance can be defined as any structured activity that is oriented towards enhancing environmental performance (Lindenberg, 2014; OECD, 2020; Zhao et al., 2024). There is still no single and universally accepted definition; in fact, many national and international institutions offer their own characterizations. The United Nations Environment Program defined “green finance as the amount of financial flows, which are produced by banking activities, micro-credit activities, insurance activities, and investment activities, and are channeled towards the priorities of sustainable development by the public, private, and non-governmental sectors (Lazaro et al., 2023; UNEP, 2018).

International Finance Corporation (IFC) is defined as "the allocation of financial resources for projects that yield beneficial environmental results (Carolina & Rambaud, 2022; IFC, 2020; Zournatzidou, 2025). According to the Group of twenty countries (G20), “green finance is a broad concept that cuts across the significant redirection of financial resources necessitating initiatives to improve both environmental and societal well-being by cutting down on pollution or managing climatic changes (Aizawa, 2016).” Green finance as defined by the World Economic Forum is "any systematically structured financial process aimed at attaining better environmental results, and the reserve bank of India defines green financing as project-specific efforts that are environmentally sustainable or considerate of climate-change factors (Ahmad et al., 2025; WEF, 2020).” The anthropogenic rise in carbon pollution poses a significant challenge to the world's carbon intensity and contributes to significant global warming (Chowdhuri & Gupta, 2023; Kabir et al., 2023; Redlin & Gries, 2021). The resultant increase in temperatures is threatening biodiversity, posing a grave danger to human health, and threatening food security (Muluneh, 2021). The international community, in its turn, is working towards a net-zero carbon emissions goal and a vision towards sustainable economic growth by 2050 (Asif et al., 2022; Shelly et al., 2025).

India aims to produce 50% of energy (non-fossil-fuel) by 2030 and achieve a 45% carbon intensity by 2045. It is estimated to create 35 million green jobs in 2047 (Gulagi et al., 2022; PIB Delhi, 2025). It has contributed directly to the increase in global carbon emissions because it is the most populous nation, with a population of 1.4 billion (Hussain et al., 2024; Mehmood et al., 2024).

India is the third-largest emitter of carbon dioxide, behind China and the United States (Sajeev & Kaur, 2025; Sajid, 2025; Samal et al., 2024; Zafarullah et al., 2025). Sustainable development should be prioritized, and economic growth can be supported by green investment or financing (Suriani et al., 2024). Environmentally sustainable financing or growth will be used to attain the Sustainable Development Goals and refers to investments and financial transactions in projects and activities that tend to be environmentally sustainable, especially in renewable energy (Desalegn, 2022; Raman et al., 2024). Green finance mechanism mobilizing both private and public capital to curb financial risks associated with renewable energy investments and improve economic viability (Isah et al., 2023; Rasoulinezhad, 2022). It empowers the public or private organizations to invest more resources in green operations to reduce carbon emissions and ensure sustainable growth (Naderi, 2022). It is necessary to reduce and avoid climate risks, thereby mitigating carbon emissions and enhancing sustainable economic development (Onofrei et al., 2022; Thyil & Wise, 2012). Green energy sources strengthen the clean energy sector, regulate the planet's temperature, and reduce carbon emissions (Sharma & Dubey, 2022). This review of the literature is systematic because it examines how green finance can be used to reduce carbon intensity, manage energy resources, and ensure sustainable economic development. The evaluation takes a holistic approach, assessing green finance, digital finance, gender equity, poverty alleviation, and sustainable social development.

1.1Evolution Of Green Finance And Its Mechan

Green finance has become an important tool towards promoting sustainable development, low-carbon transitions, and climate-resilient economic growth (Cong & Cong, 2023; Fu et al., 2023, 2024; ÖZBEK, 2024; Swaty, 2023). The industry has changed considerably over the last thirty years; initial aspects of environmental banking have been replaced with advanced international financial markets that focus on climate risk, integration of ESG, and new financial products (Bilimler & Cilt, 2023; Filipiak & Spoz, 2022; Saif-alyousfi, 2025; Svoboda & Ffhs, 2023). Its development is a sign of growing recognition that environmental sustainability and financial stability are closely intertwined (Billio et al., 2024; Goel et al., 2022).

In the initial stage of green finance development (Table 1), it focuses on environmental protection and corporate environmental responsibility, and introduces environmental risk assessment in the banking sector (ERA) (Oliveira, 2024; Xi et al., 2022). Launch of the first green eco program and public green fund with its key features, instruments, and drivers (Han & Gao, 2021; Pachauri et al., 2020; Sfeir-younis, 1996). Additionally, during this phase, several important green finance instruments were introduced, including green credit and environmental loans, as well as publicly funded environmental projects.

Furthermore, began environmental finance to target climate-mitigation and adaptation financing (Abdulrahman et al., 2024; Yun & Hu, 2024). This period is known as the transition phase of green finance development (see Table 2). Incentivized carbon markets, clean development mechanism projects, rapid growth in ESG investing, and the opening of private financial institutions to green finance were the primary focus areas of this phase (Shirai, 2023; Tung et al., 2025). Importantly, introduced some pivotal mechanisms of green finance, such as carbon credit, carbon trading system, green investment funds, green private equity, venture capital for clean technology, and renewable energy financing (Michaelowa et al., 2020; Nugroho et al., 2024; Oliveira, 2024; Yun & Hu, 2024).

The rise of green finance was significantly altered after the Paris Agreement was adopted in 2015; more countries saw significant growth in their commitments to net-zero trajectories (Saxena et al., 2023; UNFCCC, 2015). Some prominent features of this era included the fact that green finance has become an intrinsic element of national financial systems, central banks have begun to undertake a more systematic approach to evaluating the financial risks associated with climate change, and environmental, social, and governance (ESG) criteria have become a common investment standard (Krastev, 2024; Kwong et al., 2023; Niekerk, 2024; UNCTAD, 2023; R. Zhang, 2025). Also, new financial instruments were created- such as green bonds, green loans, sustainability function-linked bonds, sustainability bonds, green asset-backed securities, green mutual funds, exchange-traded funds, blended funds, green insurance products, and carbon pricing mechanisms that is shows (see table 3 & figure 1) maturity phase of green finance (Krause, 2024; Mudalige, 2023; Pezzey & Toman, 2002; Yun & Hu, 2024).

1.2. Green Finance in India: Country-Level Context

India is considered in this study as a country-level component of the global bibliometric landscape rather than as the exclusive geographical focus of the analysis. The India-specific discussion, therefore, provides contextual background and is interpreted separately from the global bibliometric findings. India represents current global trends but also shows a unique, policy-driven trend (Chateau et al., 2023; Pant, 2017). One of the milestones to achieving sustainability in India (see table 4) can be seen through the introduction of green bonds in 2007, massive growth in the financing of solar and wind investments between 2015 and 2023, the offering of advice on climate risk and green finance, and the issuance of a green sovereign bond in 2023 (Manaktala, 2018; Rao, 2025; Rawat, 2020; Volz, 2018). Furthermore, the focus is made on such key tools as the public and private green bonds, priority sector lending, green mutual funds and ESG funds, blended finance mechanisms with the help of sovereign and multilateral institutions, and financing energy service companies (ESCOs) to encourage efficiency (Bahadur & Jirakiattikul, 2023; OECD, 2022; Rao, 2025; Rawat, 2020).

Green finance has been developing in line with a global shift towards sustainable economic systems (Bahadur & Jirakiattikul, 2023; Swaty, 2023; Xiao et al., 2023). Designed initially as environmental lending, it has gradually evolved into an advanced ecosystem of green bonds, carbon markets, ESG-oriented investment vehicles, sustainability-linked instruments, and mechanisms

for climate risk evaluation (Mudalige, 2023; Rydzewska, 2024; Swaty, 2023; Xiao et al., 2023). With countries like India making a net-zero emissions pledge, green finance will continue to grow, thereby playing a leading role in helping transition to a more resilient, low-carbon economy across the globe (Bahadur & Jirakiattikul, 2023; Bhardwaj & Kumar, 2025; Shrimali et al., 2020). This section provides contextual background on green-finance developments in India, based on the cited literature. It is not a separate India-specific bibliometric analysis. India-related publication counts and collaboration patterns are examined separately in the global bibliometric results.

1.3. Nexus between Green Finance, Carbon Emission, and Sustainable Development Goals (SDGs)

Green financing, energy efficiency, and carbon emission mitigation are essential for achieving the Sustainable Development Goals, as stated in various studies (Agbede et al., 2021; Fu et al., 2023; H. Liu et al., 2022; Rasoulinezhad, 2022; Zournatzidou, 2025). (M. Li et al., 2021) evaluated the causal relationship between green finance, energy investment, and economic growth using Chinese economic time series data. It also showed volatility in green finance, energy investment, and renewable electricity output. Efficient utilization of energy resources, especially renewable ones, reduces carbon intensity (G. Li et al., 2020). (Bughio et al., 2025; Chen et al., 2023; J. Du et al., 2023; Khan et al., 2025; K. Li et al., 2024; Y. Sun et al., 2021; Wan & Su, 2024) Studies showed that green energy investments reduced carbon emissions, supporting the Environmental Kuznets Curve (EKC) across several regions. (D. Liu et al., 2023) evaluates how green finance and renewable energy resources affect carbon emissions in China. Furthermore, it revealed that green financing investments in renewable energy boost Chinese economic growth and cut carbon emissions. Oliveira (2024) stated that green financing helped advance sustainability through the SBM model and coordination. It was also noted that green finance improved environmental performance, but high population density hindered it. Bakry et al. (2023) confirm that green finance initiatives, particularly renewable energy, are essential to reducing carbon emissions and advancing environmental sustainability. Green finance supports economic growth and industry upgrading and influences the tertiary sector, followed by the secondary and primary sectors (Gu et al., 2023; C. Zhang et al., 2022). However, M. Li et al. (2021) and Thanh et al. (2024) reported volatility among variables using wavelet coherence and time-series data from 1990 to 2020. They found a relationship between renewable energy investment, carbon emissions, and green finance. It also highlighted unpredictable variables and the benefits of green finance from renewable energy investment.

Renewable energy and green finance investment fluctuated from 2003 to 2007 and from 2009 to 2013, among other variables in the Chinese economy (M. Li et al., 2021; Xu & Lin, 2023). It claimed that green finance and the digital economy boost green economic efficiency. Jibran et al. (2024) examined how green finance and growth affected carbon emissions in G7 countries. It stated that a threshold level of carbon emissions boosted green finance and green growth, and that G7 carbon emissions were also affected by globalization. Additionally, Zheng et al. (2021) investigated the relationship among green investment, economic development, and carbon emission. Long-term cointegration between variables and green finance minimizes carbon emissions. There is evidence from various studies, such as (G. Du, 2023; Hao et al., 2021; Huang et al., 2023; Lin & Qiang, 2021; C. Sun, 2023; G. Zheng et al., 2021), based on different groups of countries or individual countries like G7 countries, China, and Central and South Asian Countries. It states that green funding, green finance, and green enterprises decrease long-term carbon emissions, reduce environmental risks, and make it easier to achieve sustainable development goals. Likewise, green Fintech supports long-term, sustainable economic growth (Tamasiga & Onyeaka, 2022; Zhou et al., 2024).

2. METHODOLOGY:

This study uses bibliometric methods to analyse the flow of development, structural change, and the focus of academic research on green finance, carbon emissions, and sustainable development. The data were obtained from the Scopus database using comprehensive search conducted in the TITLE-ABS-KEY fields. The search strategy combined relevant keywords and Boolean operators as follows (“green finance” AND “carbon emission” AND “sustainable development”). The search was performed on retrieval date and covered publication from 2004 to 2025, capturing the growing academic and policy importance of sustainable finance and climate change mitigation. Peer-reviewed journal articles, conference proceedings, review articles, and book chapters published in English were eligible for inclusion.

The dataset was limited to Environmental Science, Econometrics and Finance, Economics, and Social Sciences using subject-area filters. After data refinement, the final corpus contained 565 documents. Descriptive and performance-based analyses were performed using Bibliometrix and its web-based interface, Biblioshiny, and VOSviewer was used to create network visualizations. The performance measures were the number of annual publications, the leading countries and institutions, the most influential authors, and the most cited documents. The science-mapping techniques studied the co-occurrence of keywords, the network of authorship collaboration, citation relationships, and bibliographic coupling. Furthermore, Thematic density maps and thematic evolution diagrams were constructed to trace the field's intellectual development and identify new, declining, and stable research themes. Such a combined bibliometric method provides an in-depth review of the field of knowledge and the research spheres in green finance and environmental sustainability.

3. RESEARCH OBJECTIVES:

RO1: To identify the dominant research themes, conceptual clusters, and emergent thematic domains within the intersection of green finance, carbon emission, and sustainable development through co-word, co-citation, and bibliographic coupling.

RO2: To analyse the publication dynamics of scientific production, including annual publication growth, citation trends, and influential time periods shaping the development of the field.

RO3: To map the contribution and collaboration network of the most influential authors, institutions, and countries engaged in this area.

4. RESULT AND DISCUSSION:

4.1. Objective 1: To identify the dominant research themes, conceptual clusters, and emergent thematic domains within the intersection of green finance, carbon emission, and sustainable development through co-word, co-citation, and bibliographic coupling. Thus, Objective 1 was addressed by identifying the major conceptual and thematic clusters.

Figure 3 shows a thematic map that organizes research themes related to green finance, carbon emissions, and sustainable development by degree of development and relevance. This map is divided into four parts, including motor themes, which illustrate well-established, highly relevant themes driving the field. In this section, green finance and carbon finance are mature and central to the research domain, indicating they are core topics with significant influence. Basic and central themes are important, but not yet fully developed or investigated in detail. In this section, sustainable development, green finance, and finance serve as foundational concepts around which much research revolves, but require further development. Niche themes are specialized and well-developed topics, but have limited influence in the broader field. Sustainability, renewable energy, and economic growth are tightly focused research areas with deep but narrow contributions. Emerging and declining themes show potentially nascent topics with limited maturity and relevance, such as carbon emission intensity, green bonds, climate finance, and bibliometric analysis, which may be new areas gaining traction or older areas losing prominence. Some terms are of intermediate relevance, such as carbon emission trading, Sustainable Development Goal 7, and greenhouse gas emissions, which are situated near the centre in the in-between quadrants, indicating evolving thematic importance. It helps to identify core research themes (motor themes) essential for academic focus and policy relevance, foundational topics needing further exploration (basic themes), specialised niche themes, and emerging or declining areas for discovering interdisciplinary linkages, and anticipating future trends for advancing knowledge and practical application of environmental economics and sustainable finance.

Figure 4 represents the intellectual and thematic landscape of research; each term represents a keyword extracted from the bibliographic dataset, while the background color gradient indicates the density of keyword co-occurrence, reflecting the relative concentration of research activity within particular thematic zones. Darker regions show high research density, indicating topics that have received greater researcher attention, whereas lighter zones indicate emerging or less-explored themes. Further, it shows that sustainable development, carbon emission, green finance, and carbon dioxide constitute the core thematic clusters. Keywords such as decentralized finance, carbon sequestration, and green development appear in relatively lighter regions, suggesting emerging frontiers that point to future directions in sustainable finance and carbon-neutral strategies.

Figure 5 shows the co-occurrence network of author keywords related to green finance, carbon emission reduction, and sustainable development. It illustrates that research on green finance, carbon emission, and sustainable development is interdisciplinary and rapidly evolving, linking environmental policy, technological innovation, and the financial system. The proximity and connectivity among central nodes such as sustainable development, carbon emissions, and green finance confirm the centrality of integrated sustainability frameworks in academic discourse.

Figure 6 shows a co-citation network (bibliographic coupling of authors), which reveals the intellectual structure and interconnection within the research domain. Each node represents a cited author, while the linkages denote the frequency with which two authors are cited together, reflecting shared theoretical or methodological foundations. The green color led by Clark (2018) and Sethi (2024) focuses on sustainability transitions and environmental policy. Similarly, the red cluster, dominated by Rasoulinezhad (2022), Umar (2021), and Habib (2022), captures studies on green finance, carbon emissions, and energy economics. In conclusion, the graph's structure underscores the growing interdisciplinary integration and dynamic evolution. It helps researchers identify the relationships among the most influential authors and clusters in the field of green finance and environmental economics.

Figure 7 shows a density visualization of the clustering and frequency of journal publications within the domains of environmental economics and sustainability. The heatmap shows the frequency and bibliometric connectivity of the journals cited in this research. Brighter (yellow) regions represent a higher concentration of journals within the research landscape, while dark blue areas indicate lower connectivity or citation frequency. It helps identify influential journals and research clusters, and the network reflects the disciplines of sustainability, energy, and environmental economics, thereby shaping the field's knowledge structure.

4.2. Objective 2: To analyse the publication dynamics of scientific production, including annual publication growth, citation trends, and influential time periods shaping the development of the field. Thus, Objective 2 was addressed by demonstrating the strong increase in scientific production.

Table 5 present the annual scientific production of publications on green finance, carbon emissions, and sustainable development. The publication trend shows a substantial increase in research output after 2019, indicating growing academic attention to the relationship between financial mechanisms and environmental sustainability. This trend indicates a rapidly growing scholarly interest in the green finance, carbon finance, and sustainable development over recent years. The observed increase likely reflects the expanding academic attention to sustainable finance and climate related research. However, the bibliometric data alone do not permit attribution of this growth to any specific policy event or initiative.

Figure 8 shows a network visualization of the co-citation network, which depicts the strength of connections among authors in a particular field. Clusters that show proximity between authors' labels indicate strong co-citation or thematic linkage, suggesting shared research interests. Figures like those of Zhang (2022b), Habiba (2022), and Clark (2018), with larger or more frequent clusters, are highly cited. It helps identify significant, emergent, and foundational research articles in the field.

Table 6 and Figure 9 illustrate the most cited document globally, papers such as (RASOULINEZHAD E (2022), Energy Efficiency with 498 citations, and ZHANG M (2022), Sci. Total. Environ, with 332 citations, demonstrates exceptionally high total and annual citation rates, highlighting it as an influential foundational work. Zhang Y, 2023, with TC per year and Normalized TC showing a rapid and strong influence, often indicating cutting-edge research in a fast-evolving subfield. Consistently high normalized values suggest a paper's impact is notable even against rising publication and citation rates in the field. It helps identify, track, and understand emerging trends and the topics and methodologies shaping the evolution of this research field. The top-cited articles often serve as benchmarks for policy and methodology, guiding future research.

4.3. Objective 3: To map the contribution and collaboration network of the most influential authors, institutions, and countries engaged in this area. Thus, Objective 3 was addressed by identifying the leading countries, authors, and institutions.

Table 7 and Figure 10 show the most relevant countries of the corresponding authors in this field. It provides specific metrics for single-country publications (SCP) and multiple-country publications (MCP). China leads by a large margin, contributing 297 articles, which is 57.9% of the total. Of these, 185 are single-country publications (SCP), and 112 involve international collaborations (MCP), accounting for about 37.7% of China's articles. India ranks second, with 32 articles: 21 SCP and 11 MCP, indicating a moderate level of international collaboration at 34.4%. Australia stands out with a relatively small total number of articles, with 16, but a very high share of MCP, with 87.5%, indicating a strong tendency toward international collaboration and so on. It reflects the international collaboration tendencies in research output across different countries. Countries like China and India focus more on domestic research output compared to international cooperation, while Australia and France focus more on international cooperation. It helps build research network dynamics, identify collaboration hotspots, and potentially guide policy for researchers.

Single-country publications (SCP) are publications whose authors are affiliated with institutions in the same country, whereas multiple-country publications (MCP) involve international collaboration among authors affiliated with institutions in different countries. The results indicate that China contributes a substantially larger share of publications in the dataset than India. This difference may reflect variation in research capacity, institutional support, policy development, and the maturity of national green-finance systems. However, publication volume alone cannot establish the effectiveness of a country's green-finance policies.

Table 8 show the most influential authors in the field of research. Wang Y and Zhang Y both have the highest number of total articles, with 12 each, making them the most prolific contributors in this field. Zhang Y and Liu Y have the highest fractionalized article counts, suggesting not only frequent publication but also significant contributions as leading authors. Furthermore, the article metrics identify influential authors in green finance and environmental economics. The article's fractionalized metric reveals authors who may have had a more substantial role in fewer papers or who had widely shared authorship roles, making it a more nuanced measure of individual research productivity. A disparity between total and fractionalized articles indicates a tendency toward multi-author research teams, in which the individual contributions, involvement, and influence of authors are considered within a collaborative research environment. It provides crucial information for evaluating not only quantitative but also qualitative involvement and influence of authors in collaborative research.

Table 9 shows the trend in research article output by various academic institutions over time. Highlighting changes and growth in publication activity over time. Adnan Kassar, School of Business, Jiangsu University; Qingdao University, School of Economics and Management; Shenzhen University; and Southwestern University of Finance and Economics are affiliated with this research field. It demonstrates a significant expansion of research activity across several institutions in the period 2020.

Limitations

This study has some restrictions. First, the analysis focused only on publications in the Scopus database, so the results may not fully reflect those that are found in the other databases. Secondly, the results of the bibliometrics are dependent on the words used in the search terms, and research conducted with other words may not have been included. Third, limiting the publications to English could result in language bias. Fourthly, indicators based on citations are affected by the nature of publications and citation habits, and can vary with time. bibliometric analysis is able to reveal trends in scientific research, but it is not used to derive causal relationships or directly evaluate the impact of specific policies or financial instruments designed to boost green finance.

5. CONCLUSION

This study explains the multidisciplinary nature of research at the intersection of green finance, carbon emissions, and sustainable development. The bibliometric analysis shows that green finance and carbon finance are the two central, well-developed themes already driving the field. In contrast, sustainable development, finance, and other underlying ideas represent important but under-studied domains that require additional academic coverage. The most promising and untapped issues include carbon emission intensity, green bonds, climate finance, decentralized finance, and carbon sequestration, which are growing rapidly and demonstrate the transition to comprehensive practice and practical strategic applicability. The publication dynamics analysis shows a significant increase in scientific production after 2019, driven by growing academic and policy interest in the conditions of global climate change. China is the most active participant in the current body of research, with substantial but relative international cooperation observed, whereas countries such as Australia show strong interest in international cooperation. The high density of collaboration and citation networks consists of prolific writers and influential journals, highlighting the main areas of knowledge diffusion. The major works that can be mentioned mostly focus on sustainability transitions, environmental policy, and energy economics, thereby providing a direction for future research. The findings suggest clear policy implications: long-term support for the development of green finance is a key element of climate action, requiring the establishment of policy frameworks that facilitate innovation in green bonds, carbon markets, and sustainable investment frameworks. The identified critical gaps in sustainable development finance and interdisciplinary interconnections require targeted research and joint programs. The high rate of publications and the diversification of themes are adequate indications that now is the right time to synchronize scientific investigation with feasible, low-carbon innovation plans, which would contribute to greater policy coherence, resource mobilization, and financial market innovation, in turn boosting global sustainable development goals. The findings provide a rigorous empirical basis for strategic interventions to harness the full potential of green finance to reduce carbon emissions and drive sustainable economic transformation.

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Figures

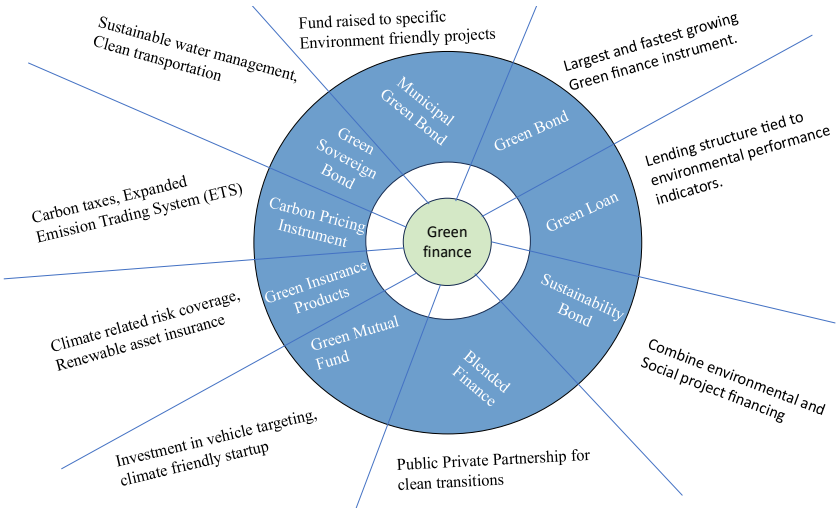


Figure 1. Instruments of green finance

Source: Author's compilation based on literature

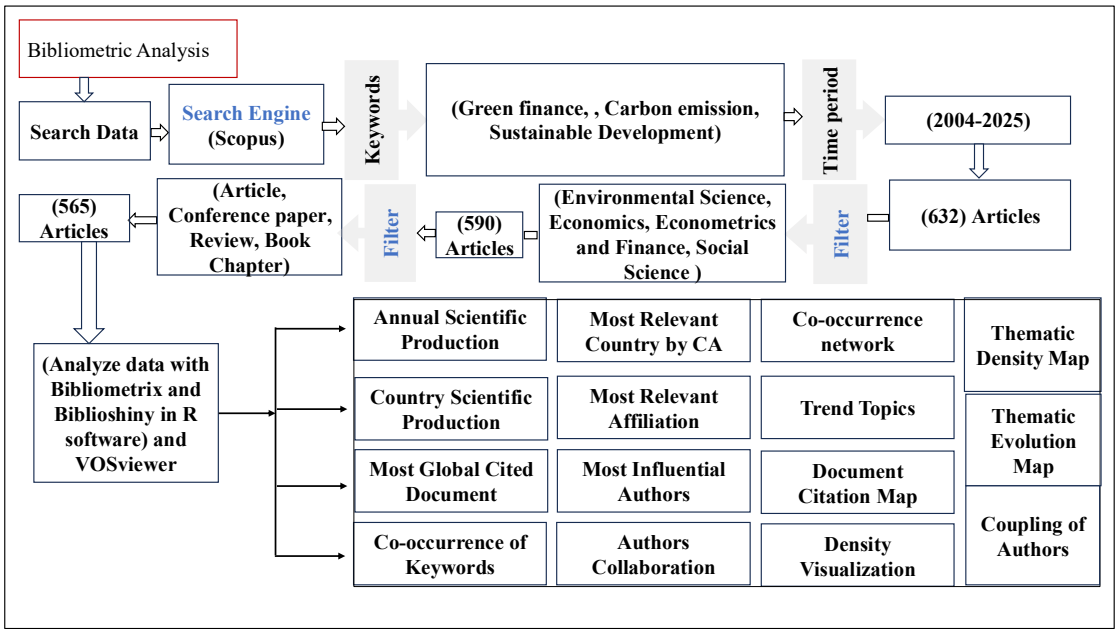


Figure 2. Illustration of methodology
Source: Author's interpretation

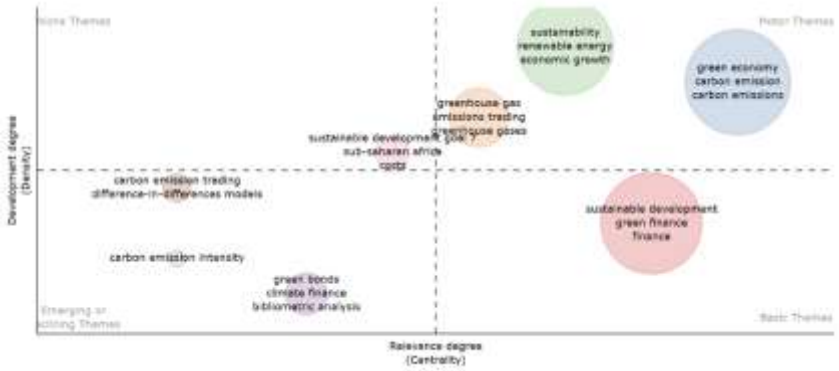


Figure 3. Thematic evolution map
Source: Author's interpretation using Biblioshiny

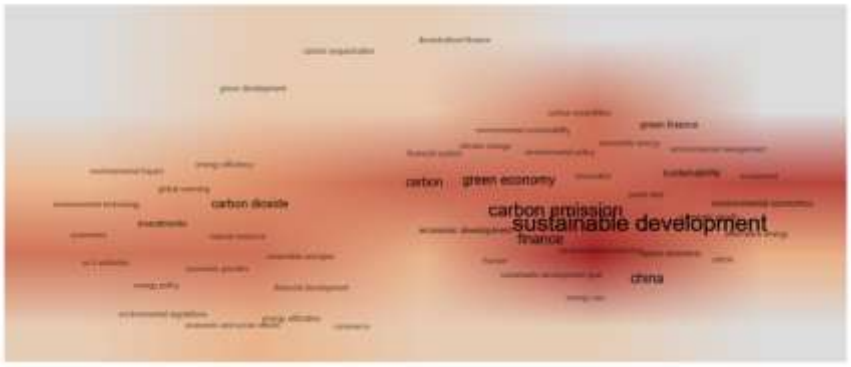


Figure 4. Thematic density map
Source: Author's interpretation using Biblioshiny

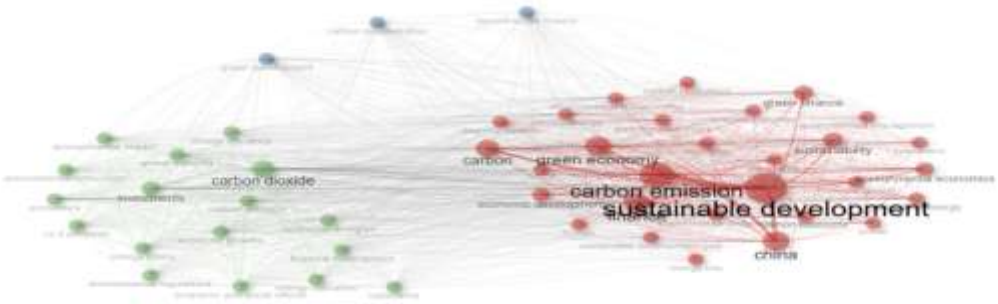


Figure 5. Co-occurrence network map
Source: Author's interpretation with the help of Biblioshiny

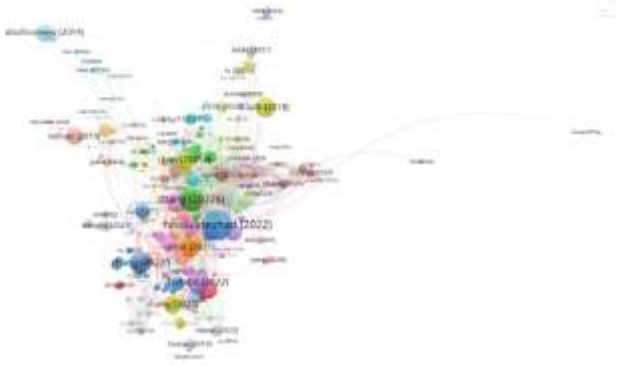


Figure 6. Bibliographic coupling of authors
Source: Author's interpretation using VOSviewer

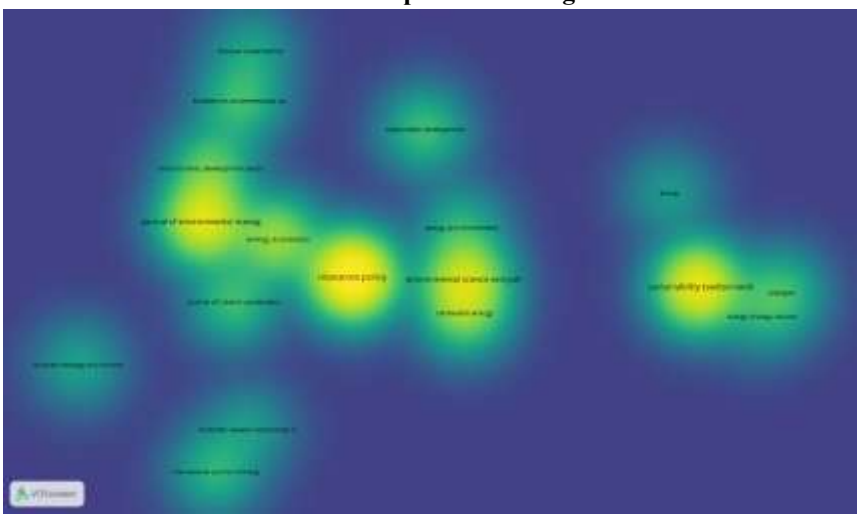


Figure 7. Density visualisation of journals by bibliographic coupling
Source: Author's interpretation using VOSviewer



Figure 8. Overlay visualisation document citation

Source: Author's interpretation using VOSviewer

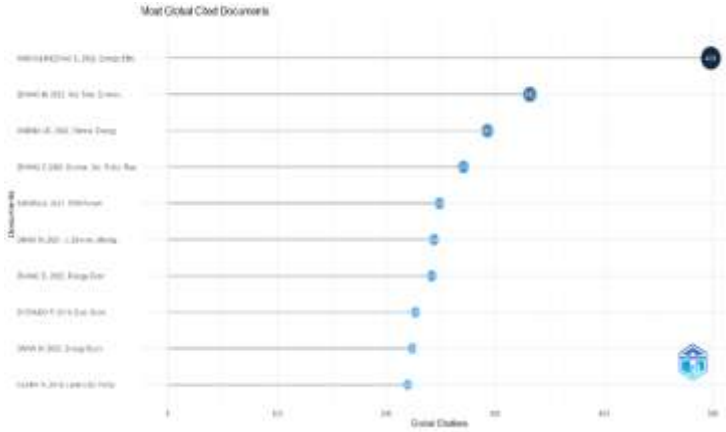


Figure 9. Most globally cited documents
Source: Author's interpretation using Biblioshiny

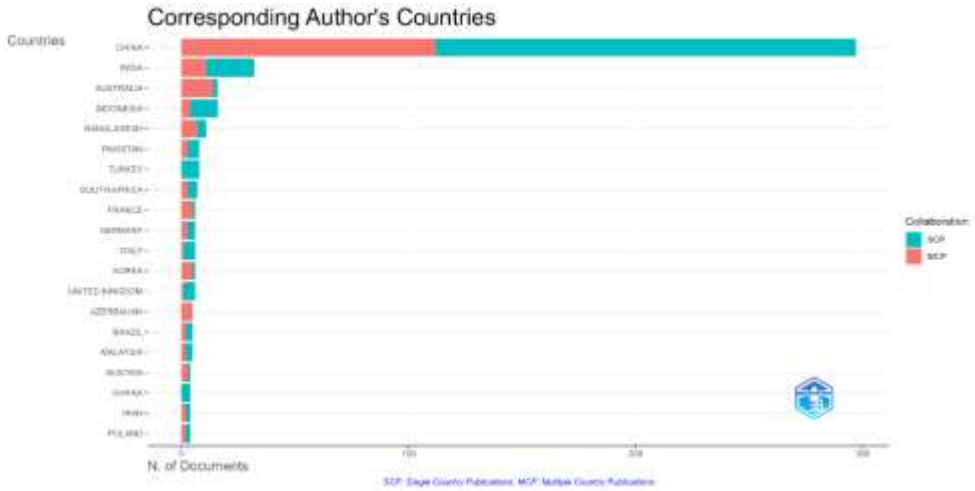


Figure 10. Corresponding authors countries
Source: Author's interpretation using BiblioshinyTables

Table 1. Initial Stage of Green Finance (1990s-2005)

Introduced the public green fund and the eco loan programme.	Create moral pressure on the firm for environmental regulation.	Public-funded environmental project.

Source: Author's compilation based on literature.

Table 2. Transition Phase of Green Finance (2005-2015)

Key features	Important instrument
Incentivised Carbon Market Introduced clean development mechanism (CDM) projects. Rapid growth of ESG investing. Entry of a private financial institution into green finance.	Carbon credit and carbon trading system. Green investment funds. Green private equity and venture capital for clean technology. Renewable energy financing (solar, wind, biomass).

Source: Author's compilation based on literature.

Table 3. Maturity Phase of Green Finance (2015-Present)

Major Trend	Innovative Instrument Introduced
Green finance became integral to the national finance system. Central banks started assessing climate-related financial crises. ESG becomes a global investment norm.	• Green bond • Green loan • Sustainability bond • Sustainability linked-bond • Green mutual fund • Blended finance • Carbon pricing instrument

Source: Author's compilation based on literature and UNFCCC report

Table 4. Green finance milestones and instruments in India

Key Milestone	Instruments
Introduced green finance in 2007.	Issuance of public and private green bonds.
Massive growth in solar and wind financing between 2015 and 2023.	Lending from the priority sector for renewable energy.
The Reserve Bank of India (RBI) published guidance on climate risk and green finance.	Green mutual funds and or ESG funds.
Introduced the sovereign green bond in 2023.	Blended finance via sovereign and multilateral support and an energy service company.

Source: Author's compilation based on literature

Table 5. Annual scientific production

Year	Articles
2008	1
2009	0
2010	2
2011	1
2012	2
2013	2
2014	3
2015	0
2016	2
2017	3
2018	3
2019	8
2020	4
2021	19
2022	43
2023	110
2024	155
2025	154

Source: Author's interpretation using Biblioshiny

Table 6. Most cited document

Paper	DOI	Total Citations	TC per Year	Normalized TC
RASOULINEZHAD E, 2022, Energy Effic.	10.1007/s12053-022-10021-4	498	124.50	6.60
ZHANG M, 2022, Sci. Total. Environ.	10.1016/j.scitotenv.2022.156463	332	83.00	4.40
HABIBA UE, 2022, Renew. Energy	10.1016/j.renene.2022.05.084	293	73.25	3.88
ZHANG Y, 2023, Environ. Sci. Pollut. Res.	10.1007/s11356-023-27870-w	271	90.33	7.06
SIKORA A, 2021, ERA Forum	10.1007/s12027-020-00637-3	249	49.80	3.21
UMAR M, 2021, J. Environ. Manag.	10.1016/j.jenvman.2021.113156	244	48.80	3.14
ZHANG D, 2022, Energy Econ.	10.1016/j.eneco.2022.106183	242	60.50	3.21
D'ORAZIO P, 2019, Ecol. Econ.	10.1016/j.ecolecon.2019.01.029	227	32.43	2.37
UMAR M, 2023, Energy Econ.	10.1016/j.eneco.2023.106560	224	74.67	5.84
CLARK R, 2018, Land USE Policy	10.1016/j.landusepol.2017.12.013	220	27.50	2.08

Source: Author's interpretation using Biblioshiny

Table 7. Most relevant countries by corresponding authors

Country	Articles	Articles %	SCP	MCP	MCP %
CHINA	297	57.9	185	112	37.7
INDIA	32	6.2	21	11	34.4
AUSTRALIA	16	3.1	2	14	87.5
INDONESIA	16	3.1	12	4	25
BANGLADESH	11	2.1	4	7	63.6
PAKISTAN	8	1.6	5	3	37.5
TURKEY	8	1.6	8	0	0
SOUTH AFRICA	7	1.4	4	3	42.9
FRANCE	6	1.2	1	5	83.3
GERMANY	6	1.2	3	3	50

Source: Author's interpretation using Biblioshiny

Table 8. Most Influential authors

Authors	Articles	Articles Fractionalized
WANG Y	12	3.14
ZHANG Y	12	3.95
LI X	10	3.33
LIU Y	10	3.93
CHEN Z	9	2.78
WANG Z	9	2.77
LI J	8	2.40
WANG J	8	2.33
AL-FARYAN MAS	7	1.78
CHEN S	7	2.43

Source: Author's interpretation using Biblioshiny

Table 9. Most relevant affiliation network

Affiliation	Articles
JIANGSU UNIVERSITY	17
SOUTHWESTERN UNIVERSITY OF FINANCE AND ECONOMICS	17
ADNAN KASSAR SCHOOL OF BUSINESS	13
QINGDAO UNIVERSITY	12
SCHOOL OF ECONOMICS AND MANAGEMENT	12
SHENZHEN UNIVERSITY	12
JILIN UNIVERSITY	11
SCHOOL OF MANAGEMENT	10
WUHAN UNIVERSITY	10
CITY UNIVERSITY OF MACAU	9

Source: Author's interpretation using Biblioshiny