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Article

Navigating the green finance frontier: a bibliometric and content analysis of green finance and environmental sustainability

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Navigating the green finance frontier: a bibliometric and content analysis of green finance and environmental sustainability

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ABSTRACT

The present study explores the intersection between green finance (GF) and environmental sustainability (ES) with the help of comprehensive bibliometric and content analysis techniques, unveiling new perspectives on this synergy and contributing novel insights to the field. By synthesizing a wide range of literature, this study provides an important understanding of the dynamics of GF and its implications for ES. The bibliometric analysis helps identify key trends, emerging themes, influential contributors, prominent journals, and institutions contributing to the field of GF. For analyzing the co-citations of authors, publications, journals, and generation of keywords VOSviewer software has been used. Based on an extensive exploration of past research, this study synthesizes the academic literature and offers a comprehensive overview of the emerging field of GF. The findings of our study reveal that GF fosters ES through green innovation, public spending, private participation, and digital finance. These results broaden the current state of GF and provide significant implications for policymakers, researchers, practitioners, and other stakeholders in navigating the complexities of GF and its role in promoting sustainable growth. Through its interdisciplinary approach and rigorous analysis, this manuscript enriches the growing body of knowledge on GF and its role in fostering a sustainable future. Furthermore, the study points out several limitations and knowledge gaps, suggesting avenues for future research to address these gaps.

IMPACT STATEMENT

Using extensive analysis of published research with bibliometric and content analysis techniques, this manuscript provided an overview of the relatively new field of study by synthesizing the academic literature on green finance. The study incorporates the bibliometric analysis for studying the descriptive statistics of the study, visual analysis for highlighting conceptual and social structure of the field, and then finally the content analysis is performed to gain valuable insights in the area of green finance and environmental sustainability.

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F64; F65; Q01; Q56

1. Introduction

Throughout history, mankind has faced numerous challenges to its very existence with economic sustainability and environmental preservation emerging as the most portentous. The severity of the situation at hand is underscored by the rapid deterioration in environmental conditions as a result of the increased greenhouse gas emissions, extensive dependence on fossil fuels, depletion of natural resources, higher energy consumption, and greater vulnerability to natural disasters (Bhatnagar & Sharma, 2022; Edwards, 2011; Sandberg et al., 2019). Addressing these persistent challenges requires immediate actions, such as initiating proactive measures for aligning financial development with sustainable economic growth, controlling the rise in global temperature levels, and encouraging the widespread adoption of renewable energy sources to fulfill the present and future energy demands (Aneja et al., 2023).

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The rising discussions on the connection between financial development and sustainable growth across international platforms including the United Nations (UN), also emphasize the critical need to integrate economic development with environmental sustainability (ES) (Afzal et al., 2022; Soti et al., 2024). As He et al. (2019) pointed out, robust green financial development promotes the expansion of the renewable and sustainable energy sector and is vital for achieving sustainable growth. Acknowledging this, 194 countries established the Green Climate Fund in 2010, to offer financial assistance to developing nations to reduce carbon emissions thereby alleviating the adverse impact of climate change.

Globally, countries are adopting pathways to unlock the financial aid that facilitates the transition to low-carbon emission economies. The aim is to allocate actual wealth towards fulfilling the enduring requirements of a sustainable and inclusive economy (Falcone & Sica, 2023). Within this context, green finance (GF) has emerged as an innovative and effective mechanism for fostering a sustainable future by directing financial resources towards sustainable and environment-friendly projects (Falcone & Sica, 2023; Ibrahim et al., 2023).

According to the United Nations Environment Programme GF increases the financial flows from the public and private sector to sustainable development priorities (Edmans & Kacperczyk, 2022). The emphasis is on creating stringent infrastructure by mobilizing financial support for new investments in the domains of clean energy, green supply chains, resource management, clean tourism, and pollution prevention and control (Ilyas et al., 2020; Kumar & Soti, 2023) aligning well with the 2030 Sustainable Development Goals (SDGs). The empirical studies also confirm that GF helps mitigate the detrimental effects of climate change by creating climate-resilient urban infrastructure and nurturing sustainability (Flammer, 2021; Taghizadeh-Hesary & Yoshino, 2019).

To this discourse, to meet the ever-expanding global demand, new financial products including green bonds, weather derivatives, debt-for-environment swaps, forestry securitizations, environmental funds, biodiversity funds, carbon market instruments, and nature-linked securities, have been created (Zahoor et al., 2022), to promote green and sustainable projects (Wang & Zhi, 2016).

The 2023 report by the International Development Finance Club (IDFC) highlights the increasing momentum in climate policy initiatives. According to it, current investments in green projects have reached USD 288 billion, marking a 29% increase from 2021, with the public sector playing a central role (CPI, 2023). Although the expanding funding has primarily supported clean energy and efficiency projects, this rapid growth of the sector has not been without challenges (Hafner et al., 2020). First, striking a balance between social spending and green investment requirements is challenging, given the limited resources, especially in the context of developing countries (Falcone, 2023). Next, transitioning to a low-carbon energy economy is difficult, especially in the light of a lack of standardized policies, and norms for the promotion of GF (Shao & Haung, 2023). Furthermore, the impact of GF on ES is not uniform across nations (Ghazouani et al., 2021).

The academic inclination towards the subject is evident through the past studies exploring various aspects of GF, from the perspective of fintech (Udeagha & Muchapondwa, 2023), decarbonization (Hafner et al., 2020), certification (Ehlers & Packer, 2017), corporate green bonds (Flammer, 2021), and green investment (Samour et al., 2022). However, there is a noticeable research gap that links GF with ES which underscores the need for a comprehensive literature review in this domain. While much of the existing literature focuses on specific regions, particularly China, there is a need for research that encompasses a broader panel of countries especially in developing nations. Furthermore, there is a dearth of empirical studies on the subject, resulting in a limited understanding of the association.

Given the gaps in extant literature, we address the following research questions:

- RQ1. How has the literature on GF and ES evolved?
- RQ2. Which journals are the most productive in ES and GF research?
- RQ3. Who are the leading contributors to the literature on GF and ES?
- RQ4. Which papers hold significant dominance in the areas of GF and ES?
- RQ5. Which important research works have influenced the discourse about GF and ES?
- RQ6. What are the most important themes and trends in the domain of GF and ES?

Our study makes a novel contribution to the literature and provides a ready reference and comprehensive bibliometric analysis of the published research indexed in the Web of Science (WoS) database on the integration of the two fields -GF and ES. The research investigates the evolution of literature on GF and ES, identifies productive journals and leading contributors, analyses influential papers, and examines important themes and trends in this interdisciplinary field. Further, the manual content analysis was performed to identify important themes focused on GF in the context of green innovation, climate mitigation, adaptation policies, empirical methodologies, and geographical contexts, which help enrich the literature. The structured framework of our study will serve as a precursor in the discourse on the significance of GF in addressing global challenges such as climate change, resource management, and sustainable development.

Our study serves as a foundational resource for policymakers, academics, and practitioners interested in leveraging financial mechanisms to achieve the SDGs'.

The study is structured as follows. [Section 2](#) presents the methods and the data sources used. The primary findings, including the relational and evaluative methodologies, are presented in [Section 3](#). [Section 4](#) presents a thematic analysis of the paper. [Section 5](#) provides a discussion of the findings. [Section 6](#) presents the conclusion, followed by implications in [section 7](#), and the future research agenda in [Section 8](#).

2. Data collection and methodology

The use of bibliometric methods is a common practice among researchers for exploring and analyzing the literature (Liao et al., 2018). Recently, the research community has begun to pay more attention to these methods (Corsini et al., 2019). The study uses the VOSviewer for relational analysis and content analysis for the comprehensive review of the literature as suggested in many of the previous studies (Noyons et al., 1999, Van Eck & Waltman, 2010; Van Raan, 2005). These approaches provide a comprehensive and objective summary of the chosen scientific literature, which provides more information than traditional methods of literature review. The specific techniques used in our study are listed in [Table 1](#).

One of the most widely used databases in the social sciences, the WoS provided citation information, references, and keywords, which served as the foundation for our search. The social science citation index is used in the manuscript process to improve the reliability of the results (Yang et al., 2021). The authors used PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) for systematic reviews to ensure the logic and accuracy of the data selection method (Gallego-Losada et al., 2023; Mashari et al., 2023).

The publications were chosen through a literature search using keywords because this method is automated and is free from the researchers' biases. The papers in the selection process were restricted to scientific works published in peer-reviewed journals that are part of the WoS core collection. Book chapters, early access articles, and other types of documents were eliminated, leaving only empirical and review studies. The search approach is crucial for such investigations. We chose to conduct a thorough search that included a variety of synonyms and terms associated with the subject to prevent the possible removal of pertinent works. '(Ts= ('Green Bonds') Or Ts= ('Green Finance') Or Ts= ('Sovereign Green Bond'))', And (Ts=('Sustainab*') Or Ts=('SDG') Or Ts= ('Sustainable Development Goal') Or Ts= ('Climate Change'))' were

Table 1. Bibliometric techniques employed to analyze the research topic.

Techniques	Objective	Research questions	Bibliometric method	Analysis
Method of Evaluation: Bibliometrics	1 To evaluate the relative influence and academic impact	RQ1. Literature on historical evaluation RQ2. Journals with highest productivity RQ3. Most prolific authors	Measures productivity	Evolution of publications throughout history. Article distribution according to the journal. Authorwise distribution of articles.
Relational Techniques: VOS Viewer	2 To ascertain the intellectual structure 3 To recognize the thematic organization	RQ4. Most notable documents RQ5. Primary Literature influencing the intellectual framework	Impact metrics	Co-citation analysis: documents. Co-citation analysis: authors. Co-citation analysis: journals.
Review Technique: Content Analysis	4 To know the conceptual structure	RQ6. Trends and popular topics	Co-occurrence and important themes	Co-word and Content analysis.

Source: Author's Compilations.

the terms used for this purpose. The subfields 'title,' 'abstract,' and 'keywords' are all subjected to the search chain. The search period was restricted to December 2011 to December 2023 (Figure 1).

The initial process led to the collection of 793 articles which were examined again, and those articles that did not relate to the study's topic were discarded. All of the authors took part in this second screening to promote objectivity, which resulted in a final sample of 447 articles. Table 2 provides specifics on the selection procedure. The selection procedure was followed by bibliometric analysis, which began with a productivity analysis, followed by article distribution based on authors, journals, countries, and institutions considering the change in total number of publications. The manuscript has considered the documents with the highest number of citations (both absolute and relative number of citations), to assess the impact of different studies. After that, we employed relational techniques to determine how the research area was formed using the VOSviewer software and a bibliometric mapping approach (Van Eck & Waltman, 2010), which helped in developing various network connections based on co-word and

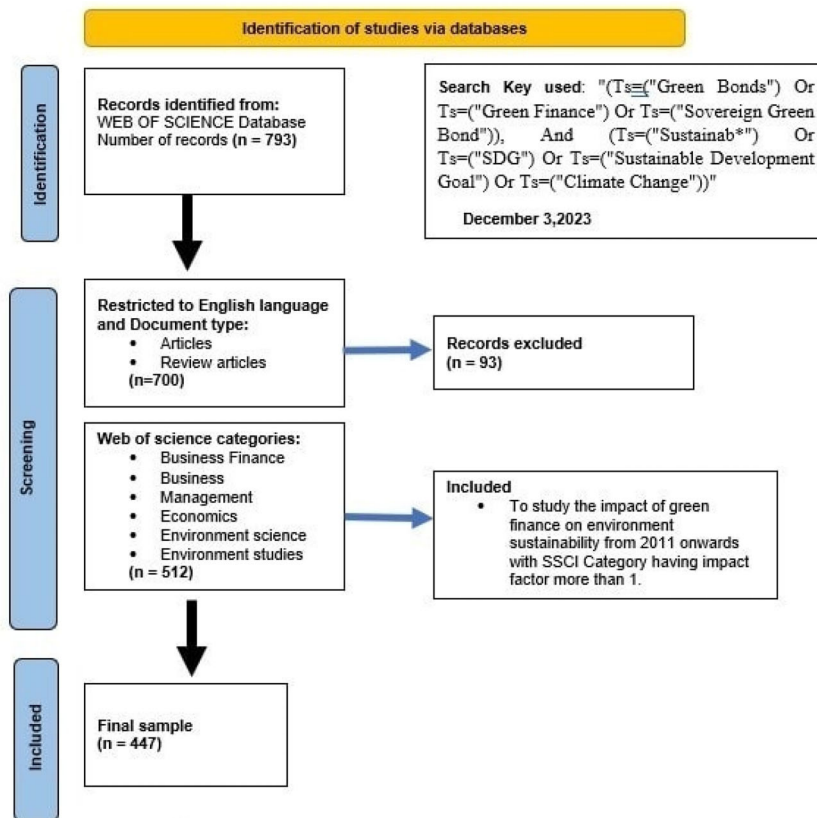


Figure 1. PRISMA framework.

Table 2. Search protocol followed.

Database	Web of Science (WoS)
Geographical Range	Worldwide Scientific Output
Language	English
Search Parameters	Topic
Criteria for Inclusion	Articles and Review Articles
WoS Categories	Environmental Science, Environmental Studies, Management, Business, Business Finance, Economics
Range of Data	All years to 2023 included (2011-2023)
WoS Index	Social Science Citation Index (SSCI)
Search Date	3 December 2023
Search Terms	(Ts= ('Green Bonds') Or Ts= ('Green Finance') Or Ts= ('Sovereign Green Bond')) And (Ts= ('Sustainab*') Or Ts= ('SDG') Or Ts= ('Sustainable Development Goal') Or Ts= ('Climate Change'))
Initial Number of Documents	793
Final Filtration Process	Filtration is made on the Basis of Abstract of Papers
Final Selection	447

Source: Authors' compilations.

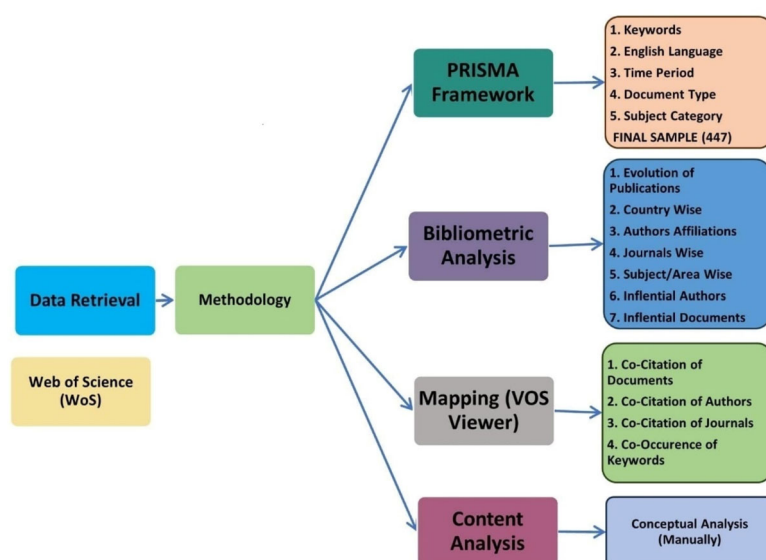


Figure 2. Research procedure.

Table 3. Distribution of articles by year of publication.

Publication year	Articles count	%Age (N/447) *100	Annual growth rate (in %age)
2023	179	40.045	38.76%
2022	129	28.859	74.32%
2021	74	16.555	174.07%
2020	27	6.04	28.57%
2019	21	4.698	110.00%
2018	10	2.237	150.00%
2017	4	0.895	100.00%
2016	2	0.004	100.00
2011	1	0.002	–
Annual Growth Rate (from 2011–2023)			49.04%

Source: Author's Compilations.

co-citation analysis. A diagrammatic presentation to clearly define the research procedure to be followed is provided in [Figure 2](#).

3. Results

Bibliometric studies are generally classified into relational, evaluative, and review techniques (Gallego-Losada et al., 2023). Evaluative methods measure the relative academic influence of a topic with the help of various productivity metrics, such as the distribution of articles across journals and authors, publication trends over time, and an analysis of the most frequently cited works (Michael Hall, 2011). Relational techniques which include co-authorship, co-citation, and co-word analysis, are commonly used to illustrate the intellectual framework of a research topic. In our study, structures appeared sufficient for analyzing chosen works, spotting trends, and identifying popular subjects (Keathley-Herring et al., 2016; Zupic & Čater, 2015). VOSviewer software offers a mapping tool to present the findings of the bibliometric technique visually (Van Eck & Waltman, 2010).

3.1. Publication growth analysis

The first research on this topic was published in 2011 by the Asian Economies Public Review (Nishizawa, 2011). However, this research line did not gain prominence in the next five years after publishing the first article in 2011. There has been a noticeable increase in the number of articles published since 2016. The year 2022 marked a turning point in its growth when 129 research articles were published in this area, a development that was further validated in 2023 with 179 publications ([Table 3](#)). This highlights

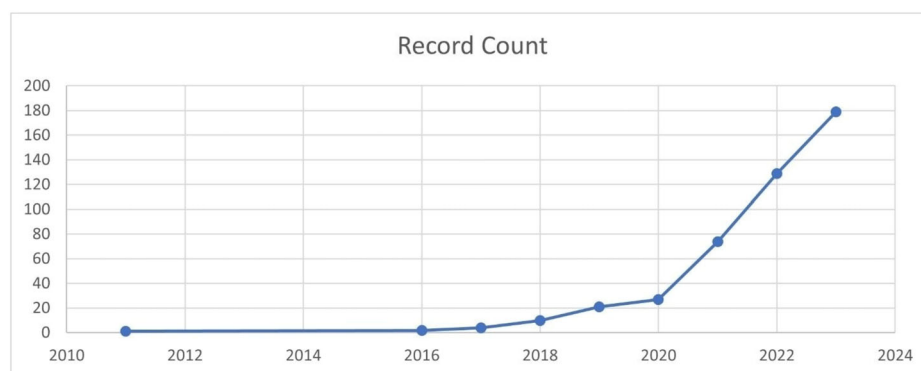


Figure 3. Evolution of publications.

Table 4. Countries with the most number of articles published.

Countries	Number of articles	%Age (N/447) *100
People's Republic of China	249	55.705%
Pakistan	39	8.725%
England	35	7.830%
France	33	7.383%
USA	32	7.159%
Italy	28	6.264%
Malaysia	27	6.040%
Australia	25	5.593%
Japan	24	5.369%
Spain	19	4.251%

Source: Author's compilations.

the growing interest of scholars in the role of GF in sustainable growth. There may be a variety of reasons for this significant expansion, e.g. increasing awareness of environmental issues such as pollution, climate change, and greenhouse gas emissions. The growth pattern in the literature in this field shows that this field of study is still evolving (Figure 3). Several significant research themes will probably continue to intensify shortly while a few others may become obsolete or lose their significance.

3.2. Countries and institutions with most articles produced

In a bibliometric analysis, it is very important to measure the institutions and countries from which the research in a discipline originates. In our study, this issue was addressed by relating the studies to the author's country of origin and institutions separately. This type of analysis helps identify the main contributors to the growth of the chosen field. We observed that a significant percentage of the authors (55.705%) were from China, followed by Pakistan (8.725%), England (7.830%), France (7.383%), the USA (7.159%), and Italy (6.264%). Among the emerging nations, Malaysia (6.04%), India (3.795%), and Vietnam (3.348%) are the other prominent contributors. A list of the top ten most productive countries is presented in Table 4. The dominance of Chinese researchers in this field indicates that institutions, research agencies, and governments, facilitate and encourage relevant research. In the international summits on climate change, the role of the emerging world along with developed nations is crucial, even though developed countries are the chief source of funding. Without the support of all countries, it is very difficult to accomplish green financing for sustainable growth. Furthermore, with the relatively inadequate studies and skewed distribution of the studies, there is a need to extend the quantum of studies, especially in emerging nations, to yield more important implications. This could be one of the key directions for future research pursuits.

The institution-wise association of the studies shows that (Table 5) there is no single institution or research agency that has a dominating share in the number of studies produced but 7 out of 10 most productive institutions are from China alone which reflects the collective dominance of Chinese institutions in this field of knowledge. The Tokai University of Japan has produced the maximum number of articles (14) followed by the Capital University of Economic Business, China (12), Southwestern University

Table 5. Article distribution based on author affiliation.

Institution	Country	Number of Articles	%Age (N/447) *100
Tokai University	Japan	14	3.132%
The Capital University of Economics Business	China	12	2.685%
Southwestern University of Finance Economics China	China	10	2.237%
Wuhan University	China	9	2.013%
Chinese Academy of Sciences	China	8	1.790%
Jiangsu University	China	8	1.790%
Lebanese American University	Lebanon	8	1.790%
Qingdao University	China	8	1.790%
University Of London	London	8	1.790%
Anhui University of Finance Economics	China	7	1.566%

Source: Author's compilations.

Table 6. Article distribution according to journal.

Journal	Number of articles	Impact factor	Total citations
Sustainability	89	3.9	1328
Finance Research Letters	15	10.4	1252
Resources Policies	56	10.2	905
Journal of Cleaner Production	12	11.1	837
Energy Policy	11	9	789
Technological Forecasting and Social Change	15	12	720
Energy Economics	28	12.8	583
Environmental Science and Pollution Research	8	5.8	533
Business Strategy and the Environment	12	13.4	303
Economic Analysis and Policy	12	6.5	215

Source: Author's compilations.

of Finance Economics, China (10), and Wuhan University, China (9). BRICS nations, the US, European Union also make an important contribution in propagating the use of GF for ES but there is no institution in the top 10 from these regions. It indicates that there is a need for further investigation and research in this field.

3.3. Important journals and research fields with a high volume of articles

96 journals published 447 articles; 45 (46.89%) of them have published only one paper, 23 (23.95%) published two, and 28 (29.16%) have published three or more. Table 6 presents the most productive journals with the highest number of published articles on the research topic under review. Approximately 261 articles, or 58.38% of all articles, were included in this category and were selected from the top 10 journals. Our findings indicate that sustainability is the most productive journal (89), followed by Resource Policies (56), Energy Economics (28), Finance Research Letters (15), Technological Forecasting and Social Change (15), Business Strategy and the Environment (12), and the Journal of Cleaner Production (12). Further, in terms of impact factor 2023, Business Strategy and the Environment have the highest value of 13.4, followed by Energy Economics (12.8), Journal of Cleaner Production (11.1), Financial Research Letters (10.4), and Resources Policies (10.2).

The classification of these 447 articles according to the research area they belong to is summarized in Table 7. Our findings reveal that these articles are associated with various fields of study, including management, business, business finance, economics, and environmental science and studies. This may be because of three important reasons. First, GF is an interdisciplinary field of study amalgamating both finance and environmental sciences. Second, the main focus of research in GF is sustainability, reducing environmental degradation. This makes the journal in the area of environmental and sustainability the preferred choice of researchers. Third, the journals from environmental science have relatively high impact factors which further motivates researchers to publish their work in these journals (Shang & Jin, 2023).

3.4. Authors' analysis

The analysis of authors is a crucial part of the bibliometric analysis as it enables the assessment of the authenticity and reliability of the content so that findings can be contextualized by looking at

Table 7. Articles distribution according to the research field.

Research Area	Number of Articles	%age (N/447) *100
Environmental Studies	228	50.667%
Environmental Sciences	147	32.667%
Business Economics	135	30.000%
Green sustainable science technology	107	23.778%
Business Finance	67	14.889%
Business	47	10.444%
Management	24	5.333%
Regional Urban Planning	17	3.778%
Energy Fuels	16	3.556%
Engineering Environmental	12	2.667%

Source: Author's compilations.

Table 8. Most active authors on GF and ES.

Rank	Name of author	Country	University/Institution	Number of publications
1	Farhad Taghizadeh-Hesary	Japan	Keio University	15
2	Nawazish Mirza	France	Excelia Business School, La Rochelle	6
3	Dongyang Zhang	China	Capital University of Economics and Business	6
4	Shunsuke Managi	Japan	Kyushu University	5
5	Asif Sharif	Pakistan	The Superior University	5

Source: Author's compilations.

the writing styles, affiliations, and backgrounds of the authors. There were 1184 distinct authors among 447 articles. Of these, 86.82% (1028) have contributed to one publication, 9.45% (112) have published two, and 3.71% (44) have produced three or more publications. [Table 8](#) shows the most productive research teams, those with four or more articles on the study's subject, focusing on the impact of GF on ES. Farhad Taghizadeh-Hesary of Keio University in Japan, Nawazish Mirza of the Excelia Business School in La Rochelle, France, and Dongyang Zhang of the Capital University of Economics and Business in China are among the most prolific writers in this field.

3.5. Most cited articles

An indication of a paper's quality can be found in the number of citations. This measure identifies the most important papers and documents on a given subject in bibliometric analysis (Zhang et al., 2019). Citation analysis determines the number of times a publication has been cited in the database. [Table 9](#) presents the ten most cited articles in our sample. These papers have been published across journals in different fields, which once again highlights the interdisciplinary nature of the subject. To consider the impact of the year of publication, papers were arranged based on the number of citations per year (C/Y). Articles in the GF are generally well-cited. In our study, the average number of citations for the sample comprising 447 papers was 25.062. In both absolute and relative terms, the most cited work was written by and released in the Energy Policy Journal in 2021 (Zhang et al., 2021) which examines how public spending on research and development impacts the sustainability of the economy and environment. Since its publication, this paper has been cited 186 times on average per year. Another paper that has received a significant number of citations (320 citations) was published in the Journal of Financial Economics (Flammer, 2021) which assesses the advantages and limitations of issuing corporate green bonds.

3.6. Visual analysis of citations and sources

Co-citation analysis helps determine the most influential aspects and their relationships in a field of study that facilitates the assessment and identification of the conceptual framework of the subject (Noyons et al., 1999). Co-citation denotes the degree of similarity between cited works. It occurs when two different documents are cited together in the same article (Hjørland, 2013). A variety of analytical units, including papers or journals, can serve as the foundation for co-citation (Hjørland, 2013).

Table 9. Top 10 most cited articles in GF and ES.

Rank	Title	Authors	Country (1 st Author)	Journal	Impact Factor (2022)	TC	(C/ Y)	Year of Publication
1	'Public spending and green economic growth in BRI region: Mediating role of green finance'	Zhang, Dongyang; Mohsin, Muhammad; Rasheed, Abdul Khaliq; Chang, Youngho; Taghizadeh-Hesary, Farhad	China	Energy Policy	9	372	186	2021
2	'Corporate Green Bonds'	Caroline Flammer	USA	Journal Of Financial Economics	8.9	320	160	2021
3	The Way to Induce Private Participation in Green Finance	Farhad Taghizadeh-Hesary, Naoyuki Yoshino	Japan	Finance Research Letters	10.4	309	77.25	2019
4	A Bibliometric Analysis on Green Finance: Current Status, Development, And Future Direction	Dayong Zhang, Zhiwei Zhang, Shunsuke Managi	China	Finance Research Letters	10.4	239	59.75	2019
5	Does Financial Inclusion Impact CO ₂ Emissions? Evidence From Asia	Thai-Ha Le, Ha-Chi Le, Farhad Taghizadeh	France	Finance Research Letters	10.4	222	74	2020
6	Influence Mechanism Between Green Finance and Green Innovation: Exploring Regional Policy Intervention Effects in China	Muhammad Irfan, Asif Razzaq, Arshian Sharif, Xiaodong Yang	China	Technological Forecasting and Social Change	12	202	202	2022
7	The green advantage: Exploring the convenience of issuing green bonds	Gianfrate, Gianfranco; Peri, Mattia	France	Journal of Cleaner Production	12	188	47	2019
8	Developing Low Carbon Finance Index: Evidence from Developed and Developing Economies	Mohsin, Muhammad; Taghizadeh-Hesary, Farhad; Panthamit, Nisit; Anwar, Saba; Abbas, Qaiser; Xuan Vinh Vo	China	Finance Research Letters	10.4	180	90	2021
9	Impact of Green Credit on High-Efficiency Utilization of Energy in China Considering Environmental Constraints	Malin Song, Qianjiao Xie, Zhiyang Shen	China	Energy Policy	9	168	84	2021
10	Role of Green Finance in Improving Energy Efficiency and Renewable Energy Development	Ehsan Rasoulnezhad & Farhad Taghizadeh-Hesary	Iran	Energy Efficiency	3.1	158	158	2022

Abbreviations: TC = Total citations; C/Y = Citations per year.
Source: Author's compilations.

3.6.1. Co-citation network of documents on green finance and environment sustainability

We performed this analysis by selecting papers that have at least 15 citations per paper (Gallego-Losada et al., 2023). The 447 documents analyzed contained a total of 19782 cited references, of which 79 satisfied this criterion. The size of each node (Figure 4) denotes the number of citations per document, and each node represents a single reference. An association between co-citations is indicated by a link between the two nodes. The connections between two nodes represent the strength indicated by the thickness of the link. Finally, the nodes were classified into various clusters based on their similarity.

The map (Figure 4) indicates the presence of four work groups. The studies in the green cluster analyzed the relationship between bond prices and pro-environmental sentiment, with a particular focus on green bonds and corporate green bonds (Tolliver et al., 2020). This cluster also analyzed the impact of GF on CO₂ reduction (Bai et al., 2022; Xiong & Sun, 2023) and its emphasis on the significance of climate risks for institutional investors (Shang & Jin, 2023). The analysis of public spending on research and development to influence the economy and ES is the focus of the most cited paper (Zhang et al., 2021).

Studies within the red cluster primarily explored how inclusive GF promotes the growth of green innovation (Madaleno et al., 2022). Another study by Taghizadeh-Hesary & Yoshino (2019) analyzed the key mechanisms inducing private participation and the important barriers inhibiting the growth of the GF ecosystem. To create a meaningful connection between the potential growth of GF and public spending in regions covered by the Belt and Road Initiative (BRI). The studies by Shao and Huang (2023) and Zhang et al. (2021) illustrated the concrete effects of GF on the economies of BRI regions. A comprehensive analysis of these studies facilitated a clear understanding of how GF innovation and promotion can act as catalysts for sustainable economic development (Irfan et al., 2022). Studies in the yellow cluster examined the role of financial institutions and instruments in transforming the economy into a low-carbon economy and promoting sustainable projects (Campiglio, 2016; Fatica & Panzica, 2021). The studies grouped in the blue cluster (Nguyen et al., 2021; Reboredo, 2018) among many others investigated the co-movement of green bonds and other financial instruments across varying periods (Ferrer, 2021). These studies focussed on ensuring compliance of green bonds and other GF instruments with environmental standards (Ehlers & Packer, 2017) within the larger framework of sustainable finance, thus contributing to effective climate policy.

3.6.2. Co-citation network of authors with expertise in GF and ES

For author co-citations, the 447 documents that were analyzed contained 13016 cited authors in total, of which 28 satisfied the requirement of having at least 40 (Gallego-Losada et al., 2023) citations. The results of this analysis with two different clusters are presented in Figure 5. The green cluster includes studies on corporate green bonds supported by major international financial institutions and organizations. The red cluster includes different institutions (World Bank, OECD) and individual authors, who mainly focus on improving energy efficiency and renewable energy development.

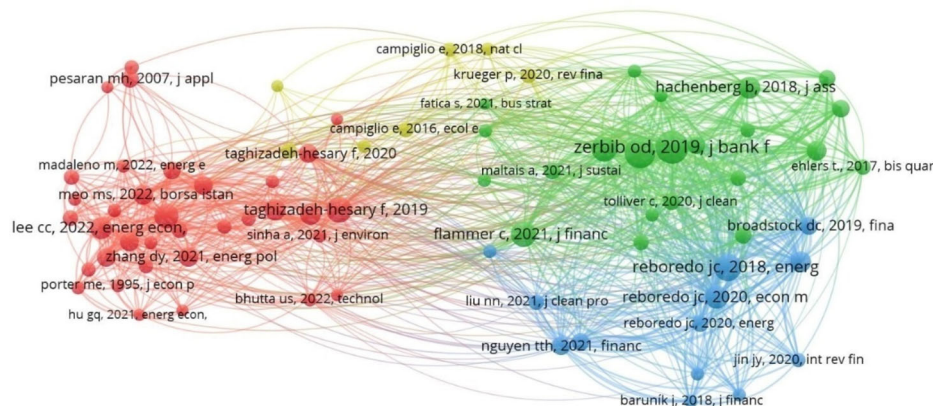


Figure 4. Co-citation of a network of documents.

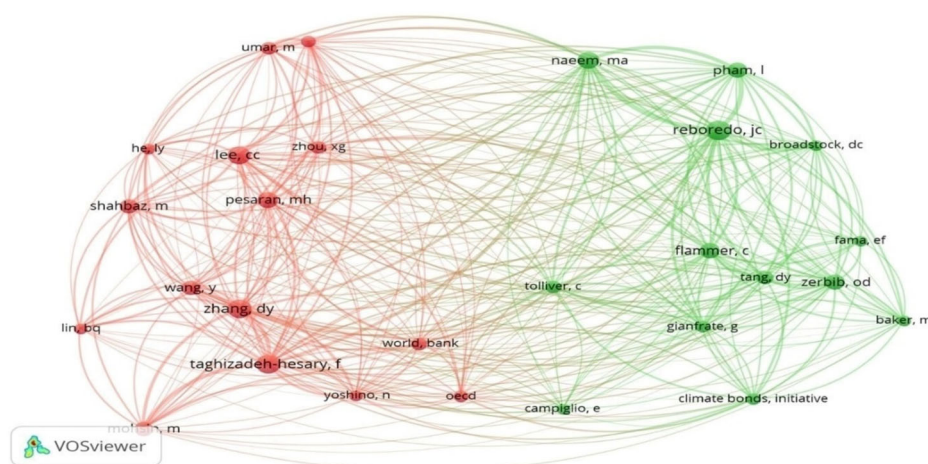


Figure 5. Co-citation network of authors.

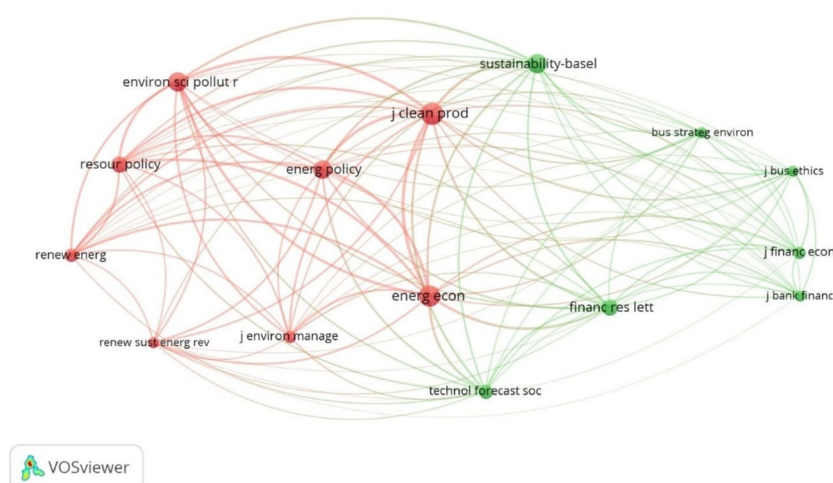


Figure 6. Journal co-citation network.

3.6.3. Journal co-citation network with a focus on green finance and environmental sustainability

The journal co-citation analysis helps in the study of the thematic organization of an area of research (Hjørland, 2013) which is illustrated in Figure 6. Similarities between the journals and their respective fields of study can be seen in the number of times the two sources are cited together. A total of 7185 cited sources were found in our sample of 447 documents, out of which 15 most influential journals as per total citations are shown in the network diagram in Figure 6. Each of these journals has a minimum of 267 citations. Each node represents a journal, and its size is proportional to the number of citations it has received. The similarity between the two journals is indicated by the co-citations they are having. This analysis helped us categorize the publications into two separate clusters. The red cluster brings together publications from journals that specifically focus on the evolution of the green bond market and its empirical analysis. The prominent journals in this cluster are Environmental Science and Pollution Research, Energy Policy, and the Journal of Cleaner Production. Journals primarily related to decarbonization, sustainable investment, and policy development for the advancement of climate finance were included in the green cluster such as Business Strategy and the Environment, Finance Research Letters, and Technological Forecasting and Social Change.

3.6.4. Keyword co-occurrence analysis

Co-word analysis uses the most popular keywords to provide a thorough assessment of major research trends and subjects (Li et al., 2016). 1847 keywords were found in the 447 articles analyzed of which 36

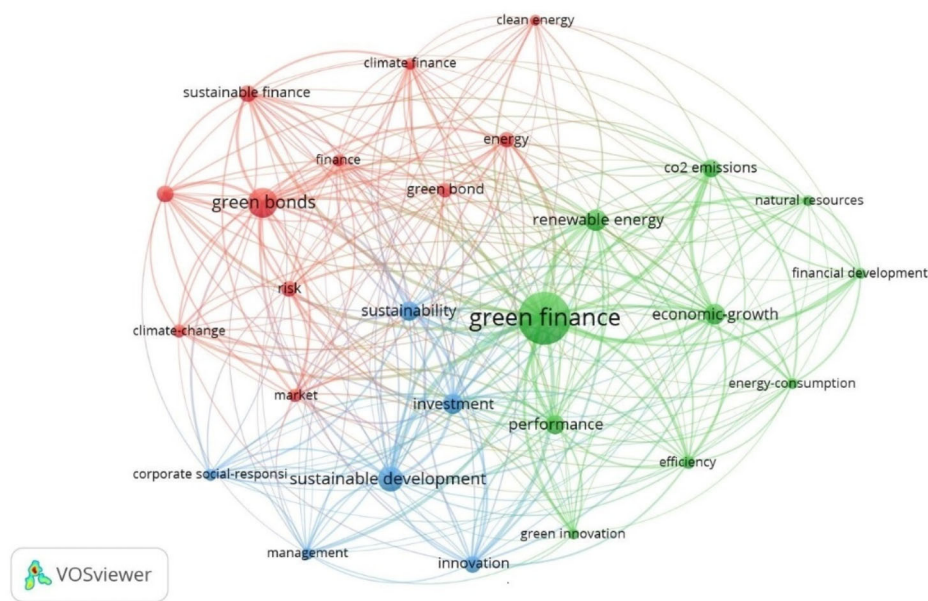


Figure 7. Keyword co-occurrence network.

met the requirement of having at least 15 occurrences (Gallego-Losada et al., 2023). These findings are illustrated in Figure 7 where the occurrence of the keywords is represented by the size of the circle, while the distance between the circles is a measure of their interconnectedness. Stronger links between keywords are indicated by the thick lines.

The keywords with the highest number of occurrences and a minimum count of 50 are GF (245), green bonds (89), sustainable development (70), renewable energy (57), investment (54), and economic growth (52). The names of the nations where the studies were conducted are also present among the most frequently occurring keywords and China is the most notable one (62 occurrences). However, because the keywords associated with nation names are unrelated to the ideas that symbolize the topic's intellectual structure, we have excluded them from the keyword map for the analysis.

The green cluster in Figure 7 indicates that the majority of the keywords are strongly associated with the term 'GF,' which is positioned in the center of the map with 245 occurrences and a total link strength of 425. In addition, the terms, 'sustainable development' (70 occurrences and 150 links), and 'renewable energy' (54 occurrences and 137 links) are crucial for understanding the literature on this topic. The other important keywords used by researchers are 'natural consumption,' 'economic growth,' and 'energy consumption' which are all gathered under the umbrella of the environmentally friendly perspective.

The red cluster shows the relationship between clean energy, sustainable finance, and climate change. It explores risk assessment, cost analysis, and methods for incorporating sustainability into financial procedures. The studies in the blue cluster deal with the issues of sustainable development, sustainability indicators, and corporate actions that address social and environmental issues. Thus, encouraging GF is expected to become one of the most popular research topics in this area as it is regarded as a crucial issue for accelerating the achievement of sustainable development (Tolliver et al., 2021).

4. Content analysis

Content Analysis is an important research methodology that is predominantly used in the field of social sciences to analyze the literature of a particular area in depth. Content analysis helped us identify key topics in this subject as well as significant empirical methods and a panel of nations that serve as the foundation for the research setting. This analysis has also facilitated the exploration of significant gaps in the body of current literature. The findings are as follows:

4.1. Climate change mitigation and green finance

According to Ren et al. (2022), an analysis of the relationship between green bonds and the eco-economy shows green bonds have long-term benefits, particularly in situations where markets are extremely volatile. Ferrer (2021) provided evidence that green bonds perform better than government and premium corporate bonds, indicating that they can effectively mitigate climate change without compromising returns. According to Flaherty et al. (2017) issuing green bonds would allow for the quick funding of climate mitigation efforts while proving the sustainability of bonds over a limited period. Tolliver et al. (2019) examined green bond allocation trends and showed that projects financed by green bonds were associated with significant reductions in greenhouse gas emissions and increases in renewable energy capacity. Nawaz et al. (2021) used a variety of techniques to validate the importance of variables such as population, foreign direct investment (FDI), CO₂ emissions, renewable energy consumption, and research and development in advancing green funding and climate change mitigation. They pointed out how crucial GF is to mitigate climate risks and reduce carbon emissions, particularly when it comes to promoting waste and pollution reduction and enhancing energy efficiency. To examine the volatility and causative linkages among renewable energy investment, renewable energy electricity output, GF, GDP, and energy investment with private involvement, Li et al. (2021) used the wavelet power spectrum approach.

4.2. Green finance: issues and challenges

Public spending on green energy technologies and human resources has accelerated economic growth. Taghizadeh-Hesary and Yoshino (2019) proposed a model that integrated green credit guarantee schemes and distributed ledger technology to bridge the GF gap for large green projects. Clark et al. (2018) pointed out that market failures, information gaps, inconsistent regulations, and reliance on voluntary commitments are obstacles to financing sustainable development. They stressed the necessity of greater investment from the private sector, which may be attained through cooperation and institutional reform. In their investigation of the relationship between central bank mandates and environmentally friendly actions, Dikau and Volz (2021) found that over half of the institutions under evaluation had mandates to support sustainability goals or encourage sustainable growth. Cui et al. (2018) examined the influence of green loans on banks' financial and environmental performance and discovered that there were benefits in terms of lower non-performing loan ratios. They proposed a theoretical framework that highlights how market-based finance and policy can bring about the convergence of green financing systems. Li et al. (2022) illustrated the beneficial effects of green funding and laws in encouraging investments in renewable energy sources in China. Additionally, they draw attention to how green rules work as moderators in reducing the negative effects of geopolitical risks and fluctuations in oil prices. The investigation of the role of green bond financing in decarbonizing the global economy by Al Mamun et al. (2022) emphasized the importance of this strategy in nations with more advanced credit markets and greater levels of technical development. Madaleno et al. (2022) examined how policy interventions may encourage green investments for sustainable development and energy transitions. Sheraz et al. (2021) investigated how globalization, energy consumption, GDP, human capital, and financial development affect carbon emissions and offered policy recommendations to support a sustainable environmental agenda. To enhance sustainability, Cui et al. (2020) underlined the significance of a complete green financial system and proposed steps to tighten government regulations and lower production costs.

4.3. Green innovation and GF

The nexus between green financing, green innovation, and sustainable development has been the subject of numerous studies (Irfan et al., 2022). Falcone et al. (2018) emphasized cooperation between national and international players, highlighting the significance of policy interventions to assist the development of green innovations. GF is one such factor that helps reduce decarbonization (Al Mamun et al., 2022). Xiong and Sun (2023) also found evidence that green innovation helps in the reduction of

carbon emissions. Wang et al. (2022) too explored an empirical relationship between GF, green innovation, and environmental performance and led to a similar conclusion. Together, these studies highlight the significance of green innovation in promoting GF and addressing environmental issues as well as the necessity of successful legislative initiatives and stakeholder cooperation.

4.4. Technique/methodology employed in the literature

The analysis of the empirical studies reveals that the researchers have employed divergent approaches and methodologies, including survey methods, quantitative approaches, structural equation modeling (SEM), systematic literature review (SLR), extended literature review, and regression and correlational process analysis for exploring the importance of GF in achieving sustainable development in an economy. Quantitative studies and secondary reports have been used in most of the investigations. (Cui et al. (2018); Nanayakkara and Colombage (2019); Tu et al. (2021), and Zhang et al. (2021) used the generalized method of moment and panel regression analysis. Few other methods which have been employed in the empirical studies are simulation techniques (Cui et al., 2020; Flaherty et al., 2017), STIRPAT Model (Le et al., 2020; Rasoulinezhad & Taghizadeh-Hesary, 2022), CCEMG (Chien et al., 2021; Tao et al., 2021) CS-ARDL (Ibrahim et al., 2023; Tao et al., 2021), difference-in-difference approach (Irfan et al., 2022; Nawaz et al., 2021) data envelopment analysis and propensity score matching technique (Gianfrate & Peri, 2019; Mohsin et al., 2021). (Ren et al., 2022; Sinha et al., 2021; Wang et al., 2023; Zhang et al., 2022) investigated the effects of GF on social and environmental responsibility and highlighted potential limitations using wavelet multiscale decomposition and quantile-quantile regression. They proposed policy frameworks intended to facilitate the attainment of the Sustainable Development Goals (SDGs). Ng (2018) illustrated the variety of risk governance, sustainable accounting, and financing strategies employed by listed companies to issue green bonds using a multiple-case study technique. An exploration of these research analytical techniques is important for advancing understanding and solving complex problems within the field of GF and ES.

4.5. Geographical analysis

Ng and Tao (2016) proposed adopting guidelines tailored to the economic growth stage of select Asian economies to increase the usage of green bonds and bridge the gap in green financing. Zhang et al. (2021) in their study on BRI nations discovered that the objectives of 'green growth' are influenced by both the composition and technological effects, with the latter promoting economic expansion and pollution reduction. Le et al. (2020) determined the variables affecting carbon emissions in Asia. Rasoulinezhad and Taghizadeh-Hesary (2022) studied the impact of energy efficiency, green energy index, and green finance on CO₂ emissions in countries having maximum investment in green projects. Their findings revealed that green bond is an effective financing tool for promoting green energy projects and reducing CO₂ emissions. According to Tolliver et al. (2021), South Korea and China saw a rise in pollution abatement-related green patents as a result of consumer demand, whereas Japan led the world in green patenting. They also observed a notable increase in revenue for large-revenue companies that correlated with the disclosure of ESG information. Mohsin et al. (2021) demonstrated how a low-carbon financing index helped to reduce carbon emissions, especially in lower-income nations. Song et al. (2021) studied the impact of green credit, environmental rules, and technological advancements on high-efficiency energy use in China and observed considerable regional effects. Wang and Wang (2021) investigated the influence of GF on China's industrial structure, emphasizing its benefits for the tertiary sector. Soundararajan and Vivek (2016) discussed the fundamentals of green investing and emphasized that its goals are to enhance social justice, sustainability, and human well-being. To examine the trade-offs between economic growth and sustainability of the environment, Zahoor et al. (2022) employed sophisticated econometric approaches to examine the relationship between clean energy investments, CO₂ emissions, and economic growth in China. The BRI member countries' energy funding patterns and carbon emission trends were examined by Tu et al. (2021), who focused on the role of GF and private investment in maximizing energy efficiency. Samour et al. (2022) found that financial

development, FDI, and economic expansion greatly enhance the UAE's use of renewable energy. Their study recommended fostering financial development and GF to ensure sustainable development.

This observation helped us to conclude that the developing world is a hotspot of GF discussions and discussion on this issue in the case of industrialized economies is relatively less (Falcone, 2023; Mohsin et al., 2021; Samour et al., 2022; Sheraz et al., 2021; Zhang et al., 2022). This gap in the literature paves the way for future research.

5. Discussion

The present study's findings shed light on the importance of GF and its association with ES. By using bibliometric and content analysis, many important themes and trends have emerged providing valuable insights for researchers, practitioners, policymakers, and other stakeholders navigating the GF frontier. The increasing attention towards GF is manifested from the growth of literature in this field as depicted by the bibliometric findings of the paper. Existing studies have made similar observations and emphasized the need to align financial activities with sustainable environmental objectives and initiatives (Afzal et al., 2022; Fatica & Panzica, 2021). The content analysis in our study revealed the diverse and expanding spectrum of GF, encompassing climate change mitigation through renewable energy investments, stringent regulatory framework, sustainable infrastructure projects, and the role of green innovation. Our results corroborate the findings of Clark et al. (2018) and Dikau and Volz (2021) wherein they have highlighted the diversity and complexity of GF mechanisms. Moreover, this study unveiled the regional disparities in adopting GF, with certain areas dominating the discourse while others lag. The study further reports that global collaboration and knowledge exchange to address environmental challenges and advance sustainable finance agendas. This proposition finds support from the study of Dörry and Schulz (2018); Falcone et al. (2018). Furthermore, this research also identifies various research clusters within the ambit of GF literature including risk management, financial performance, policy frameworks, and regulatory mechanisms which are in sync with the studies of Diaz-Rainey et al. (2023) and Li et al. (2018) which have also outlined similar thematic clusters and research priorities. Umar and Safi (2023) stressed the need for stronger policy incentives, market mechanisms, and institutional frameworks to integrate environmental criteria into investment decisions, which aligns with the conclusions drawn in our study.

6. Conclusions

Using extensive analysis of published research with bibliometric and content analysis techniques, this manuscript provided an overview of the relatively new field of study by synthesizing the academic literature on GF. For this purpose, 447 papers were extracted from the WoS database. The manuscript was divided into three parts, the first part included the bibliometric analysis for the discussion of the descriptive statistics of the topic. It assists in understanding the growth of the area, most influential authors, subject area, journals, and countries with the number of publications. In the second part of the manuscript, the visual analysis using the VOSviewer software was performed which helped the authors to highlight the conceptual and social structure of the field of GF. It included co-occurrences of keywords and co-citation of documents, journals, and authors. The final part of the manuscript was based on the content analysis which was performed manually to gain comprehensively valuable insights in the area of GF and ES.

The findings of the study revealed that although the concept was introduced in the 1980s, yet, the noticeable effect was visible after the announcement of SDGs by the UN in 2015. Since 2016, substantial growth in annual publications has been observed. The geographical spread of the literature reveals that the majority of publications in this area have taken place in China, and more than 50% of the influential researchers in this area also belong to China. It reflects that this field of knowledge is gaining intellectual attention there. The analysis demonstrated that GF is a crucial social requirement and a necessary step towards sustainable development. There are still important issues that need to be addressed, such as the lack of initiatives for the institutions and the investors, the existence of a lax regulatory framework, the lack of awareness of the benefits of GF, and the trade-offs between ES and profitability.

In this study, only the WoS database was used for the in-depth analysis which might have excluded some important studies included in other databases. The accuracy and completeness of the data in the WoS database may have affected the trustworthiness of the study conclusions. Recognizing any possible inaccuracies or omissions in the dataset is crucial because the generalizability of the results may be affected by broader aspects. If other databases will be used for analysis purposes in future studies, the conclusion might vary. Another limitation of this analysis may stem from the methodology used. For instance, biases or limitations may be introduced by coding methods, analytical techniques, or article selection criteria. In the current study, an extensive review of the nexus between GF and ES has been presented. However, various other antecedents of GF like digital finance, AI, and sustainable investments can form part of a review study to present the concept in a broader sense.

7. Implications

This review paper offers certain important policy implications for the researchers and regulators which can be stated as follows:

- i. Our study is useful for the researchers as it presents the current status of research in the field of GF and ES by highlighting the prominent themes, trends, focus areas, journals, researchers, and most importantly, the knowledge gap in the literature. This information is helpful to researchers in choosing their relevant fields of study, subthemes, cross-sectional units, and appropriate journals.
- ii. This research is useful to policymakers in framing effective and evidence-based policies aimed at promoting GF, removing hurdles in its growth, and facilitating the transition towards a low-carbon economy.
- iii. The findings in our study would help regulators in resource allocation towards areas with greater potential for green innovation, addressing the issues related to climate change mitigation, and sustainable development.
- iv. Imparting financial literacy related to GF is very important for educating the general public about the adverse effects of environmental deterioration. Therefore, the government should take the initiative to disseminate knowledge and coordinate efforts to ensure the continuous growth of GF.

8. Future research agenda

The review of the extant intellectual structure led us to note various research area which needs further exploration. A few future research agendas are highlighted as under:

- i. The existing literature lacks empirical analysis establishing the relationship between GF and other variables like fintech, technological innovation, governance factor, and green growth. This can be pursued in future research studies.
- ii. The current research uses WoS to extract the data for review. Future research can extract the literature using multiple databases, including EBSCO, Science Direct, JSTOR, and Scopus.
- iii. This paper reveals that the industrialized and the industrializing nations differ in terms of GF penetration as observed by the empirical evidence available in the context of individual nations. However, no attempt has been made to conduct a comparative analysis between the developed and the developing economies. This can be studied in the future.
- iv. The findings of our study also reveal that most of the discussion on GF and its role in mitigating carbon emissions clusters around developing countries and there are limited studies in the context of industrialized economies. This gap in the literature paves the way for future research.

Authors' contribution

Conceptualization, A.K., S.A., N.S.; Validation, A.K., N.S., and A.S.; writing-original draft preparation, A.K., S.A., and N.S., B.H.; writing-review and editing, A.K., N.S., and B.H.

A.K. Ashish Kumar, S.A. Suman Ahuja, N.S. Nupur Soti, A.S. AK Saini, B.H. Bharti.

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Data availability statement

The data that support the findings of this study are available on request from the author.

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