GREEN FINANCE IN THE CONTEXT OF CLIMATE CHANGE: A BIBLIOMETRIC ANALYSIS OF THE ACADEMIC LITERATURE (2001–2025)

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Abstract.

This article analyses the evolution, structure, and dynamics of the academic literature on green finance in the context of climate change, using a bibliometric approach applied to publications indexed in the Web of Science – Core Collection for the period 2001–2025. The methodology is based on descriptive and relational bibliometric indicators, including the analysis of scientific production, sources, authors' impact, co-authorship networks, and keyword co-occurrence, complemented by thematic maps and temporal analyses of emerging themes, conducted using the Bibliometrix package within the R environment. The results highlight an accelerated growth of academic interest after 2016, with a concentration of publications in economics and finance journals such as Energy Economics, Finance Research Letters, and International Review of Financial Analysis, as well as a polycentric structure of international collaborations dominated by East Asia and Europe. The conceptual analysis reveals three major thematic clusters: the performance and impact of green investments, energy transition and sustainable economic growth, and systemic risks and financial stability. The emergence of themes such as financial digitalisation, fintech, and artificial intelligence indicates recent directions of research diversification. The article contributes by providing a systematic mapping of a rapidly maturing field and by identifying epistemic gaps, highlighting the need to expand comparative studies, interdisciplinary approaches, and analyses of green finance in emerging and transition economies.

Keywords: *green finance; climate change; bibliometric analysis; financial sustainability*

JEL Classification: *G10; G20; Q54; Q01*

1 Introduction

The intensification of extreme climate phenomena, driven by the rising concentration of greenhouse gases, has transformed the transition towards a decarbonised economy from a political option into a systemic necessity. In this context, green finance is no longer perceived merely as a niche segment of capital markets, but as an essential mechanism for resource allocation aimed at climate change mitigation and adaptation. The rapid expansion of green financial instruments, ranging from green bonds and green loans to ESG portfolios and impact investments, confirms that the financial system has begun to internalise environmental risks and to capitalise on the opportunities associated with its own sustainable transformation. At the same time, the proliferation of international regulations, national taxonomies, and voluntary reporting initiatives increases the pressure on economic actors to recalibrate their strategies in line with global climate objectives.

Against the backdrop of this growing momentum, the scientific literature on green finance has experienced exponential growth over the past decade, structuring itself around increasingly diversified thematic axes: the assessment of the performance and impact of sustainable investments, the integration of climate risks into financial stability frameworks, responsible corporate governance mechanisms, as well as the role of technological innovation and public policies in accelerating the green transition. The diversity of disciplinary approaches, ranging from econometric modelling and risk management techniques to institutional analyses and case studies, is addressed in a fragmented manner, which risks diluting the conceptual coherence of the field and limiting synergies among the results obtained.

Based on a bibliometric approach, this study aims to map knowledge flows, identify centres of influence, and make visible the dynamics of emerging themes. In addition, the quantitative analysis of scientific production is complemented by a critical reflection on the identified gaps, geographical polarisation, and interdisciplinary trends.

Bibliometric analysis is a quantitative method used to evaluate, synthesise, and visualise the scientific literature within a research field. In the context of green finance research, this method becomes an effective tool for mapping thematic developments, identifying influential authors, key sources, and emerging trends. Bibliometrics can provide a rigorous framework for understanding the structure and evolution of scientific knowledge, with critical applications in research strategic planning (Zhang et al., 2019; Nasim, 2023). It is grounded in established databases such as Scopus, Web of Science, or Dimensions, with document selection conducted through the use of relevant keywords. Following metadata collection, bibliometric methods may include co-citation analysis, keyword co-occurrence analysis, bibliographic coupling, or collaboration network analysis (Dar et al., 2024; Judijanto et al., 2024). These techniques enable the exploration of relationships among publications, authors, institutions, and research themes.

The rigorous application of bibliometrics also requires transparency in the methodological process: source selection, inclusion criteria, temporal coverage, and processing techniques must be clearly defined to ensure the reproducibility and validity of the study (Zhang et al., 2019; Malhotra and Thakur, 2020). Spulbar and Cinciulescu (2025) emphasise the need to complement such studies with qualitative or thematic analyses in order to add interpretative depth to quantitative results. In this research context, the present study assumes the dual objective of providing a comprehensive overview of the existing literature and, at the same time, of substantiating the research directions required to address the theoretical and practical challenges that the green transition places at the core of contemporary economic sciences.

2. Research Methodology

In order to achieve the proposed objectives, namely the examination of the specialised literature addressing green finance activities in the context of intensifying climate change, a methodological approach based on bibliometric analysis was adopted. The choice of this type of analysis was justified by its ability to capture, in an objective and replicable manner, the evolution of academic literature, the main trends of the field, and the interconnections among authors, themes, and institutions involved in the research process.

Given that the topic of green finance has experienced rapid development over the past two decades, the temporal interval selected for analysis covered the period 2001–2025. This choice was motivated by the fact that relevant scientific literature on the concept of green finance began to emerge predominantly after the year 2000, as a response to the first significant international policies addressing climate change and financial sustainability. Although the initial queries explicitly targeted the period starting in 2000, the first relevant article in the final corpus dates back to 2001; therefore, the effective lower bound was set at this year. Extending the upper bound to 2025 ensures the inclusion of the most recent scientific contributions, which are essential for identifying emerging trends in the academic literature.

The bibliometric analysis was conducted exclusively using the Web of Science – Core Collection database, which is recognised for the rigour of its journal indexing and the accuracy of citation data and publication metadata. In order to precisely delimit the research domain, the specific categories *Economics* and *Business Finance* were employed, as they directly correspond to the central subject of the study, namely green finance in an economic and financial context.

The literature collection strategy consisted of formulating queries based on five key concepts identified in relation to the purpose and objectives of the research: (i) "green finance" OR "sustainable finance" OR "climate finance" OR "environmental finance" OR "carbon finance"; (ii) "bank" OR "banking sector" OR "financial institution" OR "green

banking" OR "sustainable banking" OR "low-carbon banking"; (iii) "climate risk" OR "climate-related financial risk" OR "physical climate risk" OR "transition risk" OR "environmental risk"; (iv) "sustainable development" OR "sustainable development goal" OR "SDG" OR "net-zero" OR "decarbonization" OR "climate change mitigation"; (v) "impact" OR "effect" OR "performance" OR "outcome" OR "efficiency", each obligatorily combined with ("green finance" OR "sustainable finance").

These terms were grouped into sets of relevant synonyms, and the queries were constructed using Boolean logical operators (AND, OR). In total, seven successive queries were generated, organised to allow a progressive exploration of the literature, from general studies on green finance to articles explicitly addressing the interaction between green finance, the banking sector, climate risks, and sustainable development, as follows:

- general query on green finance;
- green finance in the banking sector;
- green finance and climate risks;
- green finance and sustainable development;
- intersection of green finance, the banking sector, and climate risks;
- effects of green finance in the banking sector;
- restricted analysis: green finance, banks, climate risks, and sustainable development.

Following the execution of the queries, the resulting datasets were exported and consolidated into a single corpus using the Bibliometrix software package within the R statistical analysis environment. This platform enabled the verification and removal of duplicate publications as well as documents with limited relevance to the research topic. After this filtering and validation stage, the final corpus for the bibliometric analysis was obtained and prepared for subsequent processing.

The bibliometric analysis itself was structured along two complementary dimensions. The first dimension focused on traditional descriptive indicators: the annual dynamics of publications, source distribution (Bradford's Law), author ranking (number of publications and Hirsch index), institutional profiles and the geographical distribution of research, as well as citation analysis aimed at identifying publications with high academic impact.

The second dimension, oriented towards mapping the evolution of academic contributions, included an extended set of bibliometric procedures: (i) co-authorship networks to reveal the topology of scientific collaborations; (ii) keyword co-occurrence networks to delineate major thematic clusters; (iii) the identification of the most frequent keywords (*Most Frequent Words*), useful for quantifying the dominant vocabulary; and (iv) the temporal analysis of key themes, which tracks the temporal trajectories of terms and detects emerging or declining themes.

In addition, thematic evolution maps and density–centrality strategic diagrams were generated, and the Kleinberg algorithm was applied to identify abrupt semantic bursts signalling episodes of rapid growth in scientific interest. Together, these tools enabled a comprehensive assessment of the current state of the literature and highlighted epistemic gaps and frontier research directions that will underpin subsequent empirical stages of the proposed research.

Although the methodology presents certain inherent limitations, such as reliance on a single database and the influence of short citation accumulation periods on recently published articles, the results of the analysis provide a robust, up-to-date, and systematic perspective on the academic literature concerning green finance in the context of climate change. Consequently, the adopted methodological approach offers clear and rigorous benchmarks for future empirical research.

3. Results

The bibliometric analysis identified a total of 1,892 scientific articles published across 446 distinct sources (journals and academic publications), indicating a significant diversity of dissemination channels and a heightened level of interest within the academic community in this

topic. These works were authored by 4,487 researchers, reflecting a broadly distributed interest within the international scholarly community.

The indicator related to the annual growth rate (25.68%) signals a particularly dynamic evolution of the field, reflecting the increasing attention devoted to issues related to green finance and financial sustainability, especially in the context of climate risks and international requirements concerning sustainable development.

Figure 1. Main descriptive indicators of the analysed bibliometric corpus (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The analysis of scientific collaborations revealed a high degree of international cooperation, with a significant share (32.98%) of publications produced through international co-authorship, suggesting the global nature of the issues addressed. Author collaboration is further confirmed by the average number of 2.86 co-authors per article, highlighting the pronounced tendency of researchers in this field to work in interdisciplinary teams. The analysed documents include 69,866 bibliographic references, which underscores the solidity and robust documentary foundation of the research included in the final corpus. The large number of references suggests an extensive theoretical base and a deep integration within the existing literature.

On average, the analysed articles have accumulated 19.51 citations per document, indicating a considerable scientific impact and a strong level of interest from the academic community in the subject under investigation. The relatively low average age of the documents (3.21 years) confirms the topicality and thematic relevance of the field in recent literature.

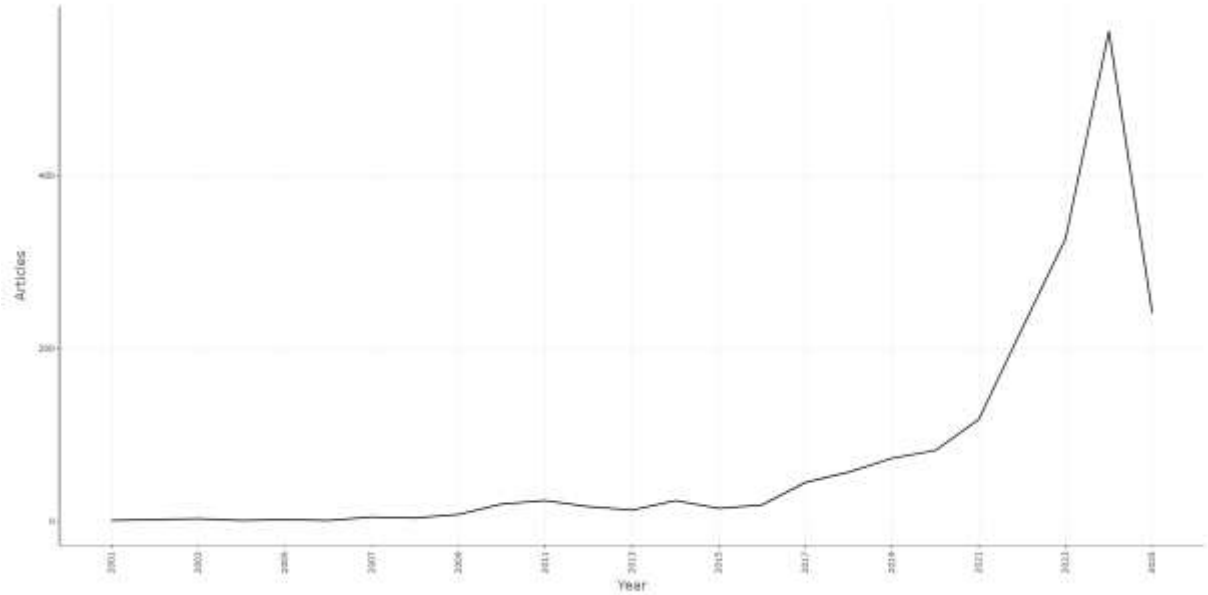

Figure 2. Dynamics of the evolution of the number of publications on green finance over the period 2001–2025

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The previous figure illustrates the evolution of the number of scientific publications related to green finance in the context of intensifying climate change over the period 2001–2025, revealing the dynamics of academic and scientific interest in this topic.

The analysis of publication trends indicates a slow and steady increase in the number of articles during the period 2001–2015, reflecting a relatively modest level of interest in the subject during this early stage. Thus, in the initial years (2001–2009), the literature is numerically limited, suggesting that research in the field of green finance was in its formative phase, without a clear consolidation of academic concerns.

Starting in 2016, a significant intensification of interest in green finance can be observed, reflected in a sharp increase in the number of published articles. This evolution may be correlated with major international events and policy initiatives, such as the adoption of the United Nations Sustainable Development Agenda in 2015 and the Paris Agreement in the same year, as well as with the increasing pressure on the financial sector to assume an active role in the transition towards a green economy.

A pronounced peak in publications is observed in the recent period 2022–2024, reaching its maximum in 2024, with 567 articles published. This remarkable increase reflects both the intensification of academic research and the growing practical and economic relevance of green finance, supported by public policies and corporate strategies oriented towards sustainability.

The apparent decline observed for the year 2025 is due to the fact that the bibliometric analysis was conducted before the complete conclusion of that year and that not all articles scheduled for publication have yet been indexed. Therefore, the number of publications for 2025 should be interpreted with caution.

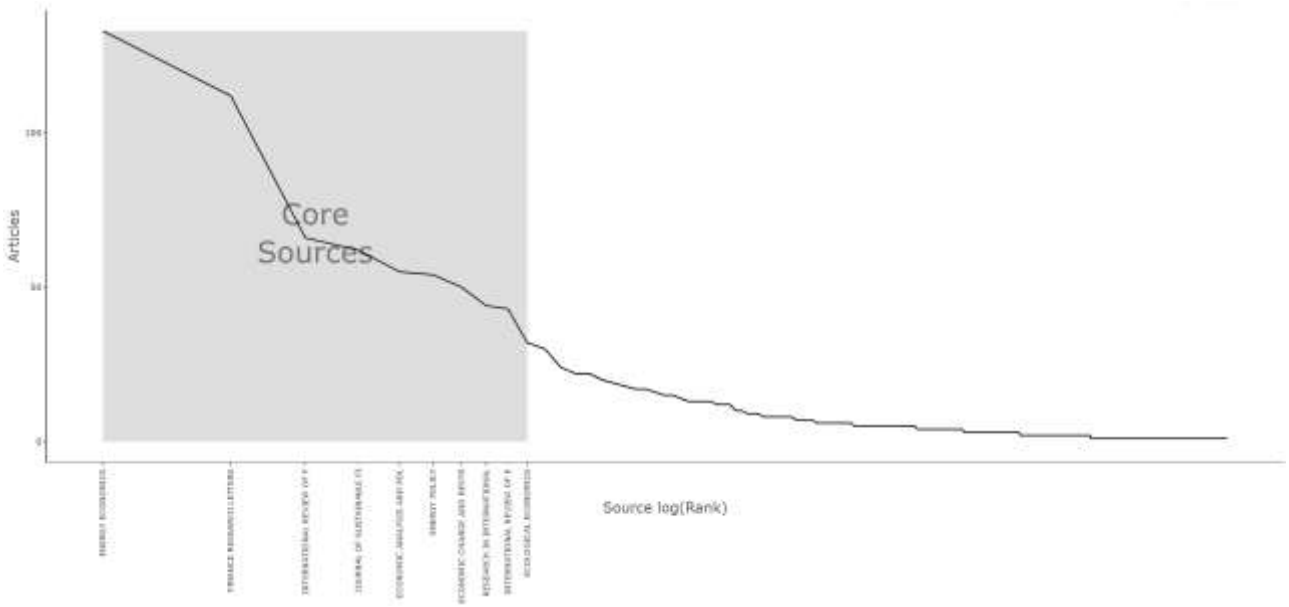

Figure 3. Distribution of publications by journal source according to Bradford's Law (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The core scientific journals that predominantly publish research on green finance in the context of climate change, corresponding to Zone 1 of the Bradford distribution, are presented in the previous figure. According to Bradford's Law, the majority of relevant contributions within a field are concentrated in a relatively small number of journals, which consequently become key sources for understanding the evolution of the studied domain.

The analysis reveals that the top ten scientific journals in the financial–economic field contribute significantly to the analysed literature corpus. *Energy Economics* ranks first, with the highest number of published articles (133 articles), underscoring the major relevance of this journal in interdisciplinary research linking financial, energy, and climate-related issues. The second position is occupied by *Finance Research Letters*, with 112 articles, indicating a strong orientation of the specialised literature towards rapid, empirical, and innovative approaches to issues related to financial sustainability and climate risks.

The subsequent positions within the core nucleus include journals such as *International Review of Financial Analysis* (66 articles), *Journal of Sustainable Finance & Investment* (62 articles), and *Economic Analysis and Policy* (55 articles), reflecting a strong concentration of research on analytical aspects and sustainable economic policy issues. These sources confirm the interest and relevance of the topic for both the academic community and practitioners and decision-makers. Continuing the list of core journals, *Energy Policy* (54 articles), *Economic Change and Restructuring* (50 articles), *Research in International Business and Finance* (44 articles), *International Review of Economics & Finance* (43 articles), and *Ecological Economics* (32 articles) complete the nucleus of the most influential sources. The diversity of these publications reflects the interdisciplinary nature and complexity of the topic addressed in the literature, integrating economic, financial, ecological, and policy-related elements.

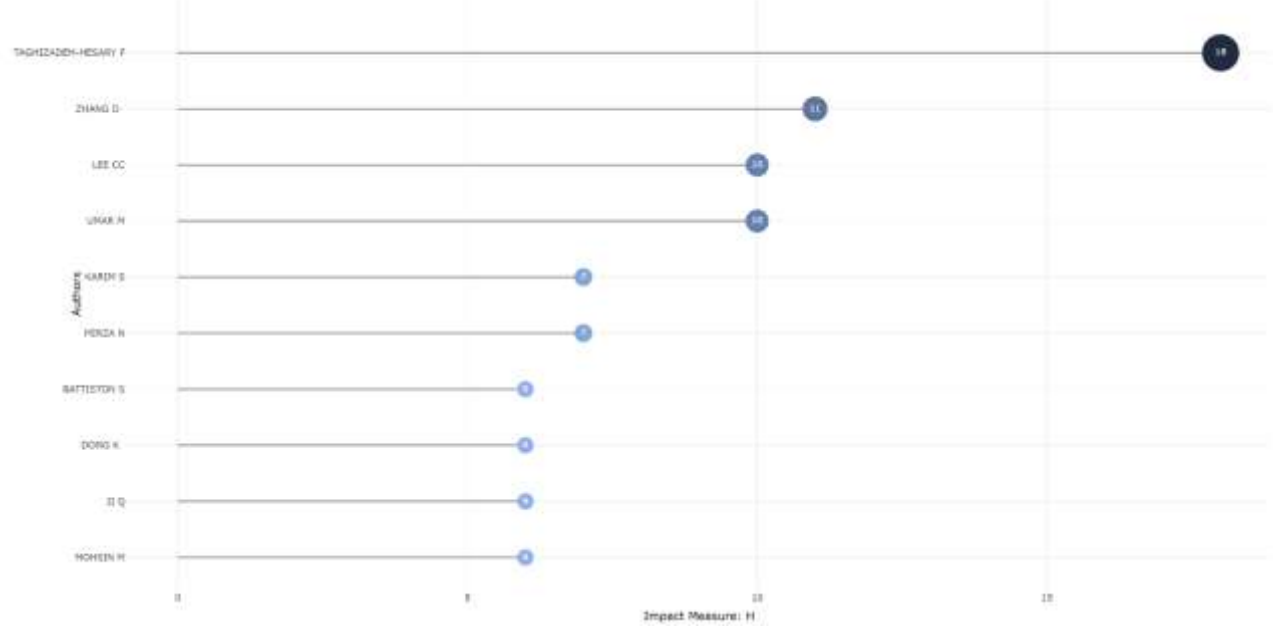

Figure 4. Authors with the highest scientific impact in the field of green finance, according to the Hirsch index (H-index), for the period 2001–2025

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

Figures 4 and 5 present a detailed analysis of the most influential authors in the academic literature on green finance in the context of climate change over the analysed period (2001–2025). Author influence was assessed both in terms of scientific output (number of published articles) and research impact, as measured by the Hirsch index (H-index). From the perspective of scientific impact measured by the H-index, the following authors stand out: Taghizadeh-Hesary F., who holds the highest H-index (18), reflecting a significant influence on academic research in the field of green finance, being the most cited and recognised author within the analysed literature; Zhang D. (H-index = 11), as well as Lee C.C. and Umar M. (H-index = 10), are also authors who make substantial contributions to the specialised literature, with high-impact publications in the analysed field.

When analysing academic output in terms of the total number of published documents, the central position of Taghizadeh-Hesary F. is reconfirmed, with 24 published articles. Other prolific authors include Lee C.C. with 20 publications, followed by Dong K. (13 articles), and Li Y. and Umar M., with 12 publications each. These authors are therefore the most active and contribute significantly to the development and deepening of research on green finance.

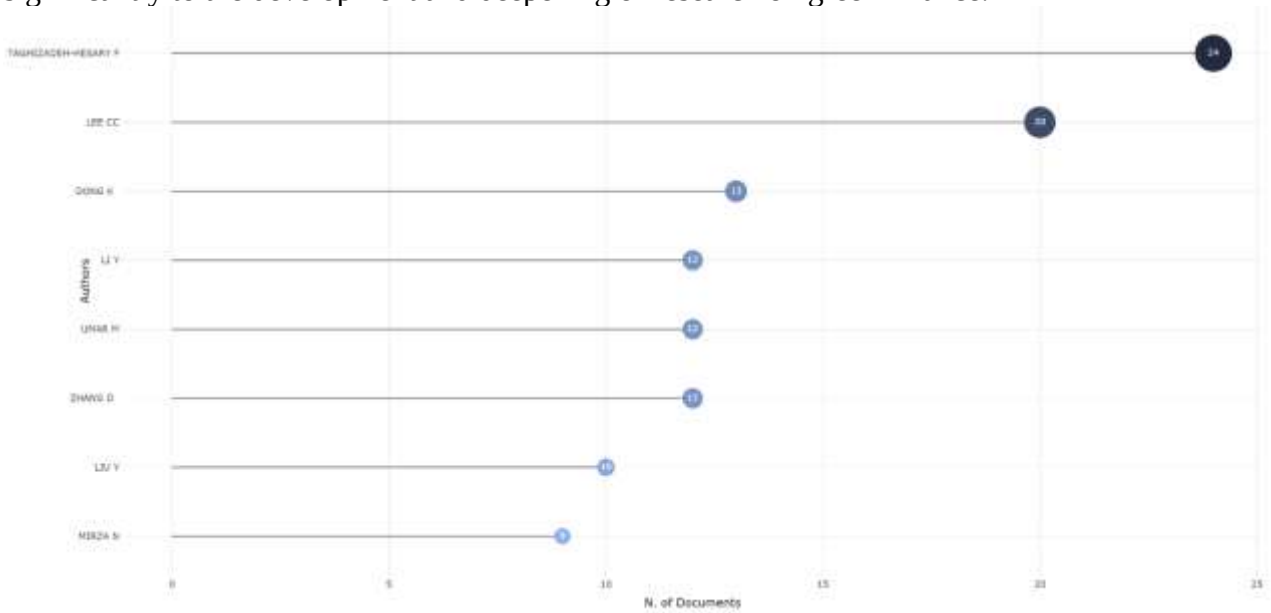

Figure 5. Authors with the highest number of publications on green finance over the period 2001–2025

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The presented results highlight a significant correlation between the number of published articles and the Hirsch index, suggesting that prolific authors also tend to exert a substantial impact on the academic literature. These findings reflect the growing interest of authors in the field of green finance, as well as the relevance and quality of their research in the context of current climatic and economic challenges.

The following figure highlights the most active academic institutions in green finance research, based on the total number of articles published over the period 2001–2025. This analysis allows for the identification of centres of scientific excellence and the dominant academic geography shaping the development of the specialised literature. Southwestern University of Finance and Economics (China) leads the ranking, with 49 publications, confirming China's consolidated position as an emerging and strategic actor in research on the transition towards a green economy. The position of the University of London (45 articles) is also noteworthy, reflecting the strong interest in this topic within well-established Western European academic environments.

The Chinese Academy of Sciences (36 articles) and Zhongnan University of Economics and Law (32 articles) complete the group of the most influential Chinese institutions in the field, further consolidating China's significant contribution to research at the intersection of finance and sustainability. Universities from other geographical areas also stand out, such as Qingdao University and Wuhan University (with 31 and 30 articles, respectively), as well as institutions outside the Euro–Asian axis, including Lebanese American University, Tokai University, and Xiamen University, each with 28 publications.

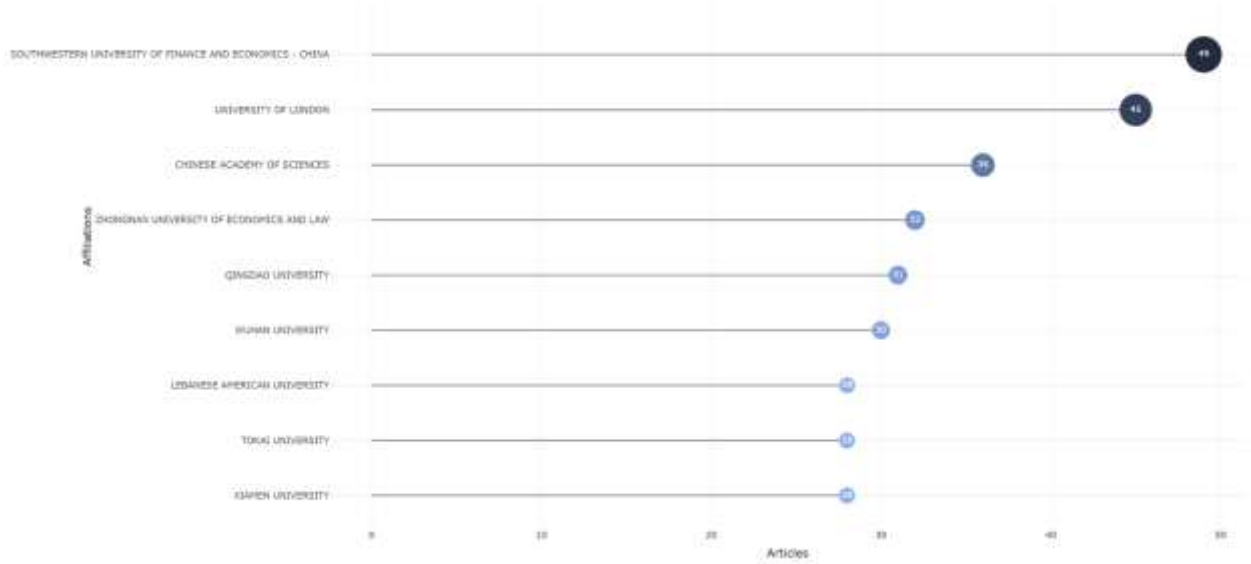

Figure 6. Academic institutions with the highest number of publications in the field of green finance (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

This concentration of scientific output around key academic institutions signals the existence of active research ecosystems, along with a potential polarisation of knowledge depending on the availability of research infrastructure and national public policy priorities. At the same time, these institutions may represent relevant partners for future international collaborations, given their established track record of publications in the analysed field.

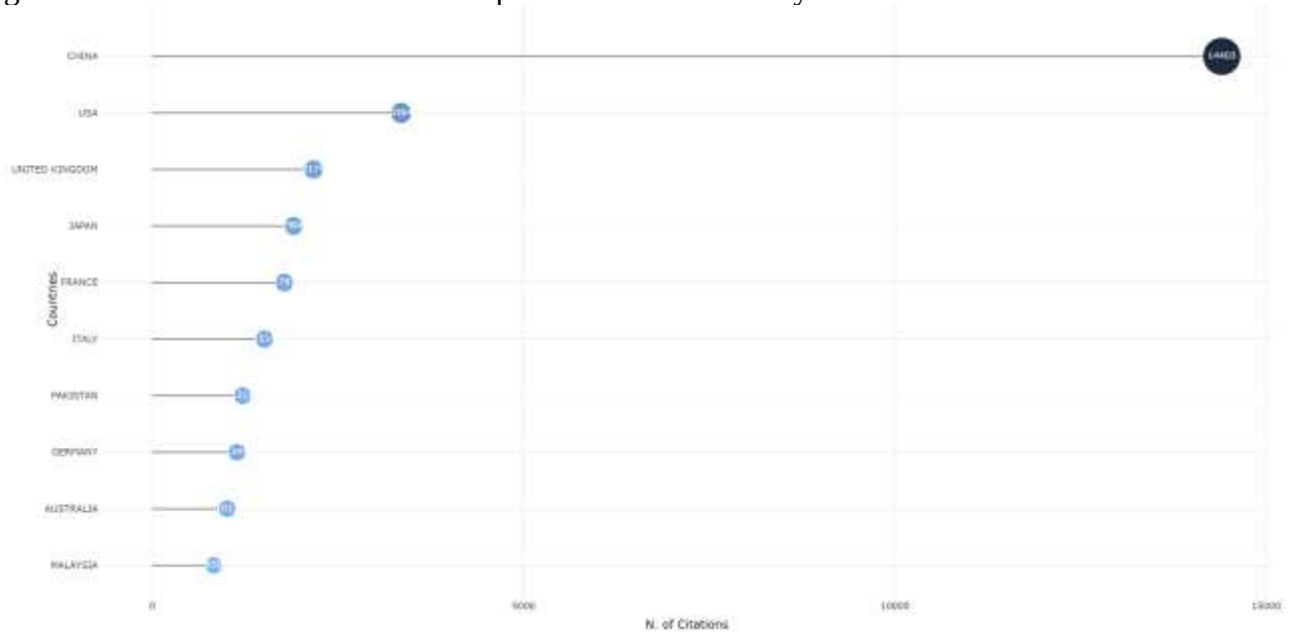

Figure 7. Countries with the highest impact in green finance research, based on the total number of citations (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The previous figure synthesises the global distribution of scientific impact in the field of green finance by analysing the total number of citations recorded by publications associated with the most active countries over the period 2001–2025. The number of citations represents a relevant quantitative indicator of the academic influence exerted by scientific contributions originating from

each country. Notably, China dominates the ranking with a total of 14,403 citations, which confirms not only the high volume of academic output but also its capacity to influence the conceptual and empirical development of the field. This leading position reflects China's strategic policy orientation towards promoting sustainable finance and green investments, as well as the mobilisation of a robust academic ecosystem around these themes.

The United States of America (USA) ranks second with 3,354 citations, followed by the United Kingdom, which accumulates 2,174 citations. These results reveal the sustained involvement of Western academic environments in the analysis of climate policies, green transition strategies, and financial instruments associated with sustainability.

Subsequent positions are occupied by Japan (906 citations), France (782), Italy (512), and Pakistan (219), indicating an active but comparatively less influential presence in terms of citation impact. The presence of Germany (144 citations) and Australia (101), alongside Malaysia (830)—an emerging country in Southeast Asia establishing itself as a regional actor in green finance studies—is also noteworthy.

The significant disparities between China and other countries can be interpreted as the result of a combination of volume (a high number of publications), thematic relevance, and international integration. On the other hand, the presence of countries from Asia, Europe, and North America highlights the transnational nature of research in this field and suggests the existence of global academic networks interested in the transition towards sustainable economic models.

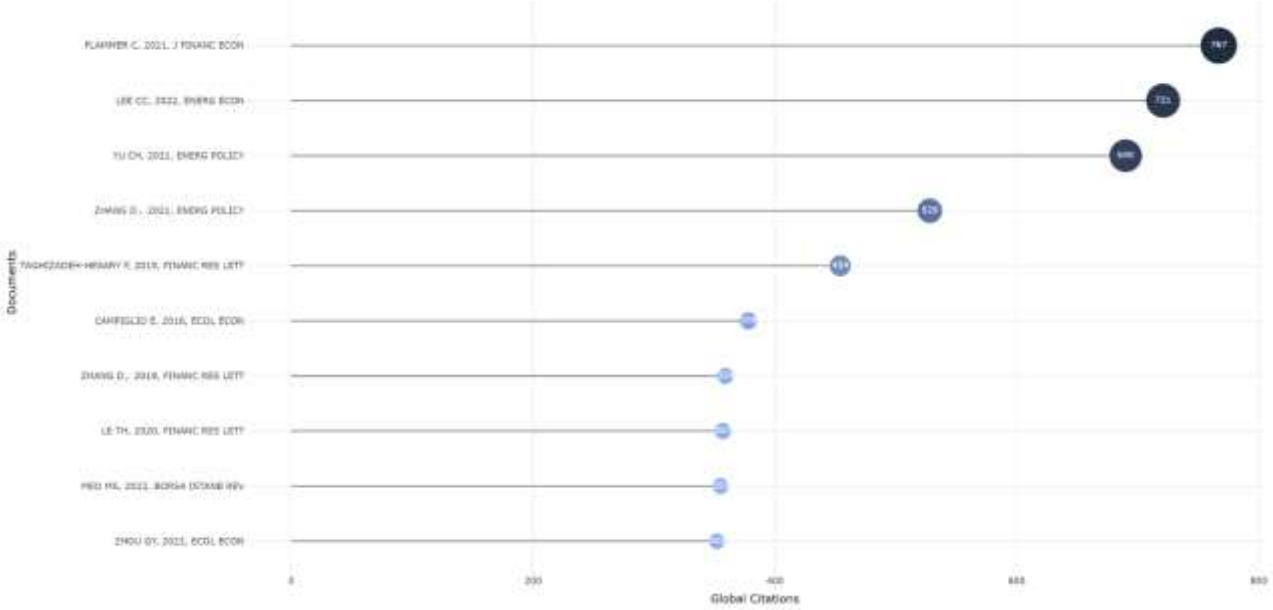

Figure 8. Most cited publications in the field of green finance (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

According to the previous figure, the most cited publication is Flammer C. (2021), published in the *Journal of Financial Economics*, with an impressive total of 767 citations. This study addresses the connection between financial performance and sustainable investments, becoming a reference point in the literature analysing the integration of ESG criteria into corporate strategies.

The next two publications with remarkable impact are published in leading energy journals: Lee C.C. (2022) in *Energy Economics* with 721 citations, and Yu C.H. (2021) in *Energy Policy* with 690 citations. These studies examine the relationships between energy transition, green finance, and economic growth, emphasising the importance of integrating sustainability into energy and financial policies. In addition, Zhang D. (2021), also published in *Energy Policy*, is highly influential, with 528 citations, highlighting the convergence between climate policies and financing mechanisms.

Taghizadeh-Hesary F. (2019), published in *Finance Research Letters*, with 454 citations, represents another essential contribution, addressing the role of financial markets in financing green technologies and sustainable infrastructure. Campiglio E. (2016), published in *Ecological Economics*, with 378 citations, is among the earliest works to argue for the integration of climate risks into macroeconomic modelling, exerting a pioneering impact on climate–finance research. The remaining publications ranked in the top 10, all exceeding 350 citations, cover a variety of topics, including financial market volatility during the green transition, the relationship between climate risk and economic stability, and the effectiveness of green financial instruments.

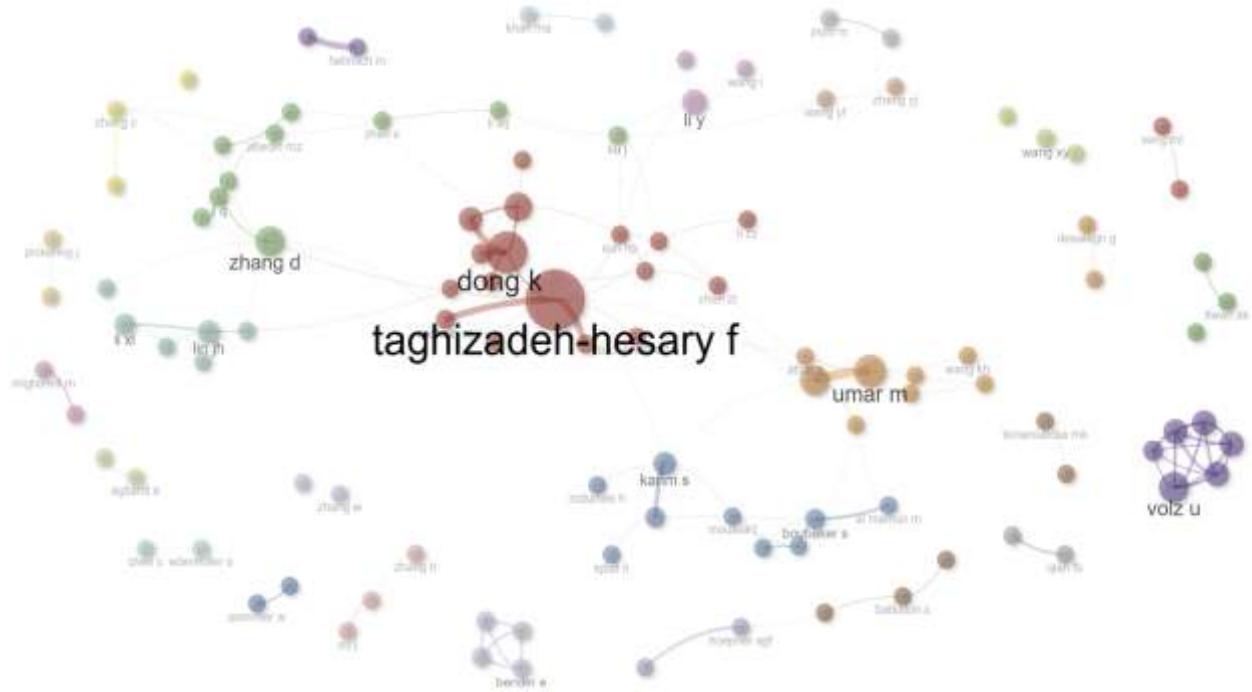

Figure 9. Author collaboration network in the field of green finance

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The co-authorship network highlights a polycentric structure, organised around several clearly delineated collaboration cores. The dominant core is formed around Taghizadeh-Hesary F., an author who by far records the highest values of betweenness centrality and PageRank; his position indicates both high productivity and the role of an intellectual intermediary between different research schools within the network. This primary conglomerate brings together strongly connected collaborators, among whom Dong K., Sun H.P., Liu Y., and Tang Y. stand out, suggesting a stable community with an intensive and diversified output of research on green finance.

A second, visually distinct pole of influence is led by Karim S., bringing together authors such as Naeem M.A., Moussa F., and Boubaker S. The internal density of ties within this cluster indicates close cooperation, yet with fewer external links to other clusters, pointing to thematic specialisation and a possible shared geographical orientation. In close proximity to this group, a cluster articulated around Umar M. and Mirza N. can be identified. These two authors act as linking nodes between research on the interaction of financial markets and climate policies, a role confirmed by their high PageRank scores and multiple connections both to the Taghizadeh-Hesary core and to the Karim group.

On the opposite side of the network graph, a block centred on Zhang D. and his close collaborators Ji Q., Liu J., and Zhao X. emerges. This cluster connects to the central group through a limited number of bridging ties, indicating that these authors operate at the intersection between

empirical research on energy markets and investigations into green financial instruments. At the same time, numerous peripheral micro-communities appear, such as those led by Volz U., Battiston S., or Hellmich M., whose low betweenness values place them at the margins of the main flow of ideas, indicating either thematic niches or locally consolidated collaborations that remain weakly integrated at the international level.

Overall, the network depicts a field in a phase of maturation, in which a robust intellectual centre—the Taghizadeh-Hesary group—ensures the rapid diffusion of knowledge, while other secondary poles reinforce thematic diversity. The high connectivity among the first three clusters suggests the existence of a shared corpus of research issues—namely the assessment of green finance impacts and the integration of climate risks into financial decision-making—while peripheral subgroups point to emerging research directions whose full integration depends on the intensification of cooperation with already established cores.

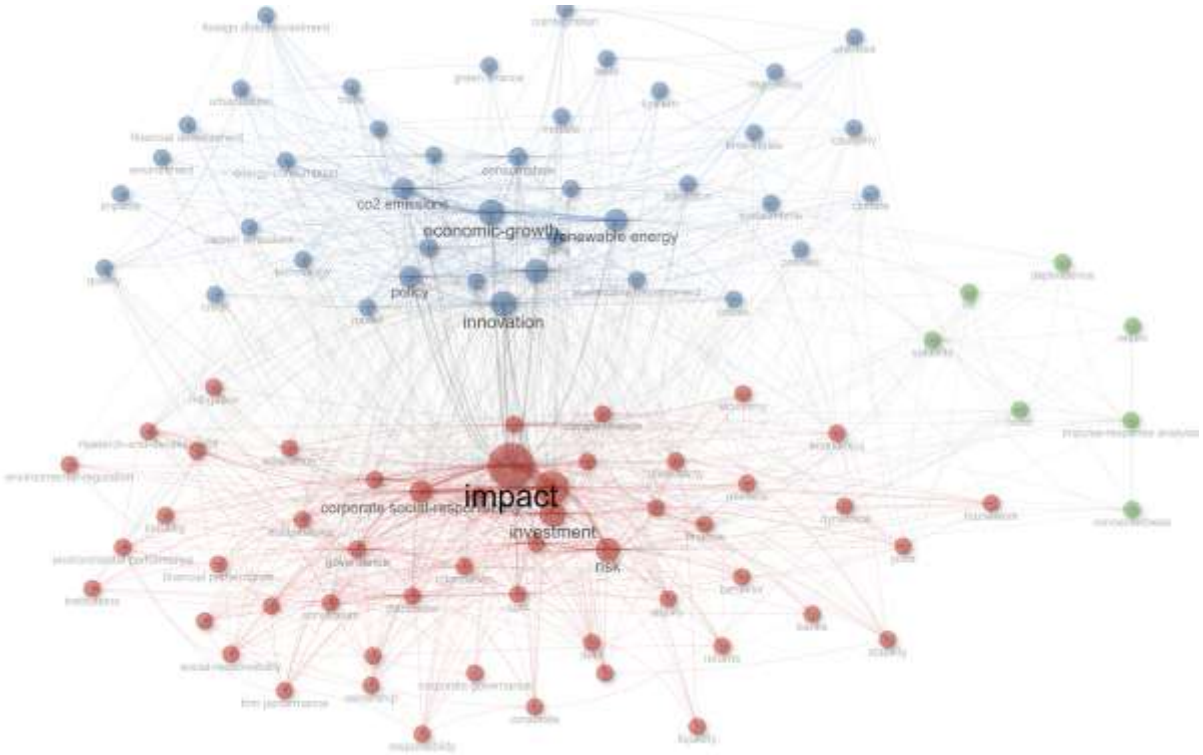

Figure 10. Keyword co-occurrence network in the scientific literature on green finance

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The term *"impact"* occupies a pivotal position within the network, as it records the highest values of betweenness centrality, closeness, and PageRank, indicating its role as an umbrella concept mediating the interaction among the other sub-themes. In its immediate vicinity, concepts such as *"performance"*, *"investment"*, and *"risk"* are clustered, forming a core focused on measuring the financial and non-financial effects of green investments and on analysing the risk–return profile.

Community detection reveals the existence of three major semantic ecosystems. The first, and most densely connected, consists of terms related to corporate performance and social responsibility, ranging from *corporate social responsibility* and *financial performance* to *disclosure* and *governance*, suggesting that the literature places strong emphasis on how green finance is reflected in firm-level outcomes and reporting transparency.

The second ecosystem, located predominantly in the upper area of the graph, concentrates terms such as *innovation*, *economic growth*, *renewable energy*, *policy*, and *CO_2 emissions*. It reflects the research stream dedicated to energy transition, climate policies, and the relationship

between innovation and decarbonisation across different economies, with a particular focus on econometric studies based on time series and panel data.

The third, more compact ecosystem revolves around the terms *volatility*, *oil*, *connectedness*, and *impulse response analysis*, expressing the orientation of part of the literature towards financial market dynamics and the interdependencies between green assets and energy shocks.

The network also highlights the emergence of new research directions, visible through the presence of concepts such as *fintech*, *digital finance*, *artificial intelligence*, and *cryptocurrency*, as well as contextualised terms such as *COVID-19*, *greenwashing*, and *climate policy uncertainty*. Although peripheral within the current structure, these concepts indicate an opening of the scientific discourse towards convergences with digital transformation, policy uncertainty, and reputational risks.

Overall, the analysis demonstrates that the field of green finance is in a phase of maturation, characterised by a stable conceptual core centred on *impact*, *performance*, and *investment*, complemented by rapidly expanding interdisciplinary extensions related to energy transition, market volatility, and new financial technologies. This mapping confirms the need for integrated approaches capable of linking perspectives from corporate finance, ecological economics, data science, and public policy in order to explain how green finance can accelerate decarbonisation without compromising global financial stability.

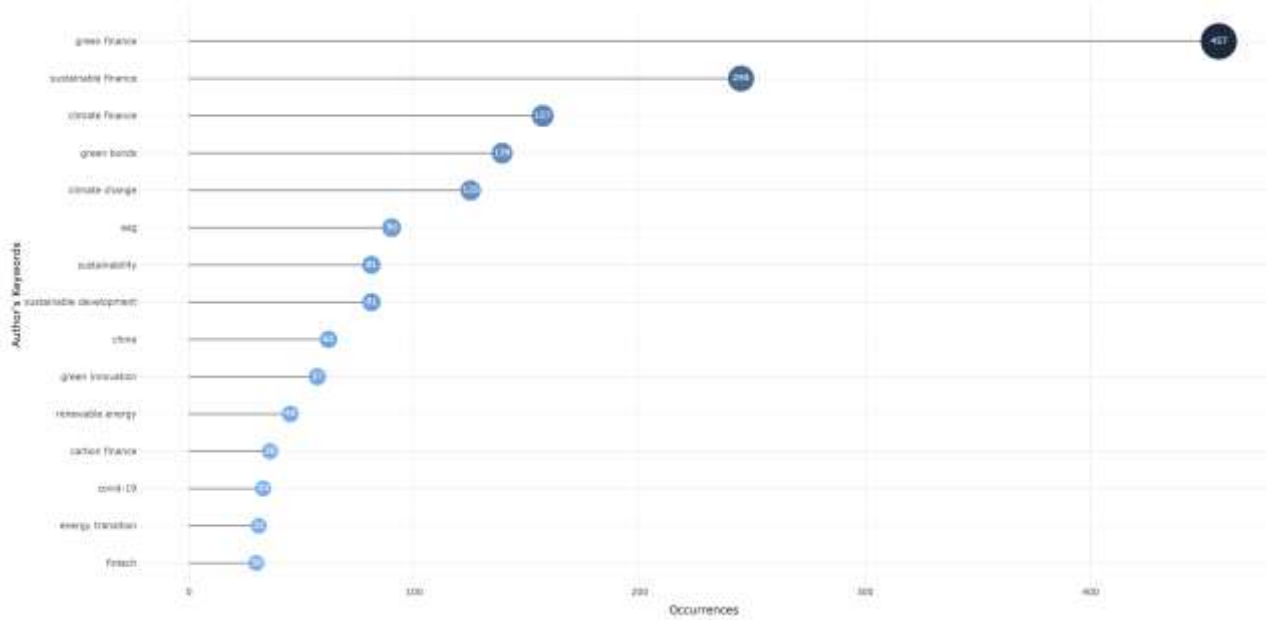

Figure 11. Distribution of the most frequently used keywords in the literature on green finance (2001–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The list of the top fifteen keywords highlights the dominant vocabulary of the field and the thematic axiology of the research. The highest frequency is recorded by the term *green finance* (457 occurrences), confirming its position as an umbrella concept under which studies addressing capital allocation for climate-related purposes are subsumed. It is followed by *sustainable finance* (245) and *climate finance* (157). Their comparable frequencies indicate both partial overlap and semantic differentiation between finance oriented towards broader sustainability objectives and finance explicitly directed towards climate transition.

The strong presence of the term *green bonds* (139) highlights the fact that the green bond market represents the most intensively investigated sub-domain, while *climate change* (125) marks the direct connection between financial topics and the climate literature. The term *ESG* (90) confirms the integration of environmental, social, and governance criteria into financial performance assessment, while the pair *sustainability* / *sustainable development* (81 occurrences

each) indicates that the discourse remains anchored in the sustainable development paradigm established by the 2030 Agenda.

The frequency of the keyword *China* (62) is noteworthy, indicating the contextual dominance of studies applied to the Chinese market, which is responsible for approximately one third of global green bond issuances. The appearance of the terms *green innovation* (57) and *renewable energy* (45) signals the convergence of financial and technological literature, reflecting the role of innovation and renewable energy in attracting green capital. At the same time, *carbon finance* (36) and *energy transition* (31) suggest growing interest in carbon pricing mechanisms and sectoral decarbonisation strategies.

The presence of the keyword *COVID-19* (33) shows that the pandemic acted as a catalyst for debates on the resilience and sustainability of the financial system, while the relatively recent emergence of the term *fintech* (30) indicates the rise of research dedicated to the digitalisation of green capital mobilisation processes.

Overall, the frequency distribution confirms the field's triple focus: (i) defining and refining green finance concepts, (ii) exploring specific instruments—particularly green bonds—and (iii) analysing the linkages between green finance, technological innovation, and climate transition policies, with particular attention to the Chinese context and post-pandemic implications.

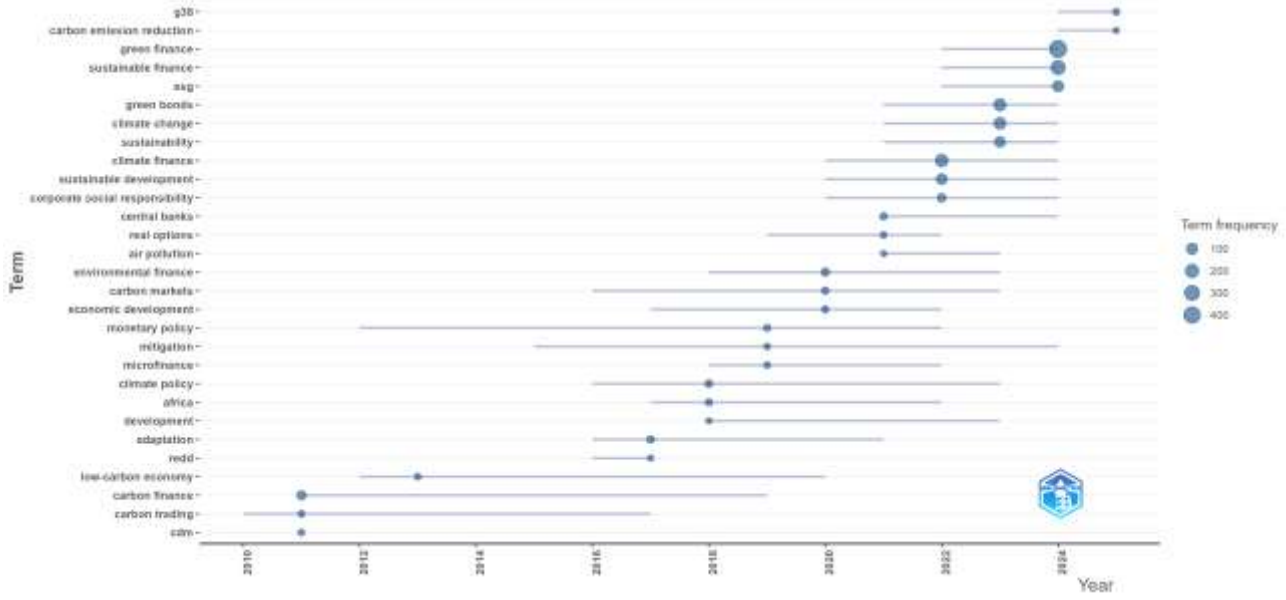

Figure 12. Temporal evolution of key themes in the green finance literature (Trend Topics, 2010–2025)

Source: authors' own elaboration based on data extracted from Web of Science, processed using the Bibliometrix package (R) and the Biblioshiny application.

The chronology of terms highlights three distinct waves of scientific concern. The first, spanning the period 2010–2013, is dominated by expressions such as *carbon finance*, *carbon trading*, *CDM – Clean Development Mechanism*, and *low-carbon economy*, indicating that the early consolidation phase of the field was anchored in the policy framework of the Kyoto Protocol and in market-based mechanisms aimed at limiting carbon emissions. The relatively low frequencies and the short duration of the temporal span indicate a targeted interest, specific to the initial development of carbon markets.

The second wave, active from 2016 until the onset of the pandemic crisis, marks an expansion of the research agenda towards macroeconomic and development dimensions. Terms such as *adaptation, REDD* (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), *climate policy*, and *economic development* emerge, alongside references to

the role of monetary institutions (*monetary policy*, *central banks*). This stage suggests a shift in focus from isolated market-based solutions towards integrated policy frameworks, reflecting both the implementation of the Paris Agreement and the early initiatives related to climate stress testing in the financial sector.

After 2020, the thematic spectrum broadens substantially: *climate finance*, *sustainable development*, and *corporate social responsibility* become central themes, while frequencies increase exponentially for *green bonds*, *climate change*, *sustainability*, and the umbrella concepts *green finance* and *sustainable finance*. The rapid amplification of these terms, visible through the considerable size of the bubbles and the concentration of the timeline around 2023–2024, highlights the maturation of the field and its integration into mainstream financial discourse. During the same period, the acronym *ESG* also consolidates, signalling the convergence between green finance and corporate governance criteria.

The emergence of the terms *G38* and *carbon emission reduction* in 2024–2025 suggests the opening of new research frontiers related to financial regulation (JEL code G38 – Government Policy and Regulation) and strict decarbonisation targets, indicating that the literature is responding to new reporting standards and the intensification of net-zero policies. Overall, the previous figure confirms the gradual transition of research from a core focused on primary carbon markets towards a broad discourse encompassing sustainable development, ESG integration, and the central role of financial institutions in global climate governance.

4. Conclusions

The bibliometric analysis conducted on the literature dedicated to green finance highlights a field undergoing a phase of accelerated expansion and intellectual consolidation. The temporal dynamics confirm a quasi-exponential growth curve starting in 2016, marked by a pronounced peak in scientific output during the period 2022–2024. This evolution coincides with the intensification of the international regulatory framework, from the Paris Agreement to the recent wave of European regulations on green taxonomy, and demonstrates how climate pressure has rapidly translated into academic interest. At the same time, the average citation rate per article and the relatively low age of the documents attest both to the contemporary relevance of the topic and to the literature's capacity to generate knowledge with prompt impact.

In this context, the present study contributes to the literature by combining relational network analysis with the temporal evolution of research themes in order to provide a comprehensive overview of green finance research in the context of climate change.

The distribution by sources underscores the existence of a narrow core of dominant journals—such as *Energy Economics*, *Finance Research Letters*, *International Review of Financial Analysis*, and *Journal of Sustainable Finance & Investment*—which concentrate the majority of highly visible scientific output. In parallel, a second diffusion zone emerges, composed of interdisciplinary journals in ecological economics, energy policy, and financial management, indicating the integration of the topic across multiple disciplinary areas.

The analysis of the co-authorship network reveals a polycentric structure, articulated around a central hub led by Taghizadeh-Hesary F., in correlation with secondary poles clustered around the authors Karim S. and Zhang D.–Ji Q. These nuclei facilitate the diffusion of ideas and the connection of sub-domains, ensuring the permeability of empirical and theoretical results. The relatively high degree of international co-authorship, coupled with an average of nearly three authors per article, confirms the collaborative and inter-institutional nature of research in this field, as well as the fact that scientific geography is predominantly concentrated in East Asia and the European space.

Conceptual mapping through keyword co-occurrence networks reveals the formation of three well-defined semantic ecosystems. The first, of a corporate–financial nature, revolves around the terms *impact*, *performance*, and *investment*, indicating the dominant interest in measuring the

financial implications of green strategies and in integrating ESG factors into capital allocation decisions.

The second ecosystem, oriented towards energy transition and sustainable economic growth, connects concepts such as *innovation*, *renewable energy*, and *economic growth*, reflecting the macroeconomic dimension of the debate. The third ecosystem, centred on volatility, interdependencies, and energy shocks, reveals the growing concern for market stability and the management of systemic risks in a carbon-constrained economy. The inclusion of emerging terms such as *fintech*, *digital finance*, and *artificial intelligence* highlights the penetration of digital technologies into green finance and points to future research directions.

Overall, the results demonstrate that green finance has evolved into a mature research field, characterised by an established editorial infrastructure, dense co-authorship networks, and a multidimensional theoretical corpus. Nevertheless, the geographical distribution of publications and the concentration of journals suggest a potential regional clustering of the scientific agenda, while the predominance of quantitative empirical approaches points to the need for comparative qualitative studies capable of capturing the institutional and cultural nuances of green finance implementation. Complementarily, the increasingly visible integration of digital technologies and alternative data opens a new research frontier regarding the potential of artificial intelligence and distributed ledger technologies in mobilising capital for the net-zero transition.

The analysis of the most frequently used keywords enabled the identification of the dominant themes structuring the research field, while the visualisation of term evolution over time through trend topic analysis highlighted how scientific interest has shifted from early emergent concepts (such as *carbon trading* or *CDM*) towards highly relevant contemporary themes, including *green finance*, *ESG*, and *climate finance*. Moreover, the application of the Kleinberg algorithm detected semantic bursts signalling episodes of sudden intensification of research around specific keywords, suggesting not only the maturation of certain subdomains but also the emergence of new directions of study.

Therefore, the main contribution of this analysis lies in providing a detailed map of scientific production, influential actors, and thematic clusters—elements that are essential for guiding future research. The results indicate that further epistemic progress depends on the consolidation of South–North collaborations, the expansion of interdisciplinary methodologies, and the testing of green finance models across diverse institutional contexts in order to ensure the scalability and equity of the transition towards a decarbonised economy.

As a final conclusion, the bibliometric analysis of the literature on green finance in the context of climate change reveals a significant expansion of academic interest, reflected in the steady growth of scientific output, increasing thematic diversification, and the pronounced internationalisation of research collaborations. The specialised literature has matured around well-defined conceptual cores centred on the impact of sustainable investments, financial performance, the integration of climate risks, and market-based instruments such as green bonds. At the same time, the mapping of co-authorship and semantic co-occurrence networks reveals the existence of poles of intellectual influence and a high degree of connectivity across subdomains, alongside the persistence of weakly integrated peripheral clusters that signal both research niches and potential epistemic gaps. Furthermore, the emergence of new terms and directions—such as financial digitalisation, artificial intelligence, climate policy uncertainty, and greenwashing risks—indicates a rapid adaptation of research to contemporary technological and institutional transformations.

Based on these findings, several relevant directions for future research can be identified. First, further in-depth studies on the integration of digital technologies into green finance processes are needed, particularly through the analysis of the role played by fintech platforms, blockchain technologies, and artificial intelligence in mobilising sustainable capital. Second, the development of more robust methodologies for assessing the actual financial, social, and ecological impact of green investments, as well as the effectiveness of the instruments employed, would represent a

valuable contribution to the literature. Third, there is a need to extend investigations towards emerging and transition economies in order to explore the structural barriers and contextual opportunities associated with the implementation of sustainable finance outside the global centres of economic power.

Last but not least, the analysis of the role of corporate governance and regulation in shaping responsible financial behaviour deserves further attention, particularly through the evaluation of the effects of new ESG standards and green taxonomies on market transparency and integrity. At the same time, a frontier research theme lies in investigating the relationship between climate risks and financial stability, including through the modelling of systemic risks generated by climate change on banking and investment portfolios.

5. References

[1] **Campiglio, E.** (2016). *Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy*. Ecological Economics. https://doi.org/10.1016/j.ecolecon.2015.03.020.

[2] **Dar, B., Badwan, N., Kumar, J.** (2024). *Investigating the role of Fintech innovations and green finance toward sustainable economic development: a bibliometric analysis*. International Journal of Islamic and [1] Middle Eastern Finance and Management. https://doi.org/10.1108/imefm-01-2024-0018.

[3] **Flammer C.** (2021). *Corporate green bonds*. Journal of Financial Economics. https://doi.org/10.1016/j.jfineco.2021.01.010.

[4] **Judijanto, L., Yoga, T., Wijayanti, I.** (2024). *Bibliometric Analysis of Green Finance and Sustainable Investment Strategies*. *West* Science Social and Humanities Studies. https://doi.org/10.58812/wsshs.v2i12.1487.

[5] **Lee, C.C., Lee, C.C. (2022).** *How does green finance affect green total factor productivity? Evidence from China*. Energy Economics. https://doi.org/10.1016/j.eneco.2022.105863.

[6] **Malhotra, G., Thakur, K.** (2020). Evolution of Green Finance: A Bibliometric Approach. *GEDRAG & ORGANISATIE REVIEW*. https://doi.org/10.37896/gor33.02/067 .

[7] **Nasim, I.** (2023). *Role of Green Finance for Sustainable Environment So Far: A Bibliometric Analysis and Policy Framework*. Pakistan Journal of Humanities and Social Sciences. https://doi.org/10.52131/pjhss.2023.1102.0400.

[8] **Spulbar, C., Cinciulescu, D.** (2025). *Advancing Knowledge In Financial Risk Management: A Bibliometric Approach*. Annals of the „Constantin Brâncuşi" University of Târgu Jiu, Economy Series, Issue 1/2025. https://efaidnbmnnnibpcajpcglclefindmkaj/https://www.utgjiu.ro/revista/ec/pdf/2025-01/03_Spulbar.pdf.

[9] **Taghizadeh-Hesary, F., Yoshino, N.** (2019). *The way to induce private participation in green finance and investment.* Finance Research Letters. https://doi.org/10.1016/j.frl.2019.04.016.

[10] **Yu, C.H., Xiuqin Wu, X., Zhang, D., Chen, S., Zhao, J.** (2021). *Demand for green finance: Resolving financing constraints on green innovation in China*. Energy Policy. https://doi.org/10.1016/j.enpol.2021.112255.

[11] **Zhang, D., Zhang, Z., Managi, S.** (2019). *A bibliometric analysis on green finance: Current status, development, and future directions*. Finance Research Letters. https://doi.org/10.1016/J.FRL.2019.02.003.

[12] **Zhang, D., Mohsin, M., Rasheed, A.K., Chang, Y., Taghizadeh-Hesary, F.** (2021). *Public spending and green economic growth in BRI region: Mediating role of green finance*. Energy Policy. https://doi.org/10.1016/j.enpol.2021.112256.