

**Research**

# Unveiling research trends on the nexus between green finance and sustainable development: a systematic bibliometric review

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© The Author(s) 2025 **OPEN****Abstract**

This study attempts to provide a research landscape on the relationship between green finance (GF) and sustainable development (SD) using the Scopus database. A bibliometric analysis of a total of 1547 articles published during 2010–2024 is conducted to examine the relationship between the given variables. The study found that China is the leading contributor to research on green finance and sustainable development, followed by India and the United Kingdom. Green finance, sustainable development, renewable energy and climate finance are the key research themes, which are determined through analyses of keyword frequency and centrality. On the other hand, clean development mechanisms, financial instruments, technological advancement and the energy sector were identified as research hotspots. This study is mainly helpful for policymakers, researchers and their funding agencies, as it assists them in setting research, funding and policy priorities related to green finance and sustainable development.

**Keywords** Bibliometric analysis · Green finance · Sustainable development · Biblioshiny · VOSviewer · SCOPUS**JEL Classification** Q5 · C1 · F64 · Q01

## 1 Introduction

The academic literature related to green finance and sustainable development is expanding exponentially. There has been a rise in the total number of research publications, with an annual growth rate of 36.99% from 2010 to 24. Thanks to the mounting environmental concerns across the world, whose logical corollary was a heightened demand for green financing and sustainable projects. Both the terms ‘sustainable development’ and ‘green finance’ are often seen being used together, given their strong interrelation. As outlined by Elkington’s triple bottom line approach [22, 31], GF has emerged as a pertinent and transformative force for a sustainable economy, as it directs financial resources towards socially responsible and environmentally friendly projects. This, in turn, will have positive environmental benefits and thus contribute to sustainable development [27].

In 1987, the United Nations published the book *Our Common Future*, which defined the concept of sustainability as “the satisfaction of current needs without compromising the ability of future generations to meet their own needs” [5, 11]. On the other hand, the term ‘green finance’ came into prominence after the ‘Earth Summit’, held in Rio de Janeiro, Brazil, in 1992. It is defined as the “financing of investments that provide environmental benefits” [4, 25]. Green Finance represents a financial instrument that assists individuals in making financial decisions that align with the evolving demands of society and the environment. The aim is to promote investments that are crucial for

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promoting sustainable development. The term ‘Green Finance’ includes a range of forms, including green bonds that finance environmentally sustainable projects [28], socially responsible investing (SRI) that considers environmental, social, and governance (ESG) factors in investment choices [39], and impact investing, which aims to generate financial returns while also fostering positive social and environmental impacts [32, 52].

As countries worldwide started realizing the significance of sustainable development and green financing, it led to a significant rise in the attention of researchers and policymakers worldwide. As a result, the research in this area became extensively diverse and innovative. This is evident from the research carried out on a variety of subjects such as greenhouse gas emissions [33, 40, 55], climatic disasters [23], environmental disclosures [6, 37, 50], the economic impacts of global warming and temperature changes [6, 19], the connection between temperature and overall risk [34], and the effect of climate policy risk on the financial system [51].

As the diversity of research on green finance and sustainable development became further diverse, the literature also kept expanding. This is evident from the fact that there has been a rise in the total number of research publications, with an annual growth rate of 36.99% from 2010 to 2024. Research centres increased annually from 2010 to 2024. Over time, the field of study has become more complex. The Journals are widely distributed across academic fields. Many countries have journal collaborations. However, the close relationship between academics and financial institutions and the interaction among specific researchers suggest that in the context of globalization, widespread cooperation across nations, publications, and organizations may advance this field.

This rapid increase in the pace of literature and a complex network of researchers and institutions enthused us to raise a pertinent question of how the themes of green finance and sustainable development have been studied by scholars in this field over a period of time. It also motivated us to explore the possible future research areas related to these two pertinent themes. In our quest, we found bibliometric analysis to be a scientific approach that could give us possible answers. Bibliometric analysis quantifies academic publications, author keywords, research trends, citations, and co-citations in scientific literature. It provides information on academics, research institutes, and scientific fields’ authority and influence. By visualizing research collaborations across authors, institutions, and countries, bibliometric analysis can show how research networks organize and share information. This study utilizes the SCOPUS database, recognized as the most extensive database globally [18]. Scopus features a 20% greater number of journals compared to Web of Science [29, 59].

This study distinguishes itself from previous bibliometric evaluations by conducting a more comprehensive investigation that considers several dimensions and takes a holistic approach. The study addresses five broad research questions, which are mentioned below.

- RQ1: Which institutions, authors, journals, and publications have a significant influence on GF and SD research?
- RQ2: What is the current trend in terms of the citation impact of the concept of GF, and how has it evolved in the sustainability literature?
- RQ3: What are the most significant and prominent keywords in gf research?
- RQ4: What are the geographical distributions and organizational affiliations of the research?
- RQ5: What is the scope of this study, and what are the primary areas of future research in GF for SD?

To address these research questions, the analysis was conducted for the specified research period, which spanned from January 2010 to July 2024. The study involved performance analysis and scientific mapping analysis using VOS viewer, Biblioshiny (RStudio), and MS Excel to gain a comprehensive understanding and achieve more precise results. This investigation explored a range of science maps, encompassing co-word analysis, citation analysis, thematic analysis, co-authorship analysis, and geographical analysis of publications through the lens of science maps. These maps were developed to illustrate the intellectual structure of the GF and SD fields from various perspectives. The study employed keyword analysis to explore topic clusters and pinpoint areas lacking research.

The present study contributes to the existing literature by consolidating the research in green finance and sustainable development in one place. Moreover, investigating Green Finance through bibliometric analysis could significantly improve our knowledge of the development of green financial structure. It does this by analyzing scientific output, detecting patterns and areas of deficiency, and uncovering relationships between researchers, institutions, and countries [41]. In addition, monitoring the quantity and influence of publications over time is a measure of the advancements achieved in achieving SD while identifying areas that need a greater focus on GF [26].

Essentially, conducting a bibliometric analysis of the intersection between GF and SD literature contributes to the creation of a robust body of evidence that can guide policy decisions, identify key research areas, and facilitate the

allocation of funding. This, consequently, bolsters global initiatives focused on advancing sustainable development. The study seeks to uncover the solutions to the inquiries presented in various sections. This study is mainly helpful for policymakers, researchers and their funding agencies, as it assists them in setting research, funding and policy priorities related to green finance and sustainable development. The rest of the paper is organized as follows.

While section two offers a detailed account of the materials and methods utilized, section three presents and analyses the results. It is followed by section four, which highlights the main implications of the study, provides suggestions for further research endeavours and concludes.

## 2 Materials and methods

### 2.1 Bibliometric network analysis—theoretical framework

Bibliometric analysis is a quantitative approach increasingly employed to investigate the trends, structure, and influence of literature within a specific field or topic. The theoretical framework of this analysis is linked to several theories, such as social networking theory [30], citation theory [44] and Centro matrix theory [1]. Moreover, it also includes major concepts such as Prices' law, which explains the growth of scientific literature with an exponential increase in no of publications over time [45], and Lotkas' theory, which elaborates on the productivity of a small no of highly productive authors and large no of less productive authors and the impact of their work in that particular field [36]. In order to have a thorough grasp of the research literature that can be used to propose future research agendas, the present study attempts to undertake an integrated review [12, 54] that includes both bibliometric and manual reviews.

The analysis involves collecting publication data of studies undertaken in the particular field from databases such as Web of Science, Scopus, and PubMed and analyzing publication patterns like citation network, author contributions using statistical and computational methods. Finally, the results are visualized by using techniques like network analysis, heat maps and time series analysis to present the result.

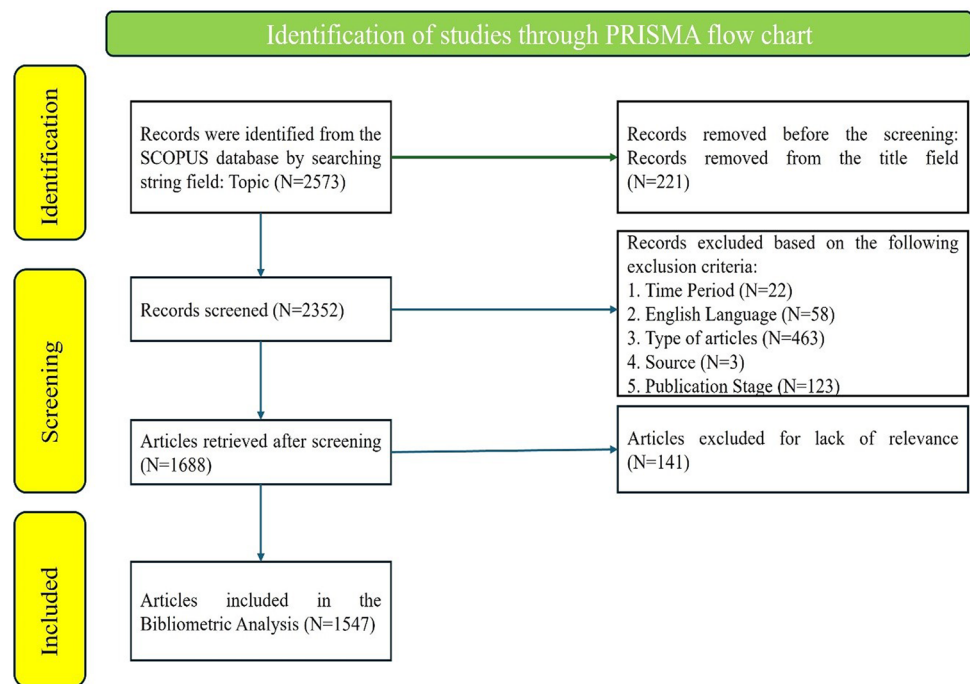
### 2.2 Data collection

A quantitative bibliometric study was conducted using VOS Viewer 1.6.194 and Biblioshiny, a tool integrated within the Bibliometrix R package. Both software programs gather bibliometric information on leading authors, citation counts, keywords, and countries of production. One should not rely on a single software to perform bibliometric analysis because each software has certain limitations. Using multiple software allows the limitations of one software to be addressed by other software. For example, the VOS viewer mainly focuses on the visualization of bibliometric networks for analysis of co-authorship, co-citation, and cluster analysis but does not provide advanced statistical and quantitative analysis of bibliometric data. The Bibliometrix R packages include additional features such as the h-index, g-index, Lotka's Law, Bradford's Law, and data cleaning and processing tools. Therefore, this study strongly believes that using these two software applications will make the analysis more comprehensive. A total of 1537 research papers were imported into both software programs for data analysis. The tool generated network diagrams illustrating the co-authorship relationships among authors, institutions, and countries. The study also analyzed patterns of source and document citations, co-occurrence of keywords, and co-citation among authors. The VOS viewer presented data through various graphs and tables. Network analyses evaluate authors, countries, documents, sources, and organizations, focusing on those with limited citations and documents. VOS Viewer visualizations illustrate the relationships among authors, organizations, publications, and countries. Labels and bubbles signify elements, while lines establish connections [2].

### 2.3 Source strategy

This study used the SCOPUS dataset. The intellectual progress and impact of GF research on SD were examined from 2010 to 2024. Figure 1 shows the PRISMA flowchart, which helps in the inclusion and exclusion of relevant studies. Green financing and Sustainable Development materials were found using a broad search method. The data was collected by searching for keywords such as "sustainable economic growth" or "economic growth" or "green growth" or "Sustainable Development" and "green financial development" or "green finance" or "climate finance" or "sustainable finance" or "environmental finance" or "carbon finance" or "green investment" or "green credit" or "green securities" or "green trade" or "green insurance". This study uses all these mentioned keywords under a broad research theme of "green finance and

**Fig. 1** PRISMA flow chart  
(Source: Authors' compilation)



its impact on Sustainable Development” to include all the above sectors in our research, and that will further improve the data accuracy [24]. As is observed from Fig. 1 by the PRISMA flowchart, we refined Scopus’s unprocessed data by searching only for articles and reviews. In addition, only the English language was used, and the data filter was applied by selecting the criterion of “relevance” [2]. Each of the 1547 research articles includes the author’s name, title, year, citation, affiliations, keywords, editors, publisher, and other relevant information.

### 3 Results and discussion

#### 3.1 External characteristics of the publication

The study conducted on the dataset comprising 1547 records clarifies the evolution of literature, the trends in inquiry, and the possibilities for forthcoming investigation. This section outlines the existing trends in publishing, relevant sources, subject areas, author details, and the thematic organization of the data.

##### 3.1.1 Information about retrieved data

Table 1 illustrates the data regarding the publishing trends of the selected articles, which shows a consistent rise in publication numbers, country participation, and author collaboration during the research period. The data obtained from Scopus spans from 2010 to 2024. According to the statistics, 1547 articles were published in 405 publications. These papers used 4068 keywords plus and 3575 keywords provided by the authors. This domain has received contributions from a total of 3386 authors worldwide. The number of citations per article is 22.48, suggesting that, on average, each item received 22.48 citations during the study period. The level of cooperation among writers was significant, with just 194 out of 1547 papers being single-authored, while the other articles were created collaboratively. The overall H-index of all publications is 91.

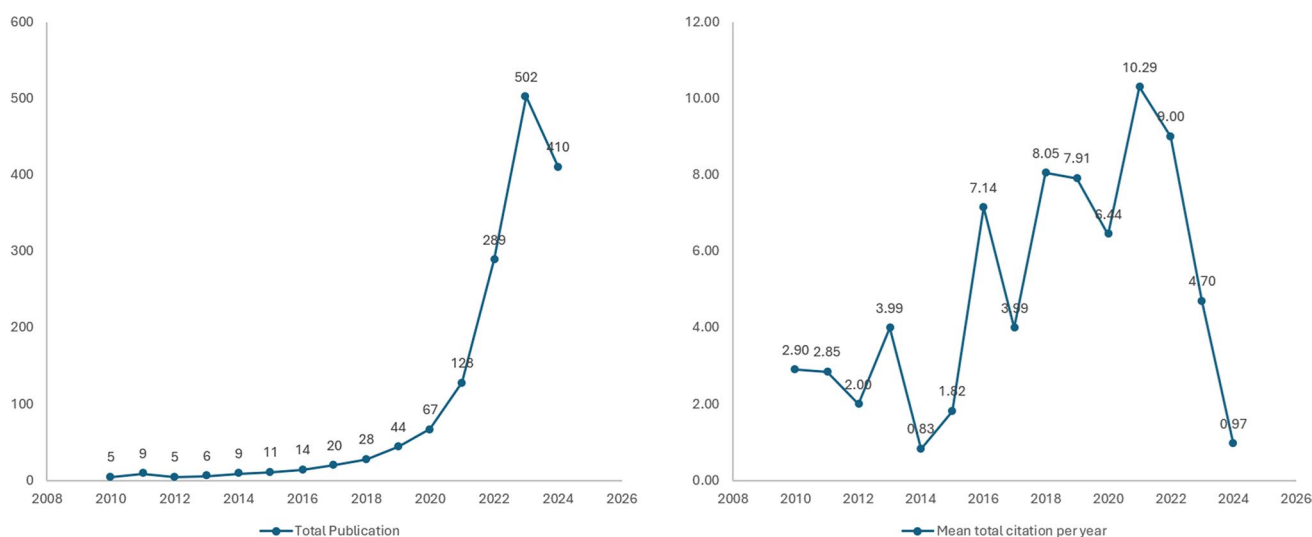
**Table 1** Publication trend

Time span	2010–2024
Sources (Journals, Books, etc.)	405
Documents	1547
Annual growth rate %	36.99
Document average age	1.86
Average citation per doc	22.48
References	
Document contents	
Keywords plus (ID)	4068
Author's Keywords	3575
Authors	
Authors	3386
Authors of single-authored docs	181
Authors Collaboration	
Single-authored docs	194
Co-Authors per Doc	3.26
International co-authorships %	33.81
Document Types	
article	1465
review	82
H-index (Publication)	91

Source: Authors' compilation using Bibliometrix R package

### 3.1.2 Trend analysis of research publications

Figure 2 illustrates the annual growth of publications and average total citations per year about the relationship between GF and SD from 2010 to 2024, which addresses RQ1. There has been a significant acceleration in the global production of publications since 2019. In particular, in 2021, there was a considerable increase, resulting in 128 articles and an average of 12.86 citations per year. The pressing demand for climate action, the effects of the COVID-19 pandemic, evolving regulations, heightened focus on ESG factors, and progress in fintech are all driving the rise in publications on GF and SD since 2021. The relationship between these factors highlights the importance of GF in tackling environmental issues and fostering sustainable economic development [26]. A total of 289 articles were analyzed, revealing an average growth



**Fig. 2** Trend of nexus of GF and SD-related publication and average citation (Source: Authors' compilation using Bibliometrix R package)

rate of total citations of 12.00 for 2022. In 2023, there were 502 articles published, with a citation count of 7.04, reflecting a twofold increase. It is suggested that the relative growth of publications began to increase after COVID-19 (2020), and in fact, it abruptly doubled. Since 2020, there has been a consistent rise in the average number of cumulative citations per year.

### 3.1.3 Systematic review of literature

The evolution of GF [15–17, 40, 42, 60] and its impact on SD [3, 4, 7, 16, 17, 33, 43] have been extensively investigated over the years. A comprehensive overview of the bibliographic literature that has explored the effect of GF on SD in recent years is given in Table 2. This review of studies confirmed that while developed countries have made significant contributions in the theoretical aspect regarding GF and its impact on SD, the research conducted in developing countries on GF still has a larger scope. However, it comes as a respite to observe that developing countries such as China, India, Pakistan, etc., are showing great interest in research in this area. This is mainly due to the environmental challenges they face and the possible threat it pose to their economies in the long run. As shown in Fig. 2, since research in the given field started gaining momentum in 2010, the current study has chosen the period 2010–2024 for its research to understand the research trends and patterns on the green finance-sustainable development nexus. By using bibliometric analysis, this study also attempts to understand the role of green finance in achieving sustainable development goals in the face of the COVID-19 pandemic. The keywords used in this study specifically focused on GF and SD to obtain a more targeted exploration of GF as an enabler of SD. Therefore, this study contributes to the comprehensive development of the literature by filling the aforementioned gaps.

### 3.1.4 Citation analysis of top journals

From Table 3, it can be observed that the preferred journal among researchers is ‘Resource Policy’, which has published 132 articles and received 2548 citations, resulting in a g-index of 48. Following closely is ‘Sustainability’, with 125 publications, 2,564 citations, and a g-index of 45. Another notable journal is ‘Environmental Science and Pollution Research’, which has published 113 articles, received 2276 citations, and has a g-index of 45. These three journals possess the greatest g-index scores. The high citation count of these top journals is a result of the reputation, relevance, and quality of the articles published [12, 14]. These journals focus on topics related to sustainability and environmental issues, and a rigorous peer review process ensures that studies are impactful to a wide audience.

In this research, we emphasize the g-index due to its ability to assign more importance to highly cited publications in comparison to the H-index. The H-index measures the number of articles (h) that have received a minimum of h citations. Still, it does not consider the citation counts of publications that exceed this threshold. However, the G-index is computed to represent the cumulative number of citations obtained by the highest-ranking g articles, where g is the maximum value for which these articles collectively have gotten a minimum of  $g^2$  citations. The G-index is capable of identifying and acknowledging writers who have a small number of highly cited publications, thereby offering a more nuanced assessment of an author’s influence [21]. The journal ‘International Journal of Energy Economics and Policy’ ranks 15th regarding article productivity, with 50 citations. The data shows that China led the top 15 countries in the volume of published works concerning the relationship between GF and SD. The comprehensive and significant studies being carried out in the areas of GF and sustainability are collectively represented in these journals. Each journal contributes uniquely through its publishing volumes, citation impact, and overall academic influence.

The Bradford law assists researchers in identifying “core journals” within their area, indicating that a limited number of journals will include a substantial part of relevant content. In Fig. 3, we can see the core five journals: Resource Policy, Sustainability (Switzerland), Environmental Science and Pollution Research, Journal of Cleaner Production, Renewable Energy, and Energy Economics.

### 3.1.5 Citation analysis of leading publications

In academia, the quality of highly cited publications holds great importance since it underscores the value of a study in a given field. Analyzing the most cited publications can help assess the current state of research and identify areas that need further research. It also helps understand how that information affects future research [19]. Based on 2010–2024 citations, the study of highly recommended articles reveals the GF and SD link’s primary focus. The ten most cited publications by



**Table 2** Comparison between a recent literature review on the green finance-sustainable development nexus

S.no	Source	Study	Methodology	Findings of the study
1	(Singh, Arun, et al., 2023) [16]	GF and its role in facilitating the transition to Industry 5.0 (I5.0) to achieve sustainability	Bibliometric analysis and SLR	The study outlines how green finance supports the transition to Industry 5.0 and ultimately Society 5.0
2	(Agrawal et al., 2024) [3]	GF and green innovation (GI) in achieving circularity	Bibliometric analysis and SLR	The study presents a framework that connects financial goals with environmental innovation, helping businesses create value while benefiting society. It also adds valuable insights to the existing knowledge of green finance and innovation within a circular economy
3	(Singh et al., 2024) [17]	GF through green energy innovations for environmental sustainability	Bibliometric analysis and SLR	This study highlights the role of green innovations in promoting sustainability, identifying key themes, and evaluating their impact on reducing emissions and energy use
4	(Singh, Kumar, et al., 2023) [15]	green venture capital(GVC) for sustainable development	Bibliometric analysis and SLR	This study shows the role of GVC in advancing sustainability across various dimensions, emphasizing its potential for fostering innovation and supporting underfunded startups and SMEs
5	(Krastev & Krasteva-Hristova, 2024) [33]	GF and SD	Bibliometric analysis	This study's Key findings include the pivotal role of green finance in energy efficiency, renewable energy development, and the promotion of sustainable economic growth
6	(Bhatnagar & Sharma, 2022) [7]	GF and its enablers	Bibliometric analysis	The study examines the evolution of Green Finance (GF), highlighting its role in climate change mitigation and renewable energy financing, with findings emphasizing the growth of academic focus, key enablers like financial policies and innovation
7	(Muhmad, 2024) [41]	GF and renewable energy development	Bibliometric analysis and SLR	This study highlights the pivotal role of green finance and technological innovation in advancing renewable energy projects
8	(Naeem & Karim, 2022) [42]	Green and Sustainable Finance	Bibliometric analysis	This study's findings show socially responsible investments, green finance, and climate finance as the three key focus areas in green and sustainable finance, aligning with prevailing trends and practices in the corporate world
9	(Maria et al., 2023) [38]	Evolution of GF	Bibliometric analysis and Machine Learning	This study maps the growth of green finance literature, identifying three key thematic groups: political propositions on financing climate projects in developing countries, and broader topics like climate policy risks and green bonds

Table 2 (continued)

S.no	Source	Study	Methodology	Findings of the study
10	(Dhayal et al., 2025) [17]	Conceptualizing GF	Network Analysis	The study findings reveal ten core dimensions: environmental, sustainability, energy, finance, economic, institutional, technology, green, societal and sectoral, highlighting their centrality in shaping the existing green finance research definitions

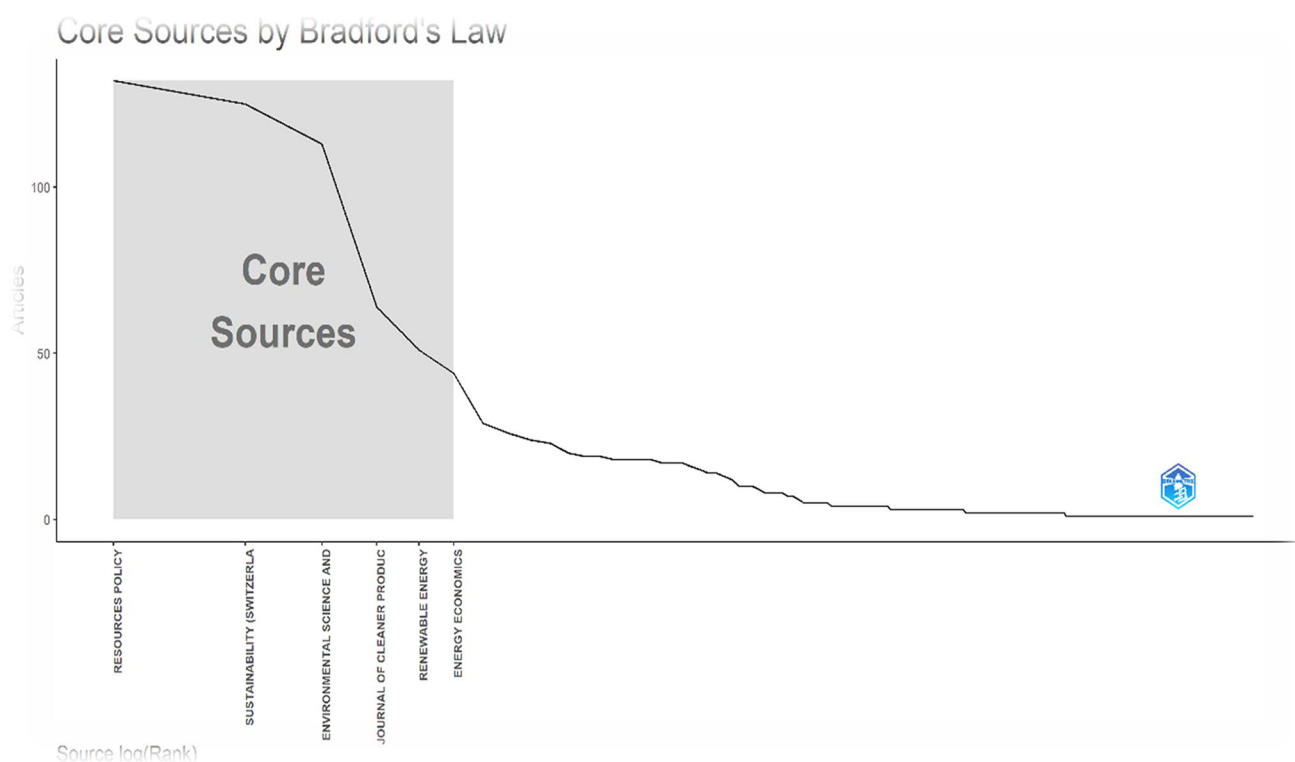
Source: Author's Compilation



**Table 3** Citation analysis of the top 15 journals

Sources	TP	H-index	G-index	TC
Resource Policy	132	30	48	2548
Sustainability (Switzerland)	125	28	45	2564
Environmental Science and Pollution Research	113	25	45	2276
Journal of Cleaner Production	64	31	56	3243
Renewable Energy	51	26	46	2177
Energy Economics	44	18	34	1647
Frontiers in Environmental Science	29	10	17	331
Journal of Environmental Management	26	14	26	1148
Sustainable Development	24	9	20	422
Heliyon	23	5	11	122
Energies	20	10	20	554
Economic Research- Ekonomika Istrazivanja	19	11	19	502
Business Strategy and The Environment	18	12	18	640
Energy Policy	17	10	17	1647
International Journal of Energy Economics and Policy	16	10	17	50

Source: Authors' compilation using Bibliometrix R package

**Fig. 3** Top 5 journals (Bradford's Law) (Source: Authors' compilation using Bibliometrix R package)

researchers are listed in Table 4 for RQ2. Hesary and Yoshino in 2019, Campiglio in 2016, Irfan et al. in 2022, Rasoulinezhad and Hesary in 2022, Liao and Shi in 2018, Li and Umair in 2023, and Zhou et al. in 2022 published the following.

The article published by Zang et al. (2021) had the most citations, 508. It examines how public R&D spending affects green economic growth and energy efficiency. Following closely is the Shen et al. (2021) article with 460 citations. This study examines the role of natural resources rent, green investment, financial development, and energy consumption in

**Table 4** Citation analysis of top leading Publications

Authors	Journal	TC	Title
Zang et al. 2021	Energy policy	508	Public spending and green economic growth in BRI region: Mediating role of green finance
Shen et al. 2021	Science of the total environment	460	Does green investment, financial development and natural resources rent limit carbon emissions? A Provincial Panel Analysis of China
Hesary and Yoshino 2019	Finance Research Letters	457	The way to induce private participation in green finance and investment
Campiglio, 2016	Ecological Economics	387	Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy
Irfan et al. 2022	Technological forecasting and social change	351	Influence mechanism between green finance and green innovation: Exploring regional policy intervention effects in China
Zang et al. 2021	Journal of environmental management	316	Fostering green development with green finance: An empirical study on the environmental effect of green credit policy in China
Rasoulinezhad and Hesary, 2022	Energy efficiency	314	Role of green finance in improving energy efficiency and renewable energy development
Liao and Shi 2018	Energy Policy	297	Public appeal, environmental regulation and green investment: Evidence from China
Li and Umair 2023	Renewable Energy	290	Does green finance development goals affect renewable energy in China
Zhou et al. 2022	Ecological Economics	281	The impact of fintech innovation on green growth in China: Mediating effect of green finance

Source: Authors' compilation using Bibliometrix R package

achieving SD and a clean environment in different provinces of China by reducing carbon emissions. Finally, the Hesary and Yoshino (2019) article had 457 citations. Its objective is to encourage private participation in GF and investment. The findings from the analysis can be used to implement GF policies within the financial system and enhance SD. There are no papers authored by Indian researchers among the top 10 most cited works.

### 3.1.6 Citation analysis of top profile authors

Table 5 provides information regarding the most prolific authors, encompassing their publication counts, citation numbers, g-index, and h-index, which address RQ1 and RQ2. The analysis reveals that “Wang Y” leads with 29 publications and 932 citations, while “Li J” follows with 21 publications and 249 citations. The findings further reveal that the leading 10 authors have been active in publishing over the past 6 years, demonstrating substantial contributions to the understanding and significance of GF within the financial system. Table 4 presents additional insights into the publications of these leading 10 authors.

Figure 4 shows the output of the authors over a timeframe. The figure shows that “Taghizadeh Hesary F” is among the prominent authors engaged in the study of GF and SD from 2019 to 2024. The diagram displays that the darker circle signifies an elevated output level for the author, specifically regarding citations and the publication of articles.

Wang Y” initiated their research on GF in 2021 and currently maintains the highest number of publications along with the most significant citation rate per publication. Li J is an innovative author in the realm of GF and has been diligently engaged in this subject from 2013 to 2024, yielding noteworthy contributions. Figure 6 indicates that the most prolific authors initiated their exploration of the relationship between GF and SD in 2020. The peak of production among the top researchers has been evident since the start of 2022.

Figure 5 depicts the network visualization of the collaboration of authors; the figure indicates that the author with a high no. of collaboration is Taghizadeh Hesary, with a g-index of 18, followed by Wang Y (g-index 29), Zhang Y (g-index 20) and Wang H (g-index 18) which shows the quality of publications in collaboration.

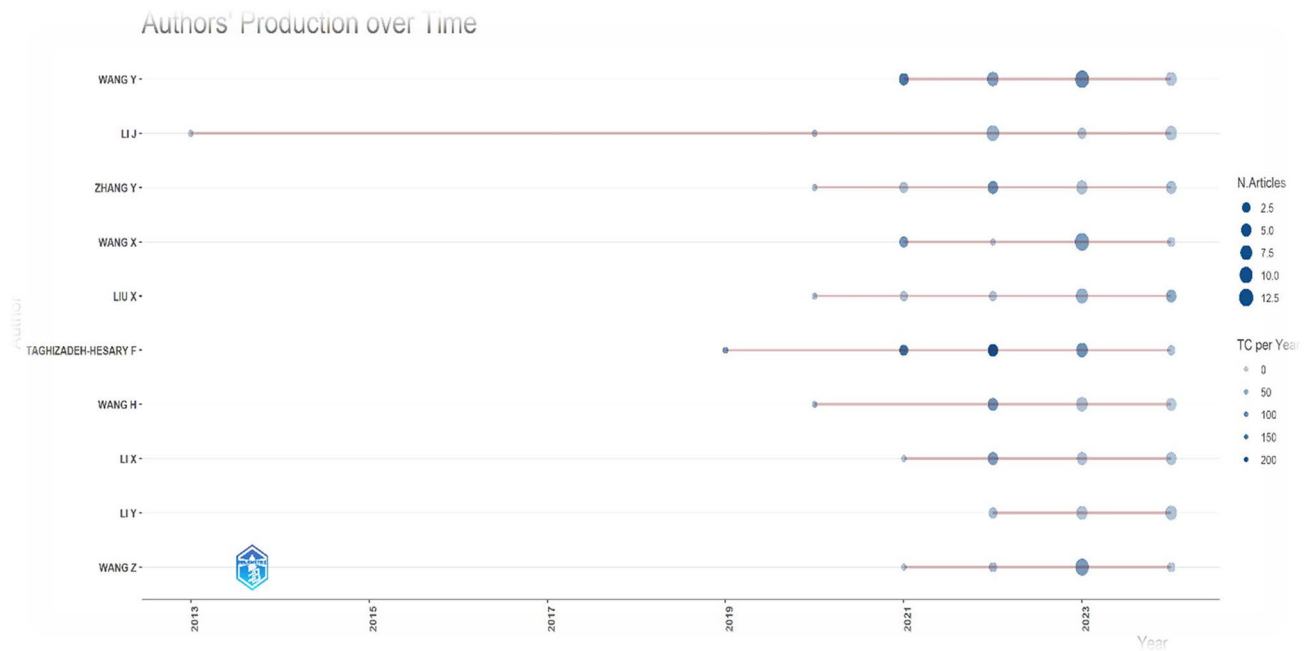
### 3.1.7 Citation analysis by country and geographical distribution of publications

Table 6 addresses RQ2 and presents the 15 nations with the most significant number of publications in GF and SD. A total of 95 countries have contributed to the publications sourced. China led with a remarkable total of 709 publications, while India followed with 58, and the United Kingdom contributed 45 publications. The dominance of these countries shows the synergy of government policies, research funding, environmental challenges, and institutional capacity, which drives their leadership in this area. For example, as rapid industrialization and urbanization pose many environmental challenges, China has taken a leading position in research on the green finance-sustainable development nexus by moving forward with policies such as green credit and carbon neutrality and promoting public and private funding in green finance. Similarly, India has a higher number of publications than Pakistan. Due to its vulnerability to climate change and energy security concerns, India is also actively pursuing policies such as the Green India Mission, promoting the use of solar and wind energy, and the National Afforestation Programme, which is aimed at sustainable development. India’s initiatives like the National Action Plan on Climate Change (NAPCC), “One Sun, one World, one Grid”, and its focus on

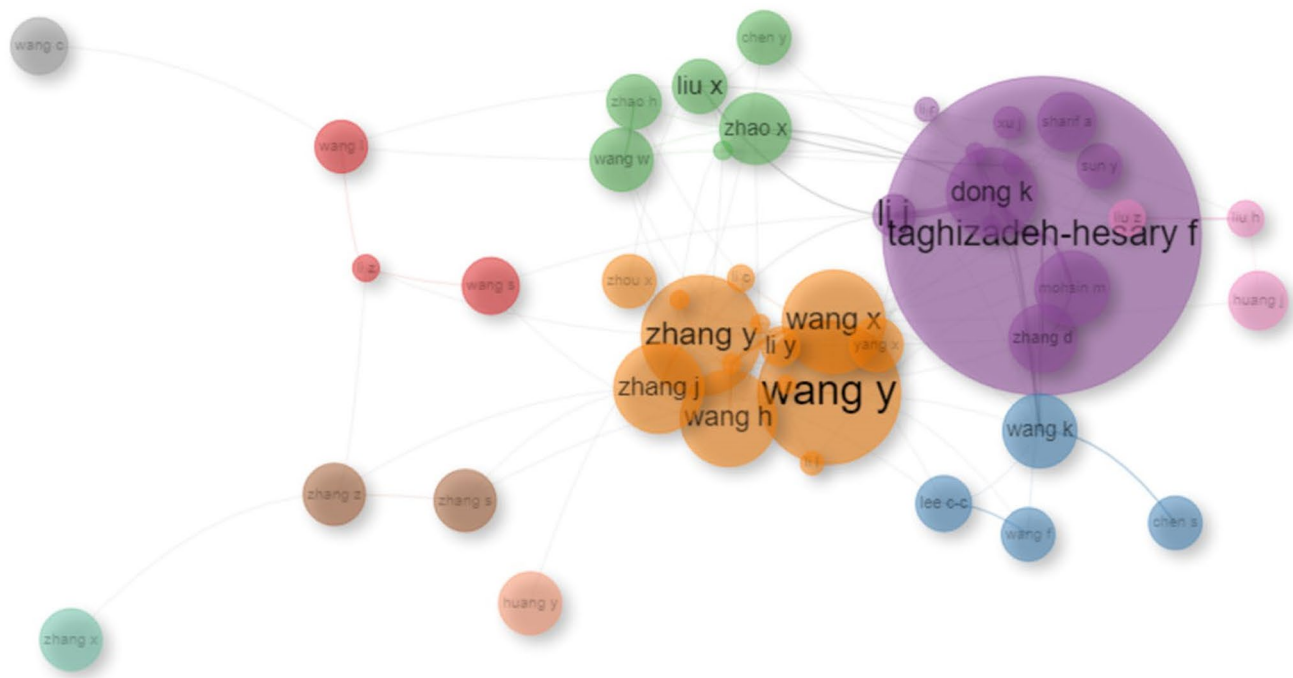
**Table 5** The top 10 most productive authors

Authors	TP	TC	G-index	H-index
Wang Y	29	932	29	13
Li J	21	249	15	8
Zhang Y	20	447	20	9
Wang X	19	477	19	10
Liu X	18	283	16	10
Taghizadeh-Hesary F	18	1872	18	13
Wang H	18	452	18	8
Li X	16	252	15	7
Li Y	16	82	8	5
Wang Z	16	227	15	9

Source: Authors’ compilation using Bibliometrix R package



**Fig. 4** Top authors' production over time (Source: Authors' compilation using Bibliometrix R package)



**Fig. 5** Network visualization of collaboration of Authors (Source: Authors' compilation using Bibliometrix R package)

renewable energy have spurred research on green finance and sustainable development. The data indicated that India, Pakistan, Indonesia, and Malaysia were the only emerging countries among the top 15 most productive nations globally. Poland has the lowest level of cooperation per publication among the top 15 prolific nations, closely followed by Spain.

The map visualization answers RQ4 in Fig. 6 displays publications published by authors from 95 distinct nations using data from the SCOPUS database. The map displays various nations and their respective number of published articles, with each country represented by different shades of blue. China has the most profound shade of blue, signifying that it has

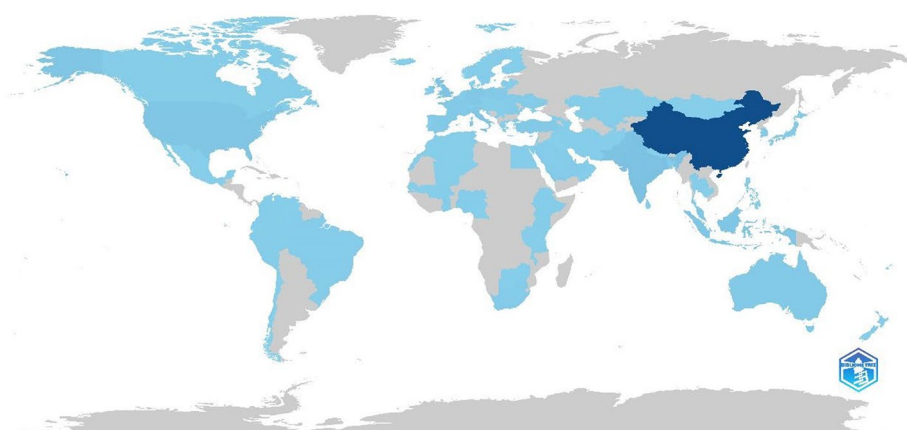
**Table 6** Top 15 hotspot countries of publication in GF and Sustainable Development

Country	TP	TC
China	709	16,509
India	58	932
United Kingdom	45	849
Italy	36	850
Indonesia	35	342
Pakistan	31	1291
Germany	29	921
USA	28	944
Malaysia	26	209
Australia	22	493
Poland	20	549
South Africa	17	297
Spain	17	273
France	15	391
Turkey	15	478

Source: Authors' compilation using Bibliometrix R package

**Fig. 6** Geographical distribution of publications in GF and sustainable development (Source: Authors' compilation using Bibliometrix R package)

### Country Scientific Production

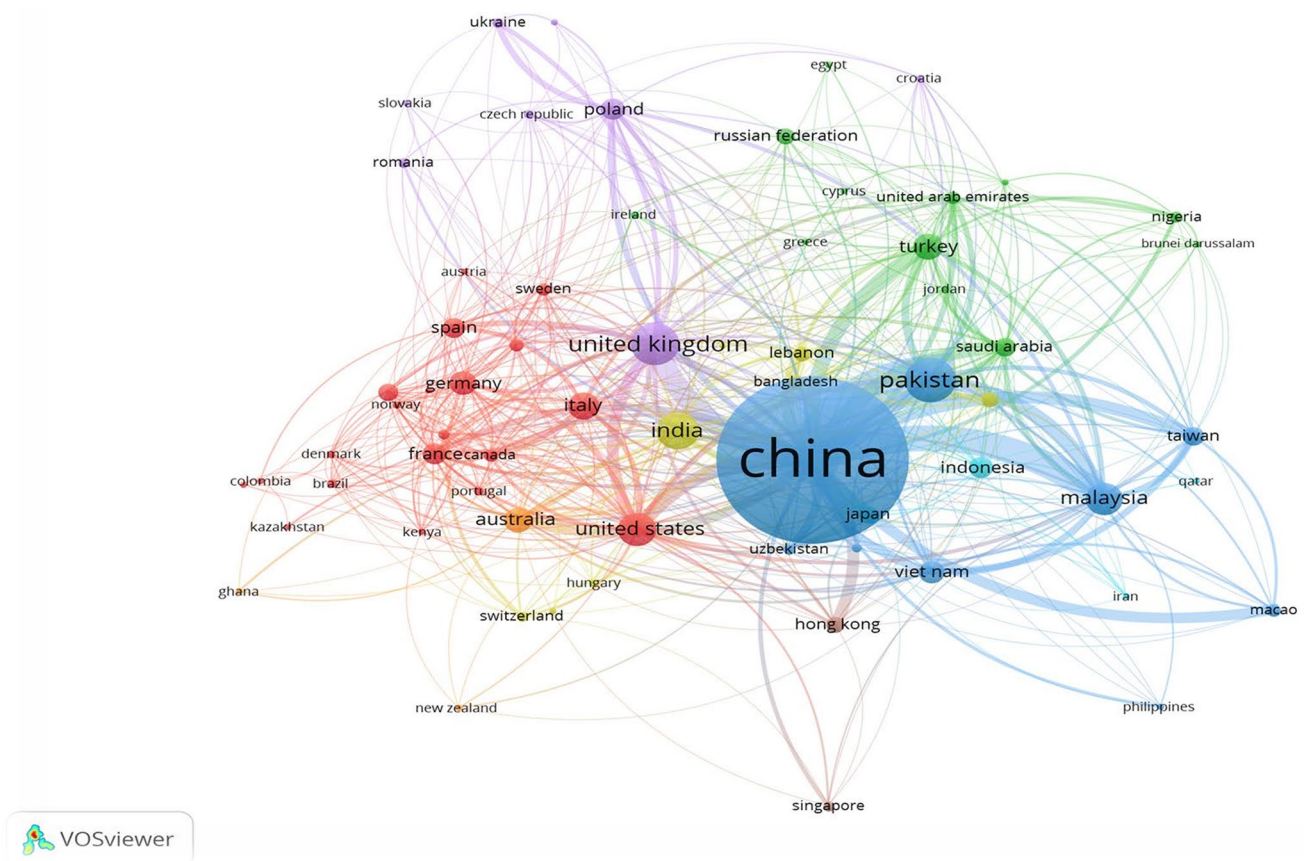


the most significant quantity of published papers (709), followed by India (58), the United Kingdom (45), and Pakistan (31). The nations shown in grey have not released any publications, whereas writers from India have published a total of 58 articles, ranking second most in Asia, after China. The study revealed that developing nations exhibit a higher degree of focus on the intersection of GF and research about SD compared to industrialized countries.

Figure 7 shows the collaboration network among the nations. The image clearly illustrates that China partners with other countries, with Pakistan, the United Kingdom, India, and the USA following in succession.

### 3.1.8 Citation analysis of the top leading institutions and organizations

Table 7 shows a compilation of the leading 10 institutions that have engaged extensively in research concerning the intersection of GF and SD, thereby addressing RQ2. Table 6 indicates that 'Jiangsu University' stands out as the leading institution in China, achieving a total of 55 publications. Following this, 'Wuhan University' has produced 49 publications, while 'Nanjing University of Information Science and Technology' has contributed 39 publications. Most of these 10 institutions (80%) are located in China, with just one Indian institute making it into the top 10. The network visualization of collaborations among the top 44 universities can be seen in Fig. 8. The nodes signify unique institutions or organizations [12], and the lines that link the nodes show the relationships between these institutions/organizations [12, 35]. The thickness of the lines indicates the strength of the connections, which is influenced by the frequency of collaboration



**Fig. 7** Co-authorship of countries (Source: Authors' compilation using VOSviewer)

**Table 7** The top 10 most productive institutions

Organisations/ Institutions	TP	Country
Jiangsu University	55	China
Wuhan University	49	China
Nanjing University of Information Science and Technology	39	China
University of International Business and Economics	38	China
Qingdao University	37	China
Southwestern University of Finance and Economics	36	China
China University of Mining and Technology	35	China
Guizhou University of Finance and Economics	32	China
Beijing Jiaotong University	27	China
Jilin University	26	China
Shandong University of Finance and Economics	26	China
Tianjin University of Commerce	25	China
Adnan Kassar School of Business	19	Lebanon
National Institute of Technology, Rourkela	09	India
Massachusetts Institute of Technology	08	USA

Source: Authors' compilation using Bibliometrix R package

among the involved parties. The dimensions of an institution's nodes serve as indicators of its overall strength or the extent of its collaborations with other institutions globally [56]. The greater the size of the node, the more robust the connection strength. A total of 44 institutions were selected from the initial pool of 3665, based on the criterion that each organization must have at least 4 documents. Figure 8 indicates that the authors affiliated with Jiangsu University





**Fig. 8** Network visualization of collaboration of institutions/organizations (Source: Authors' compilation using Bibliometrix R package)

demonstrate the most substantial collaborative efforts, contributing to 15 papers and receiving 257 citations from various organizations. The Southwestern University of Finance and Economics follows, having partnered with 13 organizations.

### 3.2 Internal characteristics of publications

This section delivers a comprehensive analysis of the intrinsic features of papers about GF and SD. Its purpose is to illuminate the various paths of development and research priorities within this field. The use of keywords can accurately indicate the main areas of interest in the study [57]. Therefore, the primary aim is to analyze the occurrences and development of keywords. Ultimately, visualization tools are employed to create a tree map that accurately displays the frequencies of keywords. A thematic analysis was performed to delineate and illustrate the conceptual and functional framework of the chosen dataset. Lastly, cluster analysis was conducted to enhance the comprehension of the intricate characteristics of GF and SD, encompassing their various dimensions.

The tree map presented in Fig. 9 displays words related to GF, SD, sustainable finance, and renewable energy. This suggests that GF and SD are interdisciplinary subjects. The term "GF" is mentioned in approximately 20% of the papers, indicating that the primary research focuses on the relationship between GF and SD. Moreover, the terms "SD" and "sustainable finance" are mentioned in 9% and 6% of the papers, respectively. This indicates that scholars view the adoption of sustainable finance as a significant factor in achieving SD. The emergence of the terms "renewable energy" and "green investment" suggests that using renewable energy sources can be facilitated through investments that prioritize environmental sustainability.

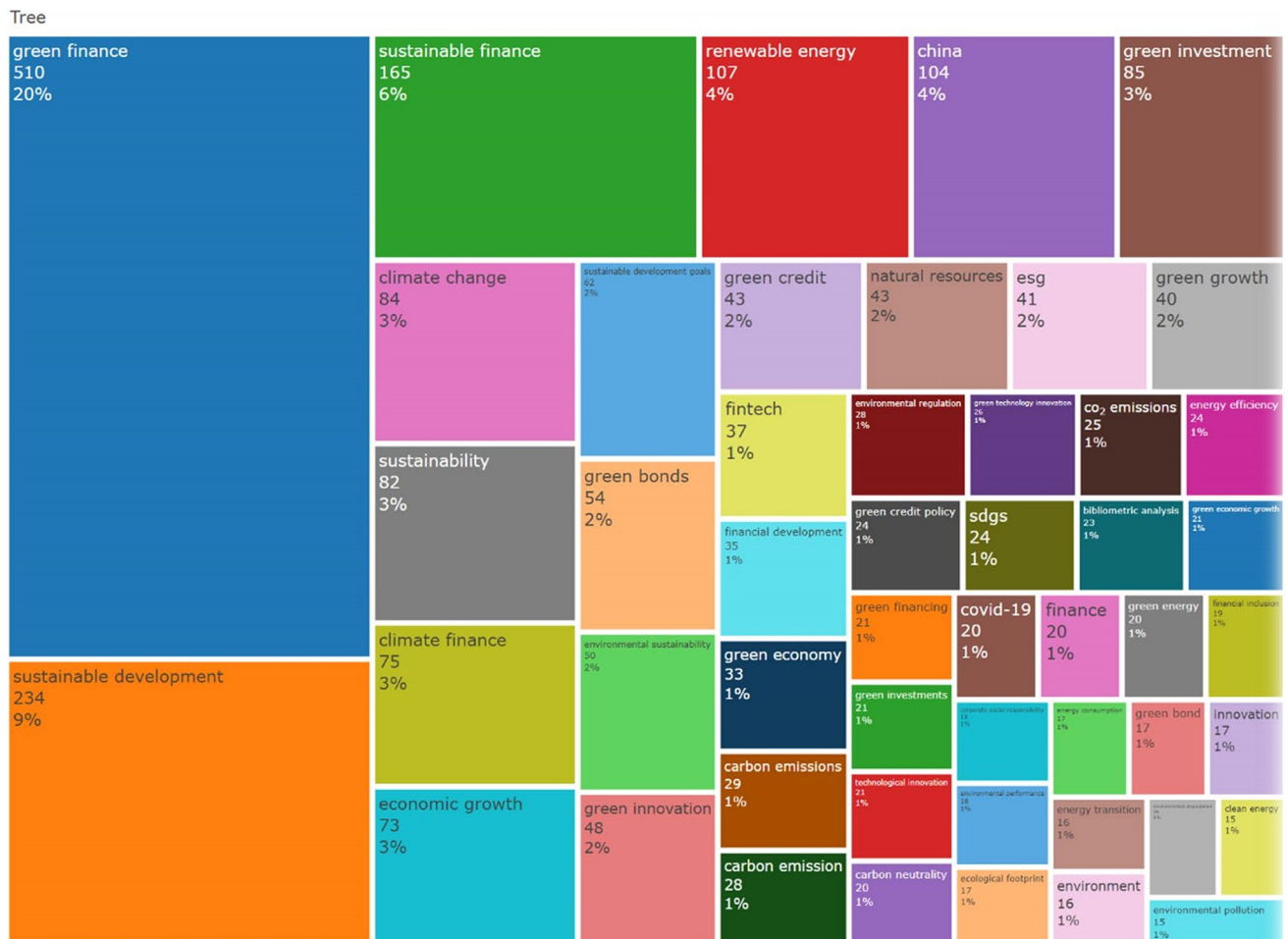
Figure 10 presents a word cloud showing the 50 most frequently occurring "author keywords," aiding in analyzing thematic clusters and specific focus areas. A total of 3,566 author keywords were collected, and 50 of these keywords were selected for analysis utilizing Biblioshiny in R Studio. The diagram illustrates that the largest font size indicates the term exhibiting the highest frequency or the most concentrated subject. "Sustainable development," "sustainable finance," "renewable energy," "green investment," and "climate change" are the most frequently employed keywords in the top 50 papers.

#### 3.2.1 Emerging trends and thematic analysis

A thematic analysis has been performed to delineate and visualize the conceptual and functional framework of the chosen dataset, emphasizing its thematic development. This examination delineates and elucidates clusters of textual knowledge or conceptual categories encompassing a variety of research subjects. This section analyses author keywords to identify trending themes related to GF and SD, which answers RQ3.

The author's keywords are analyzed thematically to determine the main topics. Users can create comprehensive themes using keywords, authors' keywords, titles, and abstracts in Bibliometrics tools. The current study analyzed

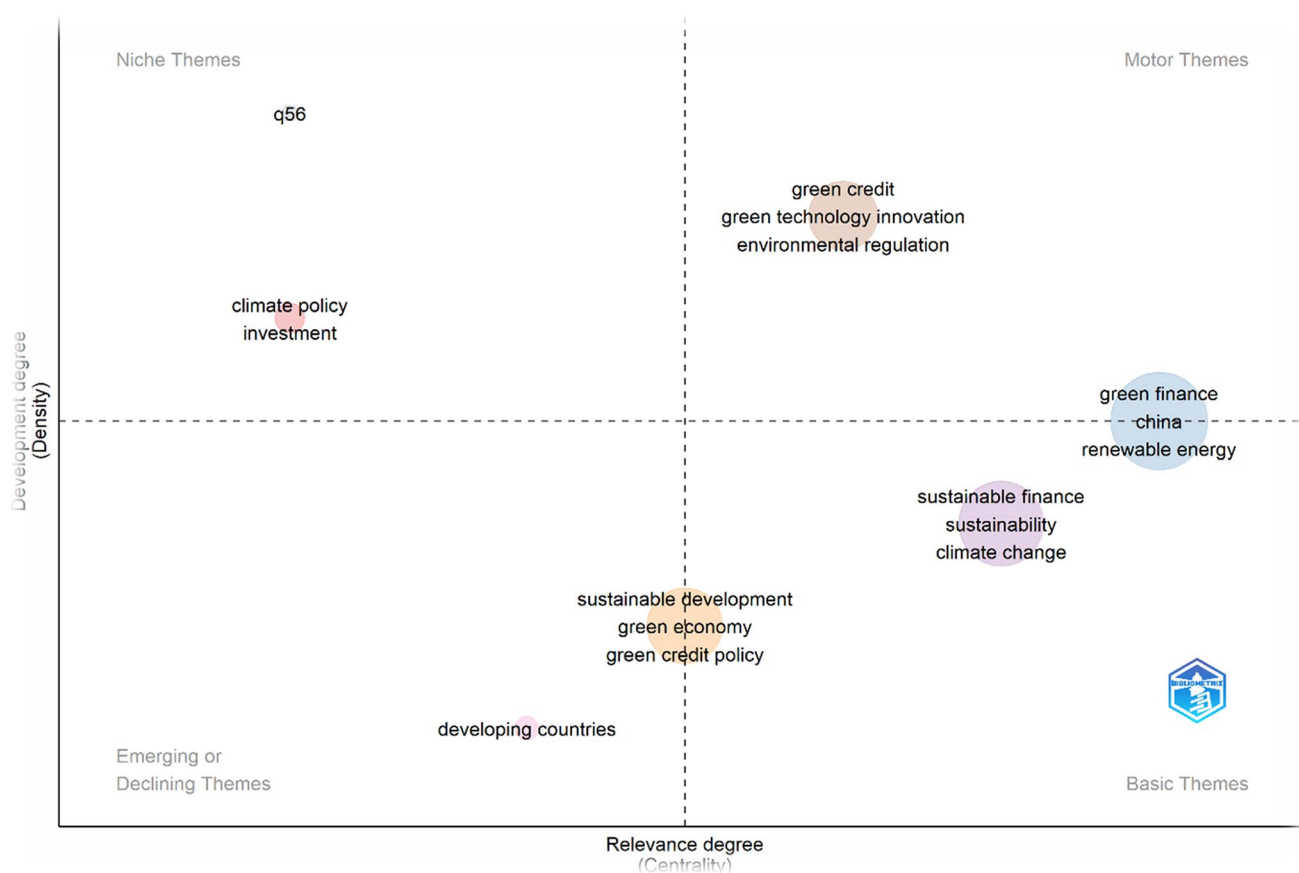




**Fig. 9** Tree map of high-frequency keywords in the field of energy poverty. (Source: Authors' compilation using Bibliometrix R package)



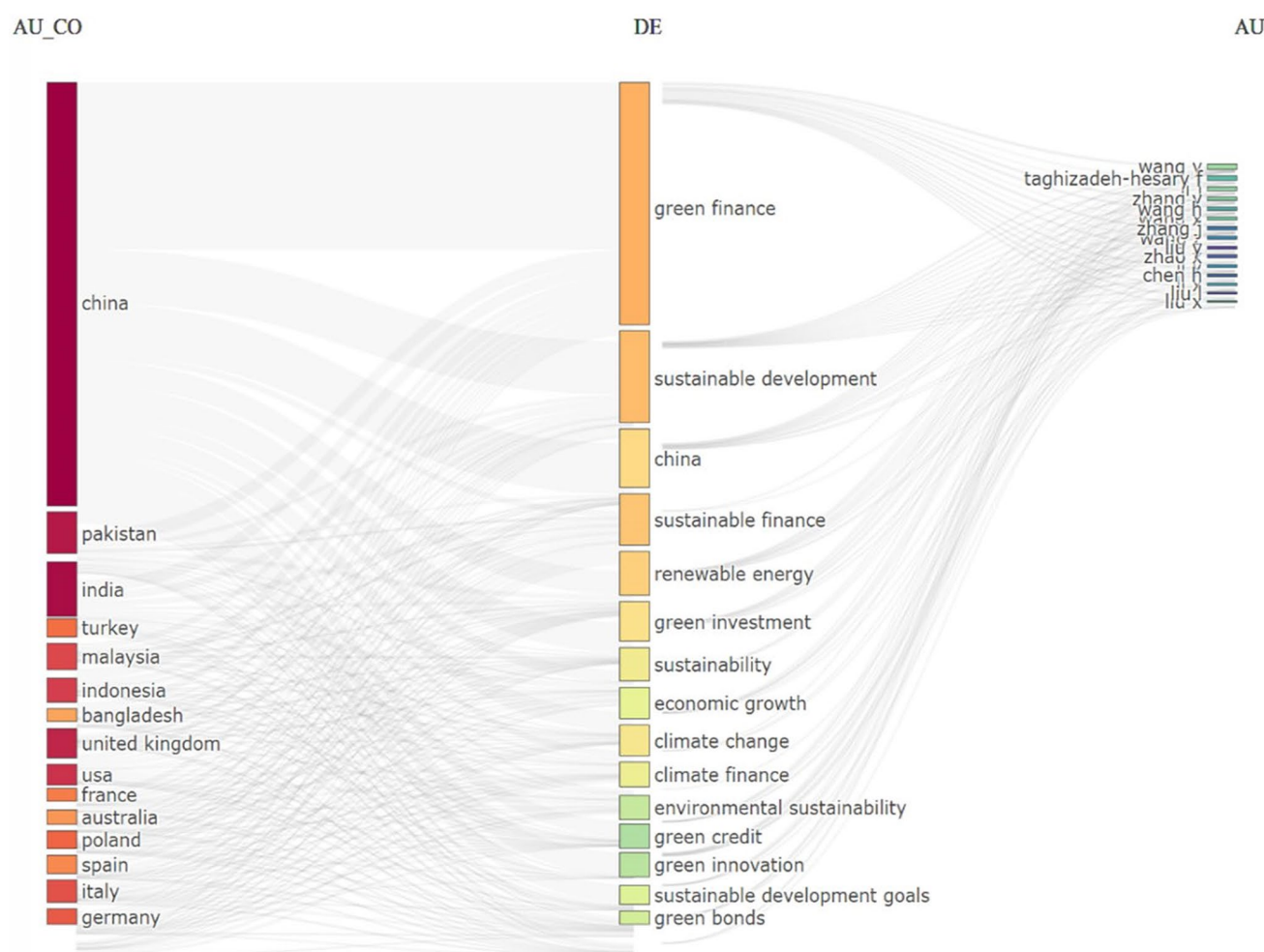
**Fig. 10** Word cloud of the top 50 author keywords (Source: Authors' compilation using Bibliometrix R package)



**Fig. 11** Thematic analysis of author keywords (Source: Authors' compilation using Bibliometrix R package)

a thematic map created using author-provided keywords. Figure 11, a thematic map, shows each term in a two-dimensional frame. The contribution of each term is quantified using a scale. Keywords are clustered to identify themes further. The placement of each cluster on the thematic map reflects its scientific importance, while the map's density signifies the subject's expansion [47]. Thematic mapping of results shows that sustainable finance, GF, SD, and green credit are the four main keyword analysis themes. The Sub-themes link GF to renewable energy and China. SD and green credit, though distinct, are closely related to core principles that may be considered major scientific issues. Climate policy is highly specialized and exclusive. The only consistent theme among the emerging and declining themes is developing countries.

Figure 12 displays a three-field plot highlighting the connections among the top 20 keywords, countries, and leading journals. The Sankey diagram illustrates the flow of academic literature across three chosen domains, aiding in the visualization of this information. The three chosen fields in this instance are the most prominent nations, the most often used author keywords, and the most popular journals. The visualizations enable the recognition of significant contributions within the flow system. The width of the flow band correlates directly with the element's contribution in that specific area. The relationship between nations and keywords reveals that most countries have produced literature about green financing and SD. The top nations often focus on renewable energy and sustainable finance in their research. However, China's publications have significantly influenced the prominence of the term 'GF'. China has a notable level of research productivity in GF and SD, whereas other nations have mostly prioritized green investment and climate financing. Nations have also been actively developing and disseminating research about green bonds and green credit, which are crucial instruments of GF. The report further emphasizes that in terms of academia, the developing countries focus on linking GF and SD. Regarding the source of publishing, the top keywords are primarily used in the field of "GF," which is also one of the top 15 journals regarding the number of papers published and citations received.



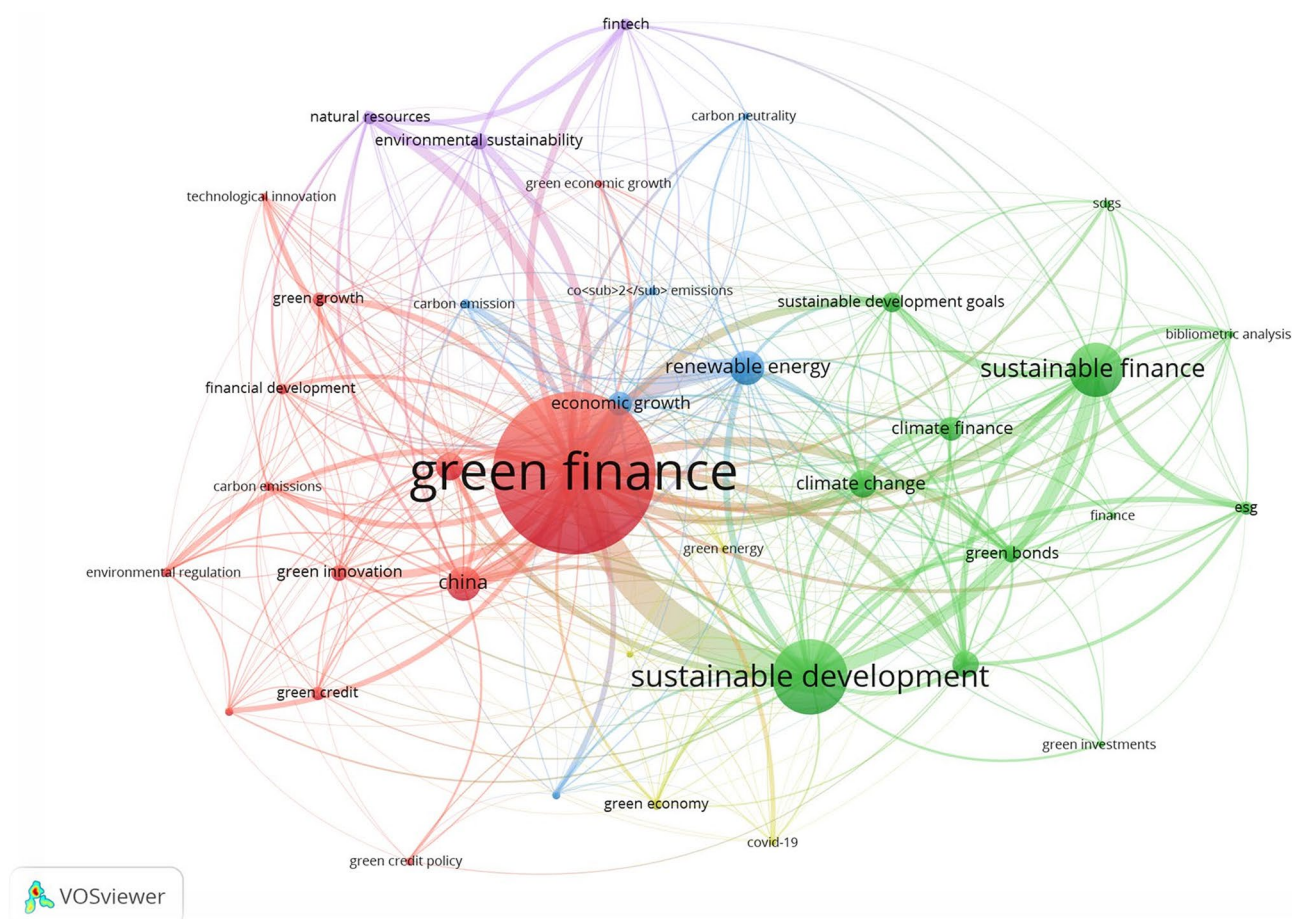
**Fig. 12** Three field analyses on the nexus of GF and sustainable development (Source: Authors' compilation using Bibliometrix R package)

### 3.2.2 Cluster analysis of themes in green finance and sustainable development for research gaps

Researchers use keywords to concisely convey the substance of their study. Hence, by doing keyword analysis, one may identify popular topics and areas of focus within a given study field [35]. Figure 13, which pertains to RQ5, examines clusters of themes at the nexus of gf and SD. This analysis provides important insights into the connections and shared characteristics within this field of study. The clusters' framework facilitates understanding the complex nature of GF and SD [26].

**3.2.2.1 Cluster 1** In the bibliometric analysis conducted with VOSviewer, the initial group of keywords discovered comprises carbon emissions, China, environmental regulation, financial development, green credit, green credit policy, green economic growth, GF, green growth, green innovation, green investment, green technology innovation, and technological innovation. The articles within this cluster demonstrate a notable focus on the correlation between environmental sustainability and economic development, specifically in China. The growing concern about greenhouse gas emissions in China, the most significant global emitter of CO<sub>2</sub>, is further highlighted by the concepts of carbon emissions and environmental regulation. The articles highlight the significance of financial systems in advancing SD, which is reinforced by the concepts of GF, green credit, and green economic growth.

Technological and green technology innovation underlines the need for creativity in reaching environmental goals. The way the terms are grouped reveals a thorough approach to grasping the link among financial systems, environmental results, and economic policies. The research shows that a strong legislative and policy framework is required to help implement green financing projects and technological developments [48, 49, 53, 58].



**Fig. 13** Clusters of themes (Source: Authors' compilation using VOSviewer)

**3.2.2.2 Cluster 2** The second group of keywords identified by the study includes climate change, climate finance, ESG (Environmental, Social, and Governance), finance, green bonds, green investment, SDGs (Sustainable Development Goals), sustainability, sustainable development, sustainable finance, and sustainable development goals. Cluster 2 indicates a growing emphasis on integrating financial plans with environmental goals, particularly in mitigating climate change. This cluster has talked about green financial instruments. The terms climate change and climate finance are meaningful in discussions regarding the required financial strategies to mitigate the effects of climate change. Climate finance is essential for mobilizing capital to achieve climate-related objectives, as outlined in international agreements like the Paris Agreement. The term “ESG” has become increasingly prevalent in recent years as investors have prioritized environmental, social, and governance factors in their decision-making processes. Sustainable finance is the term used to describe financial operations that foster economic development while concurrently promoting social fairness and protecting the environment. Green bonds are a financial instrument that funds projects that contribute positively to environmental sustainability. Green investment involves directing financial resources towards projects that promote environmental sustainability, including sustainable agriculture, renewable energy, and conservation efforts. The achievement of the SDGs and the shift towards a low-carbon economy rely heavily on these investments.

The Sustainable Development Goals (SDGs), ratified by the United Nations in 2015, offer a detailed framework for tackling global challenges such as poverty, inequality, and climate change. The concepts related to sustainable development highlight the connection between environmental sustainability and socio-economic progress. Promoting sustainable economic growth while safeguarding the environment from the negative impacts of development initiatives is essential. This can be achieved by implementing financial strategies aligned with the SDGs [11].

**3.2.2.3 Cluster 3** The bibliometric analysis conducted with VOSviewer identified a third cluster of terms: renewable energy, economic growth, energy efficiency, and carbon neutrality. The common theme of cluster 3 articles underscores



the critical relationship between environmental sustainability and economic progress, particularly in achieving carbon neutrality and reducing carbon emissions. The terms “carbon emissions” and “carbon neutrality” are essential in discussions regarding environmental policy and climate change. Carbon emissions, primarily the result of the usage of fossil fuels, are the primary cause of global warming. The concept of “economic growth” is frequently considered a critical catalyst for progress. Nevertheless, if not managed sustainably, it can also increase carbon emissions. Renewable energy and energy efficiency are indispensable to transitioning to a low-carbon economy. Energy efficiency is reducing carbon emissions by utilizing a smaller quantity of energy to provide the same level of service. Renewable energy sources, such as hydropower, solar power, and wind power, are essential to achieve carbon neutrality and replace fossil fuels.

The interlinked nature of these terms shows a comprehensive strategy for combating climate change. For instance, achieving carbon neutrality requires a concerted effort to reduce carbon emissions by enhancing energy efficiency and transitioning to renewable energy sources. Economic growth must be consistent with these environmental objectives to ensure SD [8–10, 13].

**3.2.2.4 Cluster 4 and Cluster 5** Lastly, the bibliometric analysis conducted with VOSviewer identifies two clusters of keywords: the fourth cluster comprises “COVID-19,” “green economy,” “green energy,” “green financing,” and “environmental sustainability.” In contrast, the fifth cluster comprises “fintech” and “natural resources.” The identified clusters highlight the increasing significance of incorporating environmental considerations into economic recovery efforts and the contribution of financial technology in advancing SD.

COVID-19 is a significant cluster, as shown in Fig. 13, and there is a temporary increase in research interest and its long-term impact on green finance and sustainability. The intensity of linking green finance to COVID-19 may eventually diminish, but its role in accelerating the connection between sustainability principles in financial and economic systems may remain influential. The COVID-19 pandemic has significantly disrupted global markets, exposing the deficiencies of existing monetary institutions. However, it has also offered a chance to reorganize economic frameworks to foster a more robust and sustainable future. The ideas of “green energy” and “green financing” are closely interconnected and aim to expedite the shift towards a sustainable and eco-friendly economy. Green energy includes renewable sources like hydropower, wind, and solar energy, crucial in lowering carbon emissions and achieving long-term sustainability objectives. GF refers to financial investments that are intentionally crafted to bolster projects and initiatives aimed at generating a positive influence on the environment. The green economy and green financing are rooted in the essential principle of environmental sustainability. This statement underscores the importance of achieving a balanced relationship between preserving natural resources and ecosystems and pursuing economic growth. The notion of “natural resources” highlights the critical need for efficient management of resources such as land, water, and minerals to ensure their sustainability over the long term.

The fourth and fifth groups of terms underscore the critical intersection of financial innovation, economic revival, and environmental sustainability. Amid the global conflict to address the challenges posed by COVID-19, there is a unique opportunity to reorganize financial institutions to prioritize the responsible management of natural resources, sustainable financing, and environmentally friendly energy. As indicated by cluster analysis, climate financing and renewable energy financing have been the subject of significant endeavours. Nevertheless, the theoretical aspects of this subject constitute a substantial portion of the existing literature. Quantifying the extent of green funding initiatives has been a neglected area of research. The discussion regarding green financial products is also limited to green investments and bonds. The development of alternative green financial instruments is not adequately investigated [20, 32, 46].

## 4 Conclusion

In the backdrop of a rapid increase in the pace of literature and a complex network of researchers and institutions involved in the research on green finance (GF) and sustainable development (SD), the present study attempts to understand how the themes of green finance and sustainable development have been studied by scholars in this field over a period of time. It also made an attempt to explore the possible future areas of research related to these two pertinent themes, given their growing significance in academic and policy circles.

Research in GF has steadily risen since 2010, with a notable increase beginning in 2019. In 2020, there was a significant increase in publications addressing the growing involvement in creating strategies to transform the financial system for sustainability. The findings of the present study suggest that participation and academic engagement levels in affluent nations have exceeded those in developing countries. China, India, and Pakistan hold positions

within the top 10 countries in terms of the total volume of publications among emerging nations. The leading three journals that feature articles on the subject of GF and SD are Resource Policy, Sustainability, and Environmental Science and Pollution Research. Recently, several notable authors have begun to contribute to the field. Alongside the primary subject areas like environmental sciences, social sciences, economics, econometrics, and finance, a considerable volume of interdisciplinary research has been conducted in recent years.

The examination of author keywords using thematic and trend analysis indicates the rise of GF. Over the years, there has been a strong emphasis on renewable energy and sustainable finance as key strategies for SD in response to climate change mitigation and adaptation. The papers that were evaluated emphasize the positive effect of GF on SD and advocate for more studies to improve our comprehension of its success. The present study reiterates the need to engage financial systems and foster the development of financial institutions. This needs to be on the top of the agenda of policymakers, given the significant shift in the focus from climate finance to Green Finance, which has recently become the intersection of climate finance and renewable energy funding.

## 4.1 Limitations

The present study adapted a purely bibliometric approach, and best efforts have been made to realise its objectives. However, it also has limitations. For instance, this study solely relies on the research works collected from the SCOPUS database. Although it is a comprehensive source of peer-reviewed articles, it may not capture works covered by other databases such as PubMed, Web of Science, Google Scholar, and regional sources like government reports, etc. The exclusion of government reports and various types of grey literature, which contain information on real-world applications, reduces the qualitative depth of the study and its understanding of the works on the impact of green finance on sustainable development.

Further, the present study considered the title of the research paper, abstract and keywords, and altogether omitted the conference proceedings and book chapters, which could have made a further value addition to the study. Last but not least, the absence of expert triangulation is another limitation of the study, as it could have drawn upon various perspectives to give a more comprehensive picture of the topic chosen for research. Despite all these limitations, the study still offers valuable insights which could be worth contemplating for interested researchers in this area of research.

## 4.2 Implications and future direction

### 4.2.1 Practical implications

This study has key policy implications for advancing GF in achieving SD. It is pertinent to strengthen its regulatory framework by introducing better incentives, regulations, and mechanisms for information sharing. Examining initiatives like the Green Climate Fund and understanding the benefits of carbon-neutral activities can help refine climate finance strategies. It is equally essential to study how GF contributes to reducing carbon emissions and how sustainable spending impacts investment decisions. Integrating ESG factors into financial choices, addressing challenges in implementation, and improving data collection are critical for adequate green financing. Blockchain and AI have immense potential to enhance GF and sustainable development (SD). For instance, blockchain can increase transparency and accountability in green projects through secure and traceable transactions. It is this backdrop that one needs to view this study as an essential medium that helps all stakeholders interested in green finance and sustainable development to get a glimpse of the present state of research in these areas. This allows them to develop a policy framework related to GF and SD. This study also helps them to set their priorities right in the process of achieving SD using GF.

Additionally, fostering collaboration among stakeholders, implementing legislative measures, and aligning financial incentives with sustainable outcomes can significantly promote economic growth and mitigate environmental risks. The key insights provided by the present study regarding existing research collaborations could help the interested academics, practitioners and the policy elite to build stronger networks, creating a long-term bond between them. This could be essential in developing policies driven by market forces and consistently monitoring environmental challenges, which are also key to leveraging GF for SD.

## 4.2.2 Theoretical implications

The present study provides an understanding of how geopolitical factors, such as international trade policies and climate diplomacy, influence green investment flows, which is an area that warrants further exploration. There is also a need for empirical studies to analyze how GF and SD-related variables are interconnected, especially in emerging countries. Conducting comprehensive reviews using multiple databases like Web of Science and PubMed can broaden the research scope in this field. Expanding the use of keywords in studies related to GF and SD can help track the evolution of this concept. Future research should also focus on identifying the common and country-specific factors that strengthen GF's role in achieving SD. This will provide deeper insights into how green finance can adapt to and address global and regional sustainability challenges.

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**Data availability** The authors confirm that all data analysed during this study, were obtained from the Scopus database and are available in CSV format. These data can be requested from the corresponding author.

## Declarations

**Ethics approval and consent to participate** Not applicable.

**Consent for publication** Not applicable.

**Competing interests** The authors declare no competing interests.

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