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RECEIVED 18 October 2024

ACCEPTED 10 December 2024

PUBLISHED 03 January 2025

## CITATION

Raman R, Ray S, Das D and Nedungadi P (2025)  
Innovations and barriers in sustainable and  
green finance for advancing sustainable  
development goals.  
*Front. Environ. Sci.* 12:1513204.  
doi: 10.3389/fenvs.2024.1513204

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# Innovations and barriers in sustainable and green finance for advancing sustainable development goals

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This study employs a mixed-methods approach to investigate the role of sustainable and green finance in advancing UN sustainable development goals (SDGs). We use quantitative bibliometric methods with machine learning-based BERTopic modeling and case study analysis to reveal trends. This study presents a cocitation analysis of the SDGs to visualize the interconnectedness between goals, highlighting the central role of SDG 13 (climate action) and key linkages with SDGs related to economic growth (SDG 8), industry and infrastructure (SDG 9), clean energy (SDG 7), and environmental sustainability (SDGs 6, 15). The findings indicate that innovations such as green fintech, social impact bonds, and risk models are crucial for facilitating renewable investment and mitigating environmental impacts. The identified barriers include high transaction costs and insufficient institutional frameworks in developing countries, hindering the broader adoption of green finance tools. Case studies from South Africa, Brazil, and other developing nations have examined the implementation of green bonds and loans. They highlight significant efforts by stakeholders to use these financial instruments to support SDGs, particularly SDG 7, SDG 13, and SDG 17 (partnerships). However, challenges such as nascent regulatory environments, market barriers, and capacity constraints persist, inhibiting mainstream integration. Key research avenues include quantifying investment needs, tailoring financial instruments, and developing derisking mechanisms to foster cross-sector coordination and international partnerships. The study underscores the necessity of innovative and inclusive financial mechanisms to mobilize capital flows aligned with the priorities of the Global South. Future research directions include the development of advanced data analytics, adaptation to local contexts, technological integration, and exploration of the social dimensions of sustainable finance. This study provides actionable insights for policymakers, financial institutions, and researchers, emphasizing the crucial role of sustainable finance in driving global sustainability.

## KEYWORDS

sustainable development goal, climate finance, renewable energy, green bonds, mixed methods, topic modeling, climate action, innovation

## 1 Introduction

Adverse climate change leading to extreme weather conditions, the prevalence of natural calamities, and biodiversity loss have had dire consequences on the global ecosystem, thus posing a threat to the extinction of life on earth (Ren et al., 2022). The worldwide statistics persistently showcase a steady degradation of the environment, underscoring the paucity of financial resources available to address these impending threats to the ecosphere, which traditional finance is inadequate to cater to (Dhutta et al., 2023). The report Raising Ambition and Accelerating Delivery of Climate Finance, published during COP29 negotiations on a new collective quantified goal (NCQG) for post-2025 financial support to developing countries, recommends focusing on mobilizing \$1 trillion per year for developing nations by 2030 from all available sources.

Sustainable and green finance integrates environmental, social, and governance (ESG) factors into financing and investment decisions, aligning with UN sustainable development goals (SDGs) and the Paris Climate Accord (Sharma and Kautish, 2023; Edmans and Kacperczyk, 2022). Green finance, as part of this broader category, encompasses a wide range of financial products and services, including green bonds, investment funds, and climate risk insurance, aimed at promoting environmentally friendly projects (Taneja, 2024). Similarly, climate finance focuses on the role of financial institutions in addressing climate change through investment transactions, identifying financial risks, and supporting clean and green energy development (Richardson, 2014). These interconnected forms of finance are crucial for achieving sustainable economic growth and addressing pressing environmental challenges (Mishra et al., 2023). Therefore, a fundamental question arises: What is the role of sustainable and green finance in combating these global environmental perils, and how can we relate it to UN SDGs?

The global commitment toward the attainment of UN SDGs, underlining ‘green growth’ by conserving and restoring natural resources and focusing on net-zero carbon emissions using renewable energy sources (Ostergaard et al., 2022; Zakari and Khan, 2022), has been lopsided (United Nations Interagency Task Force on Financing for Development, 2023). This is attributable primarily to capital constraints to finance this “green growth” (Sachs et al., 2022), predominantly for global southern nations (Emmanuel et al., 2024). The escalating gap between the financing needs of the SDGs and the quantum of funds deployed to meet these ambitious goals imperatively suggests the integration of finance with sustainability to foster ecological and human welfare (Yang et al., 2023). Thus, sustainable finance potentially facilitates the achievement of the SDGs by aligning financial investments with ESG standards (Ali et al., 2023). Green finance, encompassing sustainable finance, also advocates for the paradigm shift to a ‘low-carbon’ and green global economy, creating uncertainties and opportunities for its stakeholders, including governments and corporations (Haas et al., 2023). There is a strong synergy between green finance and economic inclusion, which can facilitate the necessary transition to a green, inclusive economy, thereby supporting SDG attainment (van Niekerk, 2024). Green finance also plays a crucial role in mitigating the adversities posed by climate change in emerging economies (Kumar et al., 2024).

Sustainable financing actively supports the UN SDGs by financing projects that contribute to environmental protection, social inclusion, and economic growth (Ali et al., 2023; Ziolo et al., 2021). It directs funds toward environmentally friendly endeavors, including renewable energy, energy efficiency, sustainable infrastructure, and climate change initiatives. For example, it also comprises impact finance instruments, such as social impact bonds (SIBs), which serve as effective mechanisms to support the financing of the SDGs. SIBs are aligned with SDG 17, which considers partnership priority instruments to achieve SDG targets (Rizzello and Kabli, 2020). The prevailing large financing gap poses a significant challenge to SDG financing, particularly in developing countries, where the current level of SDG-related funding and investment is limited (Barua, 2020).

The last 2 decades have witnessed growing research in many variants of sustainable finance addressing directly or indirectly the fragmented risks, funding uncertainties that impede the 2030 SDG target, and the appropriate financial instruments to fund one or more of the SDGs. For example, studies on green finance (Zhang et al., 2019; Ren, Shao & Zhong, 2020; Tang and Zhang, 2020) have explored how innovative green financial instruments (e.g., green or climate bonds) may be used to alleviate environmental pollution. Studies on climate finance have investigated how climate-related risks may interact to amplify uncertainties in global economic activities at both the micro and macro levels (Liu H. et al., 2023). Furthermore, studies on carbon finance (Mohsin et al., 2021; Lian et al., 2021) have focused on achieving a carbon-neutral environment via ‘carbon’ or ‘green’ bonds or carbon-linked innovative instruments. From these studies, we observe that SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry Innovation and Infrastructure), and SDG 13 (Climate Action) have been the most frequently addressed with sustainable financial instruments, such as ‘green’ bonds, ‘climate’ bonds, and ‘carbon’ bonds. For example, some studies (Xu et al., 2022) have investigated the extent of the implementation of SDGs 7 and 13 using ‘green’ finance instruments. Green finance also contributes to SDG 3 (good health and wellbeing) and SDG 12 (responsible consumption and production), funding sustainable infrastructure and promoting sustainable business practices (Liu et al., 2024).

Furthermore, for global southern nations, e.g., South Africa, Brazil, India, etc., green finance (also categorized as “sustainable private finance”) is advocated to promote a “green economy” through the alleviation of environmental risk and facilitating social equity, which is administered by “green deals”, i.e., policy initiatives of governments (Kumar et al., 2024). These countries also show a propensity toward adoption of the “circular economy” whereby multifaceted targets of conservation of natural resources, reduction of environmental pollution, and sustainable job creation, among other things, can be achieved, contributing directly to the 2030 SDGs (Kumar et al., 2022; 2024).

However, none of these reviewed sustainable finance studies explicitly map the specific SDGs they cater to, creating knowledge gaps. Rather, extant research has focused primarily on reducing the global funding gap to attain SDGs in fragments, employing various sustainable finance instruments, with China emerging as the leader in green finance initiatives and research (Feng et al., 2023). Other global southern countries still face various obstacles in the successful

implementation of 'green' and/or sustainable finance instruments due to funding constraints in pursuit of their sustainable goals (e.g., Ngwenya and Simatele, 2020, Che et al., 2021, etc.), as mentioned above. Moreover, although sustainable finance and green finance are acknowledged as catalysts for sustainable development and environmental preservation, exclusive monitoring of their long-term ethical and tangible impacts in terms of the 2030 SDGs is scarce (Ziolo et al., 2021; Madaleno et al., 2022).

Therefore, in this study, we perform stocktaking of prior literature, assess the contributions of various sustainable and green financial instruments, and map them to their specific SDG focus. We employ a two-pronged approach of complementing bibliometrics with case studies of the global southern economies for deeper insights (Filho et al., 2024). These economies appear to face challenges in effectively scaling green finance to meet their investment requirements, which impact the SDGs. Hence, our study focuses on the following research questions:

- RQ1: How well do sustainable and green finance contribute to the interconnected achievement of climate action (SDG 13) and other related SDGs?
- RQ2: How do green finance instruments, such as green bonds and climate finance, contribute to economic development, environmental sustainability, renewable energy promotion, and risk management in financial markets, with a focus on China's role in leveraging these tools for sustainable development?
- RQ3: How do case studies of sustainable finance, green bonds, and investment policies in global-southern countries highlight research gaps in scaling green finance for substantial climate investment needs?

This study offers several key contributions to the field of sustainable and green finance as it relates to advancing sustainable development. First, by utilizing a mixed methods research design that integrates quantitative scientometric analysis with qualitative case studies, we explore the role of sustainable and green finance in supporting the SDGs. These case studies from developed and developing nations highlight the presence and impact of green finance and sustainable finance, evidencing their significant contribution to the literature on global and regional sustainable finance. We study China (Zhou et al., 2020) as one of the prominent global leaders in the green finance space while being the world's second-largest economy and at the forefront of implementing ambitious sustainable finance initiatives, such as green bond issuances, green credit guidelines, and establishment of green finance pilot zones. Understanding China's experiences, challenges, and successes in leveraging green finance to drive sustainable development, its actions and policies have far-reaching implications for the global sustainability agenda. Our other case studies on the Global South economies underscore how these countries are innovating with sustainable finance instruments, such as green bonds, green fintech, and climate finance mechanisms, providing insights into the strategies and barriers encountered in aligning financial flows with local sustainability priorities.

Second, mere literature reviews often fail to capture the complexity of practical applications, especially in interdisciplinary

areas such as development. The mixed-methods approach employed in our study integrates BERTopic modeling with case studies and is designed to address the identified knowledge gaps by offering a dual perspective that neither bibliometric analysis nor case studies can be fully achieved alone, thus, uncovering and precise mapping of the previously underexplored themes in the field. BERTopic modeling, grounded in machine learning, enables the systematic mapping of sustainable finance topics to the SDGs, revealing trends and connections, often overlooked in traditional literature reviews. The bibliometric analysis provides a data-driven perspective on how specific themes in sustainable finance align with the SDGs, offering insights into underexplored topics and their relevance to global goals. Complementing this with case studies allows us to contextualize these quantitative findings within real-world examples, capturing applications that extend beyond theoretical models. Together, these methods bridge gaps in both theory and practice, enhancing our understanding of how sustainable and green finance contribute to SDG attainment.

Third, this research pioneers in improving the precision in aligning publications with the 17 SDGs, allowing for more accurate identification of SDG-focused research.

The subsequent sections review related work on how sustainable and green finance contributes to the SDGs and the methods employed to explore these relationships, followed by the results and discussion of policy and practical implications and the limitations of our study, suggesting future directions. Finally, the concluding section presents a succinct summary of our primary findings, suggesting how Global South nations can leverage financial innovations to achieve their sustainability goals.

## 2 Related work

This section provides a comprehensive overview of the current state of the research and development trajectories of sustainable and green finance and its variants, synthesizing the key findings and insights from the prior literature in Table 1:

Thus, the abovementioned recent bibliometric studies address the interconnected nature of sustainable, green, and climate finance; instrument vehicles; and associated risks and challenges and their significant role in promoting sustainable development. Green finance is likely to promote environmental protection and resource efficiency and foster low-carbon economies on the basis of renewable energy transition (Rasoulinezhad and Taghizadeh-Hesary, 2022; Subramaniam and Loganathan, 2024). As sustainable financial instruments (Christiansen, 2024; Huang, 2024), green bonds are convenient for investors (Gianfrate and Peri, 2019), generating funds for clean energy markets (Liu et al., 2021) and mitigating climate change (Fatica and Panzica, 2021), thereby contributing to the SDGs (Tolliver, C. et al., 2020).

However, studies on energy transition implications (Lin and Bai, 2023) for green finance have focused mostly on China (Xu et al., 2024), indicating the need for further research in related fields. Although climate finance significantly mitigates environmental degradation and enhances human development, scant research supporting vulnerable communities tackling climate change exists in lower-middle-income nations (Richardson, 2014). This indicates

TABLE 1 Recent studies related to sustainable and green finance.

Author(s), year	Main findings	Number of studies; coverage years	Search terms
Zhang et al. (2019)	Study identifies key research trends, influential publications, and significant areas of focus within green finance, emphasizing the interdisciplinary nature of the field and suggests areas for future research with critical evaluations of green finance mechanisms and their impact on sustainability goals	381 studies 2001 to 2018	Green financing, climate financing, carbon financing, green investment, and green bond
Yu et al. (2021)	Identifies key trends, influential authors, prolific institutions, and impactful journals in the green finance field	888 studies 1991 to 2021	green finance
Naeem et al. (2023)	Maps the growth of green and sustainable finance and highlights key contributors and influential works. It underscores the interdisciplinary nature of green finance research, revealing connections with economics, environmental science, and policy studies	1413 studies 1990 to 2021	Green finance, Green Credit, Green Risk, Green Bond, Green Portfolios, Green Loans, Carbon Finance, and Carbon Investment
Alshater et al. (2023)	Analysis identified four main thematic clusters - Corporate social responsibility and sustainable development, Sustainable finance and green bonds, corporate governance and ESG, Responsible investment and pension funds	263 studies 2011 to 2020	Sustainable finance and ESG
Poyser and Daugaard (2023)	Presents a framework for conceptualizing and characterizing the various stands of literature making the case for Indigenous Sustainable Finance as a distinct disciplinary field	560 studies 2017 to 2023	Keyword combinations for indigenous concepts and sustainable investments, sustainability terms
Debrah et al. (2023)	Identifies six major research hotspots in green finance- Green bond market and greenium, Green credit (loan), Carbon investment and market, Green banking, Market stress (e.g., the COVID-19 pandemic) and GF, Domestic and international climate finance policies	995 studies 1989 to 2021	Green finance, Climate finance, Sustainable finance, Carbon finance, Environmental finance, Green bonds, Climate bonds, Green investing, Eco-investing, Carbon investing)
Maria et al. (2023)	Focusses on the distribution of climate finance from developed to developing countries, including climate financial risks, green bonds, and the integration of financial development in energy-emissions-economics models	3,275 studies 1990 to 2020	green finance, climate finance, carbon finance, sustainable
Xu et al. (2024)	Results show a significant increase in publications from 2019 onward, reflecting growing interest and trends on green finance's role in reducing CO2 emissions and promoting green economic growth	328 studies 2019 to 2023	Energy transition, green energy, renewable energy, green finance, sustainable finance, environmental finance

a need for climate finance implementation in low-income regions (Rizzello and Kabli, 2020; Sachs et al., 2022; Lee et al., 2023).

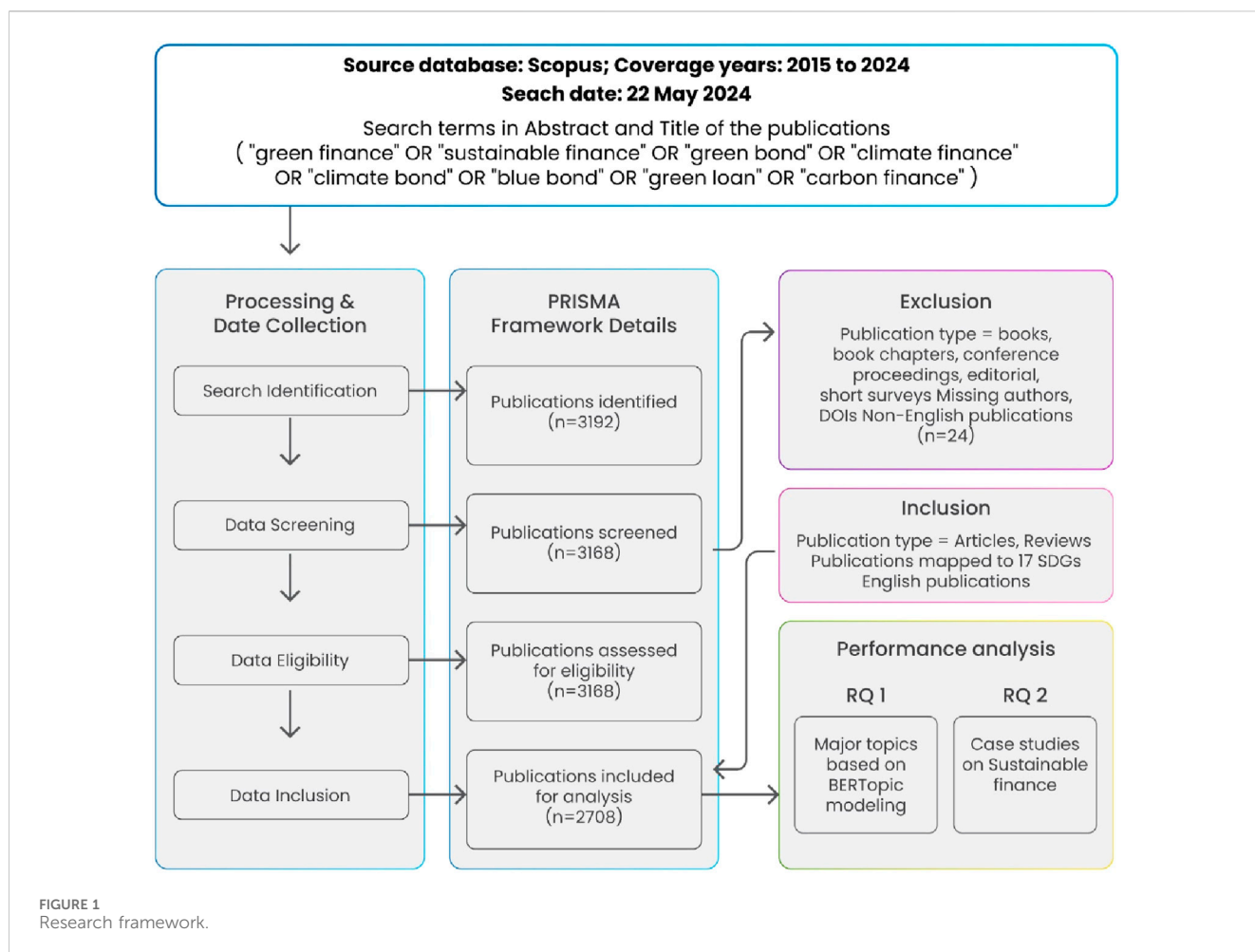
Recent research on sustainable finance (Migliorelli, 2021) has focused primarily on defining its concept and exploring its potential benefits. Their methodological inconsistencies reveal a lack of standardized frameworks hampering comparative analysis and universal metric development (Kumar et al., 2022). Furthermore, regional and sectoral diversities suggest the need for localized strategies supplemented by comparative studies across geographic regions and industries (Chen and Zhao, 2021; Olumekor and Oke, 2024). Additionally, the roles of institutions, such as central banks and self-regulatory mechanisms, in scaling sustainable financial efforts remain ambiguous (Cheung et al., 2022). Furthermore, the need for innovative financing mechanisms and policy interventions to bridge existing funding shortfalls still persists (Amighini, A. et al., 2022; Debrah et al., 2023).

To summarize, the above review highlights the fragmented approaches that focus on isolated issues, reinforcing the need for comprehensive mapping to the SDGs to promote all-inclusive

sustainable development. While previous studies have explored specific aspects of sustainable and green finance with their variations, they often lack a holistic approach that integrates financial mechanisms with broader environmental and social dimensions, particularly for indigenous and marginalized communities. By explicitly connecting sustainable and green finance to the SDGs, our study contributes to filling this gap and explores how these financial tools can support the attainment of the 2030 global goals.

### 3 Methods

This study investigated the connection between sustainable finance and the SDGs. We utilized a mixed-methods approach, combining a literature review with a case study analysis, as seen in the research framework (Figure 1). The literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) and an SDG



mapping framework (Bedard-Vallee et al., 2023), identifying relevant research and analyzing thematic trends via BERTopic modeling (Grootendorst, 2022). This was complemented by a review of six case studies illustrating various contexts in which the research topic is discussed.

### 3.1 PRISMA framework

To ensure transparency and rigor, we adhered to the PRISMA guidelines, which are widely recognized for their effectiveness in bibliometric research across disciplines (Raman et al., 2023a). We selected Scopus for its broader journal coverage, indexing over 24,600 peer-reviewed journals, compared with approximately 21,100 in Web of Science, offering 17% more coverage. This makes Scopus more suitable for comprehensive quantitative studies, particularly in interdisciplinary fields such as sustainability and green finance (Raman et al., 2023).

During the identification phase, on 22 May 2024, we conducted an extensive search of the Scopus database, covering publications from 2015 to 2024, coinciding with the formal adoption of the UN SDGs in 2015. We carefully selected terms in the title and abstracts of the publications that reflected the core areas of this evolving field. "Green finance" and "sustainable finance" capture the broad

spectrum of financial activities aimed at supporting environmentally and socially responsible projects. "Climate finance" and "carbon finance" focus on financial mechanisms addressing climate change mitigation and carbon emissions reduction, which are central to global sustainability efforts. We included "green bonds," "climate bonds," and "blue bonds" to represent specific financial instruments designed to fund environmentally beneficial projects, from renewable energy to marine conservation. Finally, "green loans" highlight the increasing role of sustainable lending in promoting eco-friendly business practices. Together, these terms provide a comprehensive framework for mapping the intersection of sustainable and green finance and sustainability in our study. The overlapping use of 'sustainable finance' and 'green finance' in literature presents a challenge in distinguishing the two terms clearly. This may complicate our analysis, as some studies focus on environmental aspects, whereas others cover broader sustainability goals. To address this, our study includes both terms to capture a wide range of financial mechanisms linked to sustainability and the SDGs, ensuring a comprehensive analysis. We identified 3,192 publications during this phase.

During the subsequent screening and eligibility phase, publications classified as books, book chapters, conference proceedings, editorials, short surveys, non-English publications,

and those with missing author details or DOIs were excluded. This process resulted in 3,168 publications for further assessment. In the inclusion phase, publications directly mapped to the 17 SDGs were identified via proprietary SDG mapping algorithms, informed by several initiatives, including the Aurora-Network-Global's SDG-Queries, the University of Auckland's SDG mapping, and Elsevier's SDG mapping initiatives. We chose Elsevier's mapping for its integration with Scopus, offering preset search queries for SDGs. This process, which considered only English-language journal articles and reviews, resulted in 2,708 publications being included in the detailed analysis.

Our analysis uses cocitation mapping to visualize the interconnections between SDGs. Using the VOSviewer tool (v1.6.20) (van Eck and Waltman, 2010), we illustrate the semantic proximity between SDGs on the basis of their cocitation frequency. In the resulting map, each SDG is represented as a node, with its size reflecting its prominence in the research landscape. The thickness of the connecting lines between nodes indicates the frequency of cocitation, revealing the intricate and cohesive network of SDGs that underpins global sustainability efforts.

### 3.2 BERTopic modeling

Hofmann's seminal work in 2001 introduced topic modeling as a powerful tool for text analysis. Since then, advancements in machine learning, such as those described by Asmussen and Møller (2019), have significantly refined this methodology. A notable breakthrough came with Grootendorst's development of BERTopic in 2022. By leveraging pretrained machine learning-based BERT (bidirectional encoder representations from transformers) embeddings, BERTopic offers more accurate and contextually rich topic representations than traditional methods such as LDA. This superiority was confirmed by Egger and Yu (2022), who found BERTopic to be more effective in capturing semantic meanings and contextual relationships within text data than latent Dirichlet allocation (LDA), probabilistic latent semantic analysis (PLSA), and To2Vec.

In our research, we employ BERTopic within a Python environment to extract and analyze meaningful topics related to our specific research area. To ensure data quality and consistency, we implement a rigorous preprocessing pipeline involving text cleaning, NLP techniques, and tokenization (Yi J et al., 2025). After simplifying the data, topics are clustered via hierarchical density-based spatial clustering of applications with noise (HDBSCAN), a technique that groups similar data points while filtering out noise or outliers. For the core topic modeling task, we utilize the "all-MiniLM-L6-v2" model from the Sentence Transformer to fit the BERTopic model to the preprocessed text. Finally, to interpret what each topic cluster represents, the model applies class-based term frequency-inverse document frequency (c-TF-IDF) to extract the most significant words or phrases from each group, allowing us to identify and rank key topics within the documents (Oh, Y et al., 2023; Kim and Jung, 2024). This process identifies distinct topics and calculates their associated probabilities, enhancing interpretability. We then analyze the topics for coherence and examine the distribution of publications across them to understand the relationships between content and identified themes. This approach is consistent with previous studies that




have used BERTopic modeling to identify emerging topics (Raman et al., 2024a; Raman et al., 2024b).

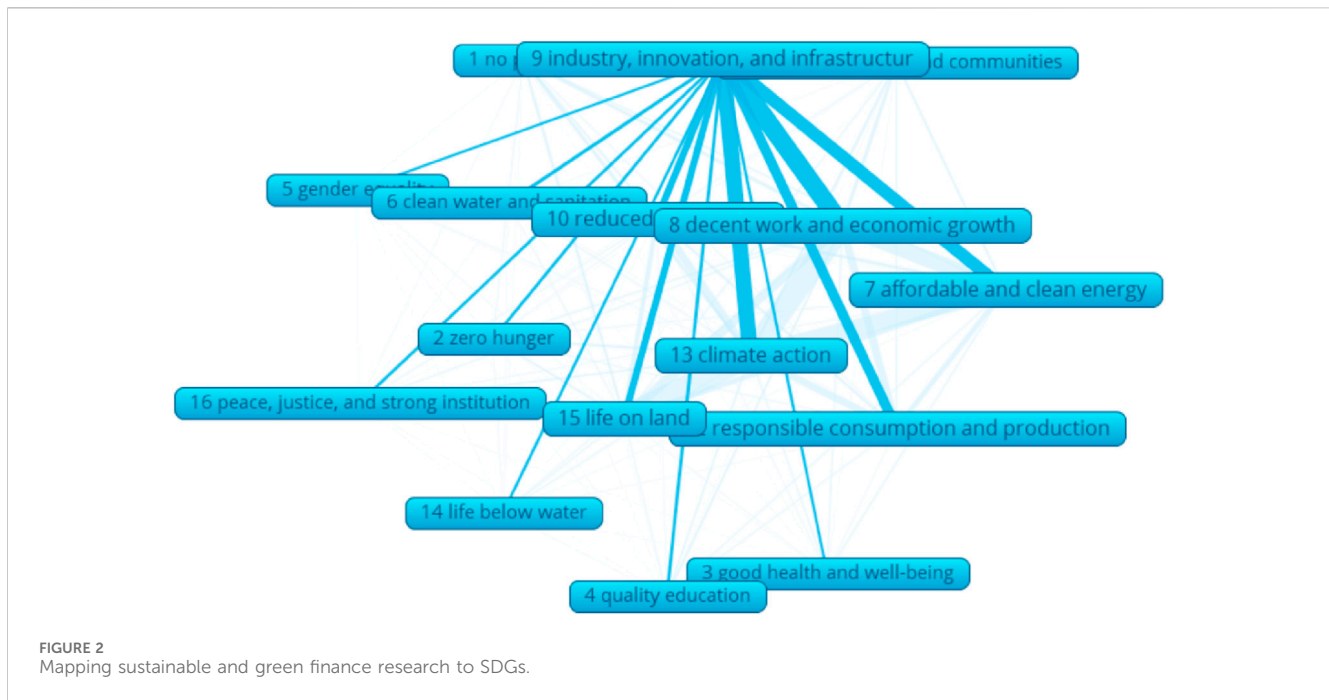
To optimize the BERTopic model for our study, we carefully selected three key hyperparameters—the n-gram range, number of topics, and minimum topic size—to enhance topic clarity and relevance. The n-gram range was set to (1, 2) to capture both single words and two-word phrases, allowing us to represent nuanced concepts without adding unnecessary complexity. For the number of topics, we conducted tests across a range from 5 to 20, evaluating coherence and intertopic distance scores to identify the point where specificity and coherence were balanced. A five-topic model ultimately emerged as optimal, as it provided both comprehensive data coverage and clear thematic separation, meeting the quantitative and qualitative requirements for coherence and interpretability. The minimum topic size was set to 20 to ensure that each topic had sufficient depth to be meaningful while limiting overly granular or ambiguous topics (Raman et al., 2024a). This threshold was chosen on the basis of coherence and relevance considerations, as it allowed us to capture key themes without creating excessively small or fragmented topics. Additionally, we limited each topic to 20 keywords to highlight the most significant terms, thus enhancing interpretability without overwhelming detail (Raman et al., 2024b).

To further refine the model, we removed stop words and other common but noninformative words such as "use," "add," and "related," following Grootendorst's (2022) guidelines, which helped reduce noise in the results. For dimensionality reduction, we configured the UMAP algorithm with default settings and enabled the "calculate probabilities" option for better document–topic associations. We also experiment with intertopic distance thresholds, setting a minimum of 0.05 to ensure clear topic separation. Using cosine similarity as our metric, we optimized for angular distance to increase topic accuracy, and a random state of 100 was applied to maintain reproducibility. We chose a  $n_{\text{neighbors}}$  value of 15 to strike a balance between capturing the local structure and preserving broader patterns (McInnes et al., 2020). In our selection of representative publications, we reviewed only the top three most cited works for each topic, emphasizing influential contributions. This approach allowed us to focus on the most significant articles within each theme, making our findings both relevant and manageable, given the large volume of publications. This systematic selection of hyperparameters and careful topic refinement ultimately supported the rigor and reliability of the model.

Despite the efficiency of machine learning techniques in clustering data, the possibility of misclassification persists (Lyutov et al., 2024). To ensure that the results were accurate and interpretable, we performed a manual review of both the identified topics and the corresponding representative publications. This process involved three experts who conducted a qualitative assessment to verify that the topics were coherent and meaningful, in line with recent BERTopic studies (Douglas et al., 2024; Wang et al., 2023). The experts evaluated the keywords associated with each topic and reviewed the representative publications by analyzing abstracts, titles, and, when necessary, the full texts. Additionally, probability values and citation counts were used to select the top three representative articles for each topic. To ensure the reliability of our process, we used a straightforward

TABLE 2 Case studies on sustainable finance.

Country	Case study focus	Authors	SDGs focus
United States of America	Role of sustainable finance and renewable energy in carbon neutrality	Qin et al. (2022)	 
South Africa	Green bond market as a sustainable finance mechanism	Ngwenya and Simatele (2020)	  
Turkey	Sustainable finance through fintech solutions for emerging market economies	Bayram et al. (2022)	    
China	Green finance, economic development, and contribution to environmental quality	Zhou et al. (2020)	   
India	Green finance and sustainable entrepreneurship	Bhatnagar and Sharma (2022)	
Brazil	Approaches to implement Climate Finance	Pinsky et al. (2019)	



scoring system to evaluate each topic's relevance. Each expert independently rated the topics on a scale of one to five, with 5 indicating the highest level of coherence, meaning that the topic was clearly relevant, distinct, and understandable. A score of 1, on the other hand, indicated that the topic required further refinement, either because it was too broad, had overlapping themes, or was difficult to interpret. After completing their ratings, the experts met to discuss their scores and address any differences. During these discussions, they reviewed specific keywords and representative articles, ensuring that each topic accurately reflected a distinct theme. If there were any inconsistencies in the scores, they worked together to either adjust the topic or find a common understanding. Topics that initially received lower scores were often refined or clarified during these meetings, leading to a more consistent set of themes across the board. This approach not only helped refine the topics but also provided a structured way to confirm the reliability of our machine-generated themes.

The integration of BERTopic modeling and cocitation analysis in this study uniquely addresses our research objectives by combining insights from both thematic and relational perspectives on sustainable and green finance and its alignment with the SDGs. While BERTopic modeling enables us to uncover key topics by clustering conceptually similar documents, this technique alone provides a limited context on how these topics relate to one another within the broader academic landscape. By integrating cocitation analysis, we enhance our understanding of these relationships, as cocitation mapping illustrates the proximity and frequency of connections between SDGs, indicating how different areas of research influence and inform each other. This dual approach offers a more holistic view, where BERTopic modeling identifies emerging themes in sustainable finance, and cocitation analysis situates these themes within the interconnected web of SDG research.

### 3.3 Case studies

Case studies are valuable research methods, particularly in sustainable development research, where they can be used independently or combined with other methods (Filho et al., 2024). We utilized the term “case studies” to present real-world examples demonstrating applications in various sustainability contexts. We complemented bibliometric analysis with a narrative synthesis of relevant publications, systematically searching for and evaluating evidence, analyzing similarities and differences between research designs, and exploring relationships within the data (Popay et al., 2006; Cruzes et al., 2015). The review question drove the selection of studies for narrative synthesis through case studies. The case studies presented in Table 2 provide a comprehensive overview of the role of sustainable finance in advancing the SDGs across both developed and developing country contexts and how these nations from different spheres of growth and development have responded to the green and sustainable finance contributing to the SDGs. Thus, the selection of these case studies is justified by their ability to collectively address key aspects of sustainable finance, including innovations, challenges, and country-specific experiences. Case studies from the selected nations illustrate green banking, bonds, and investment policies promoting low-carbon transitions in global-southern countries, highlighting research gaps in scaling green finance to meet substantial climate investment needs. We also selected the USA as a representative country from the Global North.

The case studies cover a range of sustainable finance mechanisms, such as green bonds, green fintech solutions, and climate finance instruments, and their impacts on environmental quality, economic development, and sustainable entrepreneurship. The inclusion of case studies from the United States, South Africa, Turkey, China, India, and Brazil ensures a balanced representation of both the Global North and



Global South, allowing for a finer understanding of the contextual factors that influence the adoption and effectiveness of sustainable finance initiatives by nations. These case studies were chosen to showcase a diverse set of examples that contributed to the understanding of sustainable finance and its linkages to how they have addressed SDGs, for instance, SDG1, SDG7, SDG8, and SDG9, and strikingly, most of these cases are linked to one of the highest challenges we face, which is ‘climate change’, SDG13. The case studies highlight both the potential and the challenges associated with scaling up sustainable finance, including issues related to regulatory environments, market barriers, capacity constraints, and the need for tailored financial instruments and international partnerships.

Overall, the case studies presented in the document provide a valuable foundation for understanding the current state of sustainable finance and its role in advancing the SDGs. The inclusion of both developed and developing country contexts adds depth and nuance to the analysis, although the specific rationale for selecting these case studies could have been made more explicit.

Applying these criteria, we selected six studies for narrative synthesis and analyzed their impacts on the SDGs.

## 4 Results

### 4.1 Mapping sustainable and green finance research to SDGs (RQ1)

The network map of SDGs on the basis of citations highlights the central role of SDG 13 (climate action) and its connections with various other goals (Figure 2). SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land) are also closely linked to climate action, reflecting the critical interdependence between climate finance, water management, and biodiversity conservation. These connections indicate that sustainable finance plays a key role in supporting environmental protection efforts, particularly by funding projects aimed at improving water quality, restoring ecosystems, and conserving biodiversity. SDG 3 (good health and wellbeing) and SDG 4 (quality education) further highlight how climate action and sustainable finance are tied to improving human health and education. Climate finance can contribute to healthier environments and communities by reducing pollution and supporting clean energy initiatives, whereas education in sustainability empowers individuals and societies to adopt greener practices, aligning with SDG 4.

At the heart of the map, SDG 13 connects strongly with SDG 9 (Industry, Innovation, and Infrastructure), showing that innovation and sustainable infrastructure are key drivers of climate solutions. The link between SDG 8 (Decent Work and Economic Growth) and SDG 9 demonstrates how sustainable finance supports the creation of green jobs and the development of resilient industries, aligning economic growth with environmental sustainability. The connection between SDG 7 (affordable and clean energy) and SDG 13 emphasizes the critical role of clean energy in climate mitigation, with green finance driving investments in renewable energy. Together, these linkages show that sustainable finance is essential for advancing both environmental and socioeconomic

goals by promoting integrated solutions that address climate change while fostering inclusive growth and sustainability.

The impact of green bonds extends well beyond climate finance, explaining the significant implications for advancing several other Sustainable Development Goals (SDGs), other than SDG1, SDG7, SDG8, SDG9, SDG11, and SDG13 mentioned in the case studies. Research on green bonds in India, Brazil, and South Africa shows how green bonds can act as a net receiver of risk spillovers during times of market uncertainty, helping to absorb financial shocks across different regions. This stabilizing effect promotes greater economic resilience, particularly in developing economies that are more vulnerable to volatile market conditions. This positively contributes to SDG 10 (reduced inequality). For example, in nations such as India and South Africa, green bonds have played a crucial role in channeling much-needed investments into renewable energy projects, green infrastructure, and sustainable urban development. By fostering global financial stability and improving access to sustainable financing, green bonds have contributed to reducing inequalities between developed and developing nations, aligning with the core objectives of SDG 10 (Long et al., 2022).

Furthermore, green bonds intersect with SDG 8 (Decent Work and Economic Growth) by supporting inclusive and sustainable economic transformation. The diversification benefits and risk mitigation properties of green bonds can stimulate productive employment, encourage innovation, and mobilize investment in green infrastructure, all of which are crucial for driving economic growth, which is environmentally responsible and socially equitable.

Another striking example is Brazil. In Brazil, the issuance of green bonds has supported the expansion of renewable energy projects, creating thousands of green jobs in the solar and wind power sectors. Similarly, in Kenya, green bonds have financed the development of sustainable transportation systems, such as the Nairobi commuter rail network, which has improved access to affordable and clean mobility options for local communities, contributing to both SDG 8 and SDG 11 (Sustainable Cities and Communities).

With respect to SDG 12 (responsible consumption and production), green bonds play a vital role in promoting sustainable production and consumption patterns. By channeling funds toward green projects and low-carbon initiatives, green bonds incentivize industries to adopt cleaner technologies, improve resource efficiency, and reduce waste. This helps to decouple economic growth from environmental degradation, fostering a circular economy approach that is in line with the principles of responsible production and consumption.

In China, for instance, the rapid growth of the green bond market has supported the country's transition toward a more sustainable, resource-efficient economy. Green bond proceeds have been used to finance the development of eco-industrial parks, implement energy-efficient retrofits in manufacturing facilities, and promote the use of renewable energy sources in industrial processes. These initiatives have not only reduced the environmental impact of production but also encouraged the adoption of more sustainable consumption patterns among businesses and consumers.

In the context of SDG 8 (Decent Work and Economic Growth), green bonds contribute to the achievement of sustainable and

inclusive economic growth. Research indicates that green bonds can enhance financial market resilience and stability, particularly during times of economic volatility. This stabilizing effect helps maintain economic activity, safeguard jobs, and support the transition to a green economy, all of which are essential for promoting decent work and sustained, sustainable economic progress.

The alignment of green bonds beyond general climate finance and their alignment with SDG7, SDG8, SDG9, SDG10, SDG11, SDG12, SDG13, and SDG17 gives a representation of their impact on the examples discussed.

## 4.2 Major topics (RQ2)

### 4.2.1 Leveraging green bonds to drive sustainable economic transformation

With respect to this topic, five highly cited studies provide rich insight into the potential and challenges of green bonds as instruments for fostering sustainable economic growth and achieving environmental objectives.

[Banga \(2019\)](#) investigated the role of green bonds in mobilizing climate finance for developing countries. This paper underscores the increasing awareness among investors in developed and emerging economies about the importance of green bonds in addressing climate change. However, it also highlights significant barriers in developing countries, such as high transaction costs and insufficient institutional frameworks, which hinder the broader adoption of green bonds. This study emphasizes the necessity of creating enabling environments that can lower these barriers, thereby aligning with SDG 13, which focuses on climate action, and SDG 17, which aims to strengthen the means of implementation and revitalize the global partnership for sustainable development.

In a different context, [Wang et al. \(2020\)](#) provide empirical evidence from China demonstrating the market's positive reaction to the issuance of corporate green bonds. The study reveals that green bonds command a pricing premium relative to conventional bonds, which is more pronounced among issuers with strong corporate social responsibility (CSR) and long-term institutional investor involvement. This finding aligns with SDG 9, which promotes inclusive and sustainable industrialization and fosters innovation by showing how green bonds can enhance the financial viability and attractiveness of sustainable practices. The positive stock market response further suggests that investors recognize the long-term value of green finance, encouraging more firms to adopt sustainable business models supporting SDG 12.

[Kumar et al. \(2022\)](#) take a broader approach by using big data analytics to conduct a comprehensive review of sustainable finance research. They highlight green bonds as a critical component of sustainable finance, connecting them to various themes such as climate financing, impact investing, and the governance of sustainable financing. This study underscores the multifaceted nature of green bonds in addressing complex sustainability challenges and the need for innovative financial instruments to advance the agenda of SDG 11, which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. By mapping the intellectual landscape of sustainable finance, this study provides valuable insights into the evolution and future

directions of green bond markets, emphasizing the importance of policies to prevent issues such as greenwashing, thereby contributing to SDG 16, which calls for effective, accountable, and inclusive institutions.

Considering the current barriers to scaling the green bond market, [Deschryver and de Mariz, \(2020\)](#) propose several recommendations to unlock its potential. This paper identifies the lack of harmonized global standards, the risk of greenwashing, and the perception of higher costs as key obstacles. By addressing these issues, this study aligns with SDG 8, which promotes sustained, inclusive, and sustainable economic growth, by suggesting ways to increase the scalability and effectiveness of green bonds in financing sustainable projects. The recommendations for developing clear standards and increasing transparency in the green bond market are crucial for building investor confidence and ensuring that funds are effectively channeled toward impactful and sustainable initiatives.

Finally, [Yeow and Ng \(2021\)](#) examine the impact of green bonds on corporate environmental and financial performance, highlighting their role in improving environmental, social, and governance (ESG) metrics. The study revealed that green bonds, particularly those certified by third parties, can significantly enhance environmental performance but do not necessarily improve financial outcomes. This signifies the importance of robust certification processes to ensure the credibility of green bonds and prevent greenwashing, supporting SDG 12, which emphasizes sustainable consumption and production patterns. The findings also suggest that while green bonds can drive better environmental outcomes, their financial benefits may be contingent on the maturity and governance of the green bond market, highlighting the need for stronger regulatory frameworks, as advocated by SDG 16.

### 4.2.2 China's pathway to sustainable growth through green finance

China's shift began in the early 2000s, moving away from a growth-at-all-costs model that dominated after the 1978 economic reforms. Recognizing the need for sustainable practices, China introduced policies such as the Circular Economy Promotion Law (2008) and the Revised Environmental Protection Law (2014), laying a foundation for green finance. The 11th Five-Year Plan (2006–2010) marked an initial integration of ecological goals into a national strategy, culminating in the "ecological civilization" concept in 2012, which catalyzed a comprehensive green finance framework. Since then, China has emerged as a global leader in green finance, balancing economic growth with sustainability goals and supporting international climate initiatives, particularly through South–South cooperation. This historical perspective underscores the country's commitment to advancing sustainable finance and climate action on both domestic and international fronts. The examination of China's pathway to sustainable growth and its transformation through green finance, as seen in the five selected studies, reveals innovative financial mechanisms and strengthened environmental regulations that effectively channel capital toward sustainable development projects.

[Zhou et al. \(2020\)](#) explored how green finance can simultaneously drive economic growth and environmental improvement across 30 Chinese provinces. They utilize a comprehensive green finance development index to demonstrate

that green finance initiatives not only stimulate economic development but also reduce harmful emissions, such as industrial smoke and solid waste. This dual benefit aligns with SDG 8, which promotes sustainable economic growth, and SDG 13, which emphasizes urgent action to combat climate change and its impacts.

Building on this, [Huang \(2022\)](#) delve into the spatial and nonlinear effects of green finance on green innovation. Their research highlights that green finance can lead to significant positive spillovers in adjacent provinces, promoting regional sustainable development. This regional approach underscores the importance of cooperative policies and aligns with SDG 17, which calls for global partnerships and regional cooperation to achieve sustainable development. [Huang \(2022\)](#) also emphasize that varying levels of green finance development across regions necessitate different intensities of environmental regulation, reflecting the need for tailored strategies to ensure equitable and effective outcomes.

[Wang et al. \(2021\)](#) and [Lee \(2020\)](#) contributed to the narrative by forecasting the growth trajectory of green finance in China. They highlighted that green finance has seen rapid growth, particularly driven by investments in new energy sectors and green transportation projects. This focus on future growth and sustainability underscores the relevance of SDG 7, which aims for affordable and clean energy. The emphasis on green transportation and energy projects not only supports sustainable infrastructure but also reduces the carbon footprint, reinforcing the goals of SDG 13 by mitigating the impacts of climate change.

Moreover, [Bai et al. \(2022\)](#) investigated the impact of green finance on carbon emissions, revealing a complex relationship influenced by economic structure and regional differences. Their findings show that green finance has been particularly effective in reducing emissions in the more industrialized eastern regions of China. This aligns with the broader objective of SDG 13 to reduce emissions and combat climate change but also highlights the need for region-specific policies to ensure that green finance can effectively drive down emissions across diverse economic contexts.

Finally, [Li et al. \(2022\)](#) examine the broader implications of green finance in transitioning to a low-carbon economy. They find that while green finance significantly aids this transition, its effectiveness diminishes without the support of low-carbon technological innovations. This study underscores the crucial role of technology and innovation in sustainable development, aligning with SDG 9, which focuses on building resilient infrastructure and promoting inclusive and sustainable industrialization. [Li et al. \(2022\)](#) also emphasized the importance of integrating green finance with other sustainability measures to maximize its impact on achieving a low-carbon economy.

#### 4.2.3 Sustainable energy access through climate finance

The collection of studies on sustainable energy access through climate finance offers a diverse yet interconnected exploration of how financial mechanisms can effectively contribute to addressing energy poverty and climate resilience, key components of the SDGs, particularly SDG 7 and SDG 13. Each study underscores different facets of the role of climate finance in facilitating energy access and

mitigating climate change impacts, providing a comprehensive view of the challenges and opportunities in this crucial area.

The discussion on international climate finance, as presented by [Weikmans and Roberts \(2019\)](#), highlights significant gaps in the accountability and transparency of climate finance flows. The lack of internationally agreed-upon modalities for accounting and reporting has led to discrepancies and eroded trust among international stakeholders. This finding is crucial for understanding the broader landscape of climate finance and its role in achieving SDG 17.1, which emphasizes the need for effective, accountable institutions at all levels to support sustainable development, including the mobilization of financial resources for clean energy infrastructure.

Complementing this perspective, [Lee et al. \(2022\)](#) provide empirical evidence on the effectiveness of climate finance in reducing carbon emissions and promoting green growth, particularly in small island developing states and economically advanced regions. This aligns with SDG 13.1, which focuses on strengthening resilience and adaptive capacity to climate-related hazards. The study underscores that while the flow of climate finance is pivotal in driving energy transitions and enhancing resilience, the effectiveness of these financial flows is significantly influenced by the economic and policy contexts of the recipient regions. This highlights the importance of targeted and context-sensitive approaches in climate finance to maximize its impact on sustainable energy access, as emphasized in SDG 7. b, which calls for the expansion of infrastructure and technology upgrades to provide modern and sustainable energy services.

In a similar vein, [Ha et al. \(2016\)](#) focused on the rising trend of South-South climate finance, illustrating how emerging economies are increasingly contributing to climate finance efforts. This trend is significant in that it shifts the traditional narrative of climate finance as the sole responsibility of developed nations, promoting a more inclusive and cooperative approach to addressing climate challenges. The rise of South-South cooperation in climate finance underscores the potential for these economies to mobilize additional resources for sustainable energy projects, aligning with SDG 17.3, which calls for the mobilization of additional financial resources for developing countries from multiple sources. This study also highlights the need for a coordinated effort to track and enhance the effectiveness of these financial flows to support climate mitigation and adaptation efforts, which are integral to achieving SDG 13.b.

The narrative shifts to a more localized focus with [Prasad and Sud \(2019\)](#), who explore the implementation of India's National Adaptation Fund on Climate Change (NAFCC). They emphasize the critical role of domestic finance in enabling state governments to prioritize climate actions alongside developmental goals. This perspective highlights the importance of domestic financial mechanisms in ensuring that climate finance is accessible and effectively utilized at the subnational level, aligning with SDG 13.2, which calls for the integration of climate change measures into national policies and planning. The study also points to the need for increased budgetary allocations and capacity building to mainstream climate considerations into state planning, which is essential for achieving SDG 7.1, focused on ensuring universal access to affordable, reliable, and modern energy services.

[Michaelowa et al. \(2021\)](#) extended the discussion to Sub-Saharan Africa, assessing the role of climate finance in mobilizing private

investment for sustainable energy access. They highlight the importance of international market mechanisms and tailored approaches to engage private sector participation in energy projects. This aligns with SDG 7.3, which aims to double the global rate of improvement in energy efficiency, and SDG 13. a, which emphasizes the need for developed countries to mobilize \$100 billion annually by 2020 to address the needs of developing countries. This study underscores the potential of climate finance to catalyze private investment, thereby enhancing the sustainability of energy projects and contributing to broader climate mitigation goals.

#### 4.2.4 Leveraging green financing for renewable energy and climate mitigation

The examined studies collectively illuminate the pivotal role of green finance in bolstering sustainable development and climate mitigation efforts, aligning closely with the SDGs, particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). According to these studies, there is a shared recognition of the transformative potential of green finance, particularly in promoting renewable energy and enhancing environmental sustainability, which directly supports SDG 7.2 (which substantially increases the share of renewable energy in the global energy mix) and SDG 13.2 (which integrates climate change measures into national policies, strategies, and planning).

Rasoulinezhad and Taghizadeh-Hesary (2022) emphasized the critical role of green bonds in supporting green energy projects and significantly reducing CO<sub>2</sub> emissions in major economies, which is integral to achieving SDG 13.1 (strengthening resilience and adaptive capacity to climate-related hazards and natural disasters). They highlight the necessity for long-term policy frameworks to increase private investment in green projects, which aligns with SDG 17.17 (encouraging and promoting effective public, public-private, and civil society partnerships).

Zhang et al. (2022) investigated the impact of green finance and renewable energy investment on environmental protection in G-20 countries. Their study underscores that green finance, combined with renewable energy investment and technological innovation, plays a crucial role in reducing carbon emissions and promoting sustainable economic development, directly contributing to SDG 7.3 (double the global rate of improvement in energy efficiency) and SDG 9.4 (upgrade infrastructure and retrofit industries to make them sustainable).

The thematic continuity across these studies is further reinforced by Ibrahim et al. (2022), who focus on the impact of green finance, renewable energy, and technological innovation on sustainable development in China. They underscore the indispensable role of green finance in achieving carbon neutrality and promoting economic growth, suggesting that green finance is a key driver for integrating environmental considerations into economic policies, which supports SDG 12.2 (achieving sustainable management and efficient use of natural resources) and SDG 8.4 (improving global resource efficiency in consumption and production through 2030). This notion is echoed by Lee et al. (2023), who explore the influence of green finance on renewable energy promotion in China. Their empirical analysis revealed that green finance not only directly fosters renewable energy development but also indirectly supports it through enhanced research and development, economic growth, and market openness, thereby contributing to SDG 7. a (enhancing

international cooperation to facilitate access to clean energy research and technology).

In contrast with the broader focus of other studies, Zhou and Li (2022) delved into the relationships among green finance, renewable energy sources, and sustainable development, specifically in China. They provide a detailed examination of how green finance positively impacts sustainable development and reduces carbon emissions, reinforcing the idea that green finance is crucial for achieving environmental and economic sustainability, which aligns with SDG 13. b (promotion mechanisms for increasing the capacity for effective climate change-related planning and management). The authors highlighted the need for policies that integrate green finance with renewable energy initiatives, thereby supporting long-term sustainability, addressing environmental challenges effectively, and contributing to SDG 13.3 (improving education, awareness-raising, and human and institutional capacity for climate change mitigation, adaptation, impact reduction, and early warning).

#### 4.2.5 Green bonds as risk mitigation tools in financial market volatility

This theme focuses on how green bonds have emerged as pivotal tools for mitigating financial risk and enhancing market stability, particularly in the face of economic volatility and economic crises, especially during the COVID-19 pandemic. Unlike the previous theme, which broadly emphasized sustainable economic transformation, this theme addresses the specific mechanisms through which green bonds interact with and influence financial stability and market resilience. It explores the role of green bonds in risk diversification, volatility management, and their effectiveness as safe-haven assets amidst financial turmoil.

Elsayed et al. (2022) provide a comprehensive analysis of the interconnectedness between green bonds and various financial markets, utilizing multivariate wavelet approaches to highlight how green bonds can serve as effective instruments for risk management and portfolio diversification. Their findings underscore the short-term diversification benefits and the intricate long-term integration of green bonds within global financial systems, aligning with the goals of SDG 8 (promoting inclusive and sustainable economic growth) and SDG 9 (building resilient infrastructure and fostering innovation).

In contrast, Gao et al. (2021) delve into the dynamic risk spillovers between China's green bond market and its principal financial markets, revealing significant two-way spillovers with traditional bonds. This study highlights how green bonds mitigate systemic risk while playing a crucial role in enhancing financial market resilience during periods of economic instability. This focus on risk management supports SDG 13 (climate action) by fostering financial stability by integrating environmentally sustainable investments.

Liu (2022) extend this analysis by exploring the volatility dynamics of green bonds in response to extreme market shocks, such as those induced by the COVID-19 pandemic. Their research highlights the susceptibility of green bonds to significant volatility driven by uncertainties in traditional fixed-income markets. This underscores the need for robust risk management frameworks to sustain the growth of the green finance sector through economic disruptions, aligning with SDG 12 (responsible consumption and production) and SDG 17 (partnerships for the goals).

Adding another layer of complexity, Long et al. (2022) investigate the quantile connectedness between market uncertainties and green bonds across the US, Europe, and China. Their findings indicate that green bonds act as net receivers of risk spillovers under extreme market conditions, emphasizing their role in absorbing financial shocks and contributing to global financial stability. This aligns with SDG 10 (reduced inequalities) by highlighting the role of green bonds in ensuring economic resilience across different regions and market conditions.

Finally, Wei et al. (2023) examined the interaction between green bonds and oil market shocks, particularly during the COVID-19 pandemic. Their study reveals the significant impact of oil price fluctuations on green bond markets, demonstrating how green bonds can integrate environmental considerations into financial decision-making processes, thus playing a stabilizing force. This supports SDG 7 (affordable and clean energy) and SDG 13 by promoting the development of green financial instruments that mitigate the risks associated with volatile commodity markets.

### 4.3 Case studies (RQ3)

The case studies in Table 2 represent and synthesize research on the role of sustainable finance in promoting the SDGs. Studies highlight that sustainable finance innovations such as green fintech, SIBs, and risk models can facilitate renewable investment and mitigate environmental impacts. This section contributes by examining sustainable finance initiatives such as green bonds and green loans in South Africa and other developing nations, highlighting efforts by stakeholders, although significant financing gaps persist. The key challenges identified include nascent regulatory environments, market barriers, and capacity constraints that inhibit mainstream integration. Critical research avenues include quantifying investment needs and tailoring financial instrument mechanisms, thus fostering cross-sector coordination and international partnerships to mobilize sustainable capital flows attuned to Global South contexts and priorities.

Qin et al. (2022) contributed to sustainable finance research and its effect on global warming by investigating the potential roles of sustainable finance and renewable energy in facilitating US carbon neutrality goals. Sustainable financial development, which aligns with SDG 13, which focuses on combating climate change, is found to promote carbon neutrality and has a longer and more significant direct negative impact on CO<sub>2</sub> than renewable energy. This also aligns with SDG 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Although its indirect effect by influencing renewable energy is delayed, this research highlights the need to explore further the contextual factors and mechanisms underlying the asymmetric effects observed to leverage better sustainable finance and renewable energy to achieve US decarbonization targets amid global warming challenges. Integrating SDG 7 and SDG 13 into these efforts is essential for creating a comprehensive approach to addressing climate change and ensuring sustainable energy access.

Another study by Ngwenya and Simatele (2020) examined the potential of green bonds to help finance climate adaptation and mitigation in vulnerable African nations facing insufficient

traditional climate funds, thereby contributing to SDG 13, which focuses on taking urgent action to combat climate change and its impacts. Research has validated that green bonds increase capital for environmentally friendly projects, enabling sustainable investment while providing fixed returns to investors. This aligns with SDG 8, which aims to promote sustained, inclusive, and sustainable economic growth; full and productive employment; and decent work for all. Highlighting growth in green bond markets within African economic hubs such as Kenya, Nigeria, and South Africa, this study identifies opportunities for further expansion across the continent via this emerging climate finance mechanism. Moreover, fostering green bond markets also supports SDG 15, which seeks to protect, restore, and promote the sustainable use of terrestrial ecosystems. However, critical gaps are revealed in fostering public–private partnerships, developing integrated policies and building effective institutional frameworks. Addressing these barriers through concerted efforts represents a key research avenue to unlock the impact of fully sustainable green bond development for climate-vulnerable African countries.

Research has also outlined the challenges nations face in adopting and utilizing sustainable finance and green finance. Zhou et al. (2020) examined the impact of green finance on economic development and environmental quality across 30 provinces in China. This study using a green finance development index, finds that green finance promotes economic growth (SDG 8). It also shows a positive effect on improving environmental indicators such as emissions and waste (SDG 11, SDG 13). However, the impact on the quality of environment varies with the economic development of a nation. However, gaps remain in unpacking the specific mechanisms through which green finance leads to environmental improvements, especially across development contexts (SDG 13).

Another study by Bayram et al. (2022) examines how fintech solutions can promote sustainable finance in emerging market economies, using Turkey as a case study. Research has shown that Turkey has made significant progress in increasing financial inclusivity and promoting responsible consumption through fintech solutions, thereby contributing to SDG 1 (No Poverty) and SDG 8 (Decent Work and Economic Growth). With upcoming developments, such as a sandbox environment and collaboration between the banking and fintech sectors, Turkey has the potential to improve its sustainable finance strategies further, supporting SDG 9 (Industry, Innovation, and Infrastructure). These efforts align with the broader goals of advancing SDG 4 (quality education) through financial literacy initiatives and SDG 13 (climate action) by integrating green finance solutions.

Bhatnagar et al. (2022) remarked that by assessing India's current green finance landscape and its impact on promoting sustainable entrepreneurship and startups aligned with the 2030 SDGs. Through case studies and published reports, the research revealed that India's government is providing green finance initiatives that startups leverage implementing sustainability-oriented business models crucial for economic development balanced with environmental goals such as carbon neutrality. However, gaps are identified in further scaling up green finance and ecologically friendly adjustments across India's financial sector to mainstream and accelerate sustainable business uptake throughout the startup ecosystem (SDG 8).

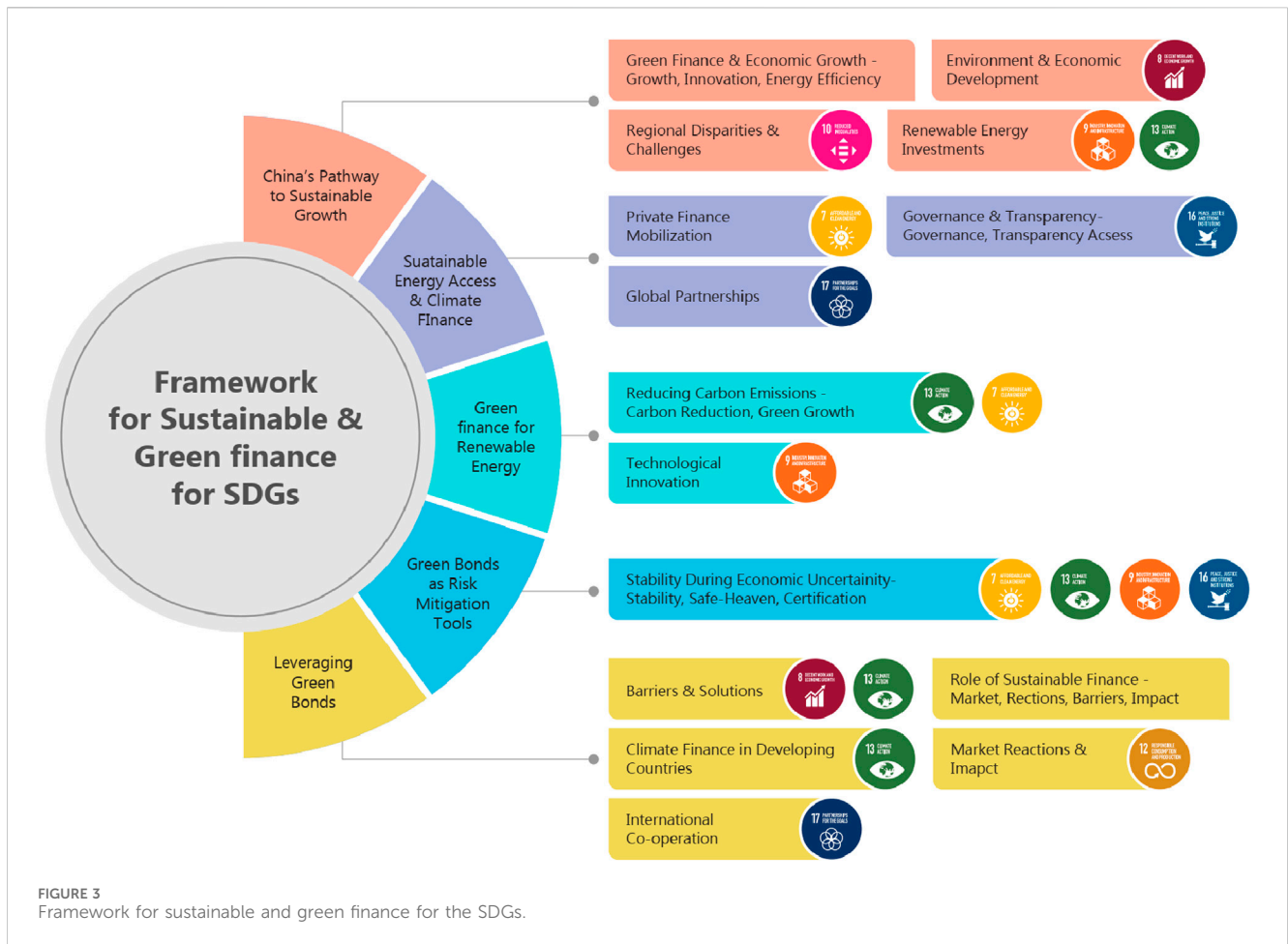


FIGURE 3 Framework for sustainable and green finance for the SDGs.

One of the Global South countries prominent in utilizing climate finance is Brazil. The case by Pinsky, V.C. et al. (2019) analyzes Brazil’s experience with the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiative under the United Nations Framework Convention on Climate Change (UNFCCC). Through interviews with 29 Brazilian policy experts, the authors revealed weak links between the international REDD + system and local implementation in Brazil. This study highlights the need for REDD + reforms to focus on promoting local policy experimentation and learning from experience rather than solely on increasing funding amounts. Research has examined the governance and implementation challenges of REDD+ in Brazil for addressing deforestation and land-use emissions contributing to SDG 13 (climate action). The authors advocate for an “experimentalist governance” approach, where local policy experiments and learning from experience inform broader international initiatives such as REDD+.

## 5 Discussion

We propose a research framework for sustainable and green financing (Figure 3) for the SDGs based on our results. This provides a comprehensive approach to leveraging financial mechanisms, particularly green bonds and green finance, to advance the SDGs.

It emphasizes the critical role of sustainable finance in driving market reactions, facilitating climate finance, and addressing barriers such as high transaction costs and inadequate institutional setups in developing countries. The framework also highlights the importance of international cooperation, stringent certification processes, and innovative finance mechanisms to prevent greenwashing and support global sustainability efforts. By aligning with specific SDGs such as SDGs 13, 12, 8, and 17, this framework aims to foster responsible corporate actions, promote renewable energy investments, and ensure financial stability.

The topic “Leveraging green bonds to drive sustainable economic transformation” highlights the role of sustainable finance, especially green bonds, in advancing the SDGs. Key points include facilitating climate finance in developing countries’ market reactions to green bonds and their impact on corporate performance and environmental outcomes. Addressing barriers such as high transaction costs and inadequate institutional arrangements in developing countries is essential to unlock the potential of green bonds, which aligns with SDG 13. Furthermore, varying impacts on corporate and market behavior underscore the role of green finance in promoting responsible corporate actions, which is linked to SDG 12. The need for stringent certification processes to prevent greenwashing aligns with SDG 8. International cooperation and global standards are vital for scaling green finance, in line with SDG 17. In addition, it is imperative to address green

bonds with challenges in the growth of green bond markets, including a lack of formal institutional setup, limited private participation, and a lack of international certification (Leimbach and Giannousakis, 2019), considering their significant contribution to renewable energy production in various countries.

The topic “China’s pathway to sustainable growth through green finance” has demonstrated the positive impact of green finance on economic growth and environmental sustainability. Green finance supports investments in renewable energy, enhances energy efficiency, and fosters innovation and industrial transformation, aligning with SDGs 9 and 13. Regional disparities in effectiveness suggest that tailored policy measures, aligning with SDG 10, are necessary to address specific challenges. Although green finance benefits both the environment and economic development, supporting SDG 8, there are long-term vision challenges, technological risks, market and demand, reputational and social risks, and alignment with global trends (Gupta M. et al., 2023). Promising aspects of green finance include opportunities to promote and invest in environmentally conscious projects, which are key to fostering sustainable development while addressing pressing ecological concerns.

The topic of “sustainable energy access through climate finance” highlights the role of sustainable and green finance in achieving the SDGs, particularly climate action (SDG 13) and economic development (SDG 8). Effective governance and transparency in climate finance are vital for SDG 16. Mobilizing private finance in regions such as Sub-Saharan Africa, where energy access and climate mitigation are critical, aligns with SDGs 7 and 17. However, research on sustainable finance in low-income nations and climatically vulnerable regions is limited, with most studies focused on developed economies, underscoring the need for further research (Singh and Jayaram, 2021). Challenges in climate finance include unresolved accounting, donor domination, and institutional weaknesses (Carè and Weber, 2023). Aligning climate finance with the SDGs requires national commitments, financial innovation, and strong governance (Raman et al., 2022; Iacobuță et al., 2022; Omukuti, 2024).

The topic “Leveraging green finance for renewable energy and climate mitigation” emphasizes the role of green finance in supporting environmental sustainability, promoting renewable energy, and mitigating climate change impacts. Effective green finance mechanisms can significantly reduce carbon emissions and foster green economic growth, supporting SDGs 7 and 13. Comprehensive policy frameworks and government support are essential for overcoming barriers to green finance. Technological innovation and economic complexity are crucial for enhancing the impact of green finance on sustainable development, which aligns with SDG 9. Green financing initiatives have been demonstrated to reduce regional carbon emissions, contributing to local environmental improvements and accelerating the transition to a low-carbon economy (Li et al., 2022). Studies show that both carbon taxes and green finance policies positively impact this low-carbon transition. Green finance policies mitigate the financial and risk-related challenges associated with energy transition, leading to increased green output and sustainable economic growth (Liu Y. et al., 2023). Furthermore, in developing countries, green finance significantly increases the number of green patent applications, necessary to promote environmentally friendly development (Ma and Chang, 2023).

Green bonds as risk mitigation tools, especially during periods of economic uncertainty such as the COVID-19 pandemic, are pivotal. They promote financial stability by investing in sustainable projects, thus supporting SDGs 7 and 13. A lower correlation between green bonds and traditional financial assets enhances their appeal as safe-haven assets, supporting SDG 9. Addressing issues such as the lack of standardized global frameworks and greenwashing concerns is crucial for maximizing the potential of green bonds, aligning with SDG 16. Establishing robust verification processes can enhance investor trust and participation, stabilizing financial systems further.

The case studies illustrate green banking, bonds, and investment policies promoting low-carbon transitions in global-southern countries, revealing research gaps in the cases of scaling green finance to meet substantial climate investment needs. The key barriers include insufficient technical capacity, regulatory shortcomings, immature capital markets, and inadequate climate risk integration by financial institutions. In terms of evidence on the contribution of sustainable finance and green finance to the SDGs, case studies show that research through cases in various nations contributes to various SDGs, including SDG 7 (Energy), SDG 8 (Decent Work), SDG 9 (Industry), SDG 13 (Climate Action), and SDG 17 (Partnerships). They highlight the potential of sustainable finance initiatives, such as green fintech, green bonds, and renewable energy investments, in promoting sustainable development. However, research gaps persist in areas such as quantifying investment needs, tailoring financial instruments, fostering cross-sector coordination, and addressing regulatory and capacity constraints, especially in developing countries to mobilize sustainable capital flows aligned with local priorities and the Global South context.

## 5.1 Implications for policy and practice

Governments play a crucial role in advancing green and sustainable financing by incentivizing environmentally beneficial investments and reducing greenhouse gas emissions. This shift toward sustainability is not confined to developed economies; many developing and underdeveloped nations are also proactively establishing and implementing sustainability frameworks (Mishra et al., 2023). The transition to a green economy is regulated by policies that incorporate environmental, social, and corporate governance criteria, underscoring the importance of government backing (Süer, S. 2020). Indonesia exemplifies this commitment through its implementation of sustainable financial policies aligned with the SDGs and the Paris Agreement on Climate Change. While green finance investments are on the rise, there remains a need for enhanced government policy support, innovation, and public awareness to drive further investments in sustainable projects (Sengupta and Patil, 2023). The global shift toward a low-carbon, green, and sustainable economy necessitates the development of a financial system that supports sustainable development, presenting worldwide growth opportunities. This transition requires coordinated efforts from both the public and private sectors to create an enabling environment for sustainable finance.

Green finance mechanisms, such as green bonds and green loans, offer essential capital for developing and scaling renewable energy projects. This capital is crucial for reducing greenhouse gas

emissions and achieving climate targets. Integrating green finance into mainstream financial markets encourages a shift in investment priorities toward sustainable projects, fostering innovation and adopting clean technologies. The integration of green finance enhances the resilience of the energy sector and stimulates economic growth through green jobs and energy security. Digital finance (e.g., introducing the usage of central bank digital currency) has the potential to promote financial inclusion, alleviate the menaces of money laundering, counterfeiting, etc., and simultaneously contribute to the SDGs (Gupta S. et al., 2023). Aligning investment portfolios with sustainable development goals caters to investors' increasing demand for environmentally responsible investment options. This alignment helps attract a more environmentally conscious investor base and promotes long-term financial stability.

Policymakers must create conducive environments for green investments with robust regulatory frameworks and clear guidelines and standards for green financial products. This includes defining what constitutes green projects and ensuring transparency and accountability in the use of green finance proceeds. Policies facilitating public-private partnerships enable the pooling of resources and expertise necessary for large-scale renewable energy projects. Policies that provide tax benefits and subsidies for green investments can significantly increase the attractiveness of green finance options. Incentives can encourage more investors to engage in green finance, thus increasing the capital available for sustainable projects.

International cooperation is essential to harmonize green finance standards and practices, ensuring a coordinated global effort toward sustainability. By fostering an enabling policy environment, governments can play a pivotal role in scaling up green finance, driving the transition to a low-carbon economy, and achieving the broader objectives of the SDGs.

Long-term policies for sustainable finance in climatically vulnerable developing regions, including Small Island Developing States (SIDS), such as the Maldives; flood-prone South Asian nations, such as Bangladesh and India; drought-affected countries, such as Ethiopia; and rapidly industrializing economies, such as China, should prioritize inclusive financing and resilience building. In SIDS, community-based financing for solar energy and coastal protection supports adaptation. In India and Bangladesh, tax incentives for flood-resilient infrastructure and green employment in sustainable agriculture address high unemployment and exposure to extreme weather. Ethiopia could benefit from green funds targeting drought-resistant agriculture and water management, whereas China can scale green bonds and incentivize carbon-neutral urban projects to reduce emissions (Lu and Xia, 2024). Policies requiring green projects to report long-term social and environmental impacts enhance transparency, and partnerships for international knowledge transfer can help adapt best practices to local contexts.

## 5.2 Future directions

The proposed research paths aim to address the challenges and trends highlighted in the studies we reviewed directly. For example, the suggestion to develop advanced data analytics tools builds on the

identified need for transparency and accountability in climate finance flows, as noted in Weikmans and Roberts (2019) and Elsayed et al. (2022). Similarly, our recommendation to explore region-specific financial products stems from findings by Bai et al. (2022) and Zhou and Li (2022), who emphasize the importance of tailored financial solutions across varying regional contexts. Furthermore, we highlight the integration of emerging technologies such as blockchain and Artificial intelligence (AI) to improve transparency and scalability in sustainable finance, aligning with findings on the risk of greenwashing and the importance of robust certification processes discussed by Kumar et al. (2022) and Liu (2022). Finally, the focus on social impacts in sustainable finance reflects studies' emphasis on inclusive growth and community resilience, aligning with insights from South-South climate finance trends noted by Ha et al. (2016). Similarly, the need for tailored sustainable finance instruments and mechanisms, as mentioned in the case study by Qin et al. (2022), aligns with findings on the delayed impact of sustainable finance on renewable energy, underscoring the importance of context-specific approaches to achieve carbon neutrality in the U.S. Similarly, Ngwenya and Simatele's (2020) case study on the barriers to scaling green bonds in African nations highlights research opportunities to foster public-private partnerships and develop integrated policies, which could unlock the full potential of green bonds in climate-vulnerable areas.

Future research should develop advanced data analytics tools to assess the impact of sustainable and green finance. These tools can help track progress, identify gaps, and optimize financial flows toward achieving the SDGs. Leveraging big data and machine learning will provide accurate insights, enabling better decision-making for policymakers and financial institutions. Tailoring sustainable finance instruments to local contexts is essential. Future studies should explore region-specific challenges and opportunities and design financial products that address unique conditions. This approach ensures inclusivity and effectiveness, especially in underdeveloped and climatically vulnerable areas. AI can play a transformative role in enhancing transparency, efficiency, and scalability within sustainable finance. By analyzing vast datasets, AI can optimize investment strategies, identifying patterns and risks that may not be immediately apparent through traditional methods. Blockchain technology is another area with transformative potential for sustainable and green finance, especially in the context of cross-border transactions and transparent reporting. Blockchain's decentralized ledger can track and verify green finance transactions with greater transparency, reducing greenwashing risk and improving accountability. For example, blockchain-enabled platforms can ensure that funds allocated to sustainable projects are utilized as intended, thereby increasing trust among investors. Moreover, in cross-border scenarios, blockchain can streamline transactions, reduce costs, and increase transparency, addressing current barriers to efficient international green finance flows. Carbon credits and global emissions trading markets are key tools in the climate action toolkit, offering financial incentives for emission reductions and fostering international collaboration toward carbon neutrality. By providing a structured marketplace, emissions trading systems allow nations and corporations to achieve climate goals more efficiently, thus supporting SDG 13 by linking financial and environmental objectives. Future research should



focus on the social impacts of sustainable finance, address social inequalities, promote inclusive growth, and enhance community resilience. By examining finance and social issues, researchers can create financial products that support both environmental and broader social objectives, such as poverty alleviation and gender equality.

Our study has certain limitations. Within the PRISMA framework, potential biases may arise from the selection of literature from a specific database. With respect to BERT topic modeling, we recognize its strength in handling large datasets and uncovering key themes by extracting coherent topic representations on the basis of the semantic similarity of words and phrases. This reduces human biases in topic classification, thereby enhancing the objectivity and reliability of the findings (Kimura, 2024). However, the effectiveness of topic modeling algorithms can be influenced by the quality of the input data and the assumptions embedded in their design. Additionally, mapping publications to SDGs is complex, and our analysis acknowledges the limitations of using a specific SDG mapping approach (Raman et al., 2023b). For future research, comparing our findings with results obtained from multiple SDG mapping initiatives, such as the Aurora Network's SDG Queries and the University of Auckland's SDG mapping, would be beneficial for providing a broader perspective.

## 6 Conclusion

Sustainable and green finance is pivotal in addressing global environmental challenges and achieving the SDGs. Green bonds, climate bonds, and other sustainable financial instruments have shown significant potential in mobilizing resources for sustainable development.

The SDG network map (RQ1) shows SDG 13 (climate action) as a central node closely linked to economic growth (SDG 8), industry and infrastructure (SDG 9), and clean energy (SDG 7). These connections highlight the key role of sustainable and green finance in driving both climate action and broader sustainable development. The map also shows the impact on environmental goals such as clean water (SDG 6) and life on land (SDG 15), emphasizing the need for integrated financial strategies that address both environmental and socioeconomic goals to achieve global sustainability.

In addressing RQ2, which explores the major topics related to sustainable and green finance, the research highlights several significant findings aligned with key SDGs. A prominent theme is the role of green bonds in driving sustainable economic transformation. These bonds mobilize climate finance, contribute to achieving SDG 13, and strengthen partnerships, as outlined in SDG 17 (partnerships). Additionally, green bonds have been shown to encourage sustainable industrialization (SDG 9) and promote responsible consumption and production (SDG 12). Despite challenges of high transaction costs among other things and risks such as greenwashing, they have gained traction, offering both environmental and financial benefits. Another important insight involves China's approach to green finance, demonstrating how such financial mechanisms contribute to economic growth (SDG 8) and emissions reduction (SDG 13), with region-specific policies enhancing their effectiveness. These findings reinforce the

significant role of sustainable finance in advancing multiple SDGs, highlighting its transformative potential in diverse contexts.

In response to RQ3, which focuses on case studies of sustainable and green finance initiatives, this research highlights several opportunities and challenges in advancing key SDGs. Green bonds and loans in developing nations are identified as powerful tools for addressing climate change (SDG 13) and promoting economic growth (SDG 8), with significant potential to protect ecosystems (SDG 15). However, gaps in financing and regulatory barriers persist, particularly in regions with underdeveloped financial infrastructure, which hampers the full integration of these tools. The case studies also emphasize the importance of domestic financial mechanisms for supporting climate action and sustainable development at the national and sub-national levels (SDG 13 and SDG 7). For example, domestic funds have been pivotal in enabling renewable energy investment and expanding access to modern energy services (SDG 7) while fostering responsible production and consumption (SDG 12). These examples illustrate how targeted financial innovations, particularly in the Global South, are essential for aligning financial strategies with broader sustainability goals.

However, effective implementation requires robust regulatory frameworks, international cooperation, and continuous innovation. By integrating sustainable and green finance into corporate strategies, building capacities, and developing supportive policies, stakeholders can enhance the impact of sustainable finance on global sustainability goals. The practical implications of leveraging green finance for renewable energy (SDG 7) and climate mitigation (SDG 13) are profound and multifaceted, offering a roadmap for policymakers, financial institutions, and stakeholders in the energy sector. Green finance mechanisms, such as green bonds and green loans, provide essential capital for scaling and implementing renewable energy projects, crucial for reducing greenhouse gas emissions and achieving climate targets. The integration of green finance into mainstream financial markets encourages a shift in investment priorities toward sustainable projects, fostering innovation and the adoption of clean technologies. This enhances the resilience of the energy sector while stimulating economic growth by creating green jobs and promoting energy security. For practitioners in the financial sector, the adoption of green finance practices offers a competitive advantage by aligning investment portfolios with sustainable development goals, thereby meeting the growing demand for environmentally responsible investment options among investors.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

RR: Conceptualization, Data curation, Funding acquisition, Methodology, Software, Supervision, Visualization,

Writing—original draft, Writing—review and editing. SR:  
Writing—original draft, Writing—review and editing. DD:  
Writing—original draft, Writing—review and editing. PN:  
Writing—original draft, Writing—review and editing.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

- Ali, E., Anshari, M., Hamdan, M., Ahmad, N., and Surieshtino, Y. (2023) “Green finance for sustainable development: a bibliographic analysis,” in *International conference on sustainable islamic business and finance*, 46–49. SIBF 2023.
- Alshater, M. M., Atayah, O. F., and Hamdan, A. (2023). Journal of sustainable finance and investment: a bibliometric analysis. *J. Sustain. Finance Invest.* 13 (3), 1131–1152. doi:10.1080/20430795.2021.1947116
- Amighini, A., Giudici, P., and Ruet, J. (2022). Green finance: an empirical analysis of the Green Climate Fund portfolio structure. *J. Clean. Prod.* 350, 131383. doi:10.1016/j.jclepro.2022.131383
- Asmussen, C. B., and Møller, C. (2019). Smart literature review: a practical topic modeling approach to exploratory literature review. *J. Big Data* 6 (1), 1–18. doi:10.1186/s40537-019-0255-7
- Bai, J., Chen, Z., Yan, X., and Zhang, Y. (2022). Research on the impact of green finance on carbon emissions: evidence from China. *Econ. Research-Ekonomiska Istraz.* 35 (1), 6965–6984. doi:10.1080/1331677x.2022.2054455
- Banga, J. (2019). The green bond market: a potential source of climate finance for developing countries. *J. Sustain. Finance Invest.* 9 (1), 17–32. doi:10.1080/20430795.2018.1498617
- Barua, S. (2020). Financing sustainable development goals: a review of challenges and mitigation strategies. *Bus. Strategy Dev.* 3 (3), 277–293. doi:10.1002/bsd2.94
- Bayram, O., Talay, I., and Feridun, M. (2022). Can fintech promote sustainable finance? Policy lessons from the case of Turkey. *Sustain. Switz.* 14 (19), 12414. doi:10.3390/su141912414
- Bedard-Vallee, A., James, C., and Roberge, G. (2023). Elsevier 2023 sustainable development goals (SDGs) mapping. *Elsevier Data Repository* V1. doi:10.17632/y2zy9vwvzy.1
- Bhatnagar, M., Taneja, S., and Özen, E. (2022). A wave of green startups in India—the study of green finance as a support system for sustainable entrepreneurship. *Green Finance* 4 (2), 253–273. doi:10.3934/gf.2022012
- Bhatnagar, S., and Sharma, D. (2022). Evolution of green finance and its enablers: a bibliometric analysis. *Renew. Sustain. Energy Rev.* 162, 112405. doi:10.1016/j.rser.2022.112405
- Carè, R., and Weber, O. (2023). How much finance is in climate finance? A bibliometric review, critiques, and future research directions. *Res. Int. Bus. Finance* 64, 101886. doi:10.1016/j.ribaf.2023.101886
- Chen, Y., and Zhao, Z. J. (2021). The rise of green bonds for sustainable finance: global standards and issues with the expanding Chinese market. *Curr. Opin. Environ. Sustain.* 52, 54–57. doi:10.1016/j.cosust.2021.06.013
- Cheung, H., Baumber, A., and Brown, P. J. (2022). Barriers and enablers to sustainable finance: a case study of home loans in an Australian retail bank. *J. Clean. Prod.* 334, 130211. doi:10.1016/j.jclepro.2021.130211
- Christiansen, J. (2024). State capacity and the ‘value’ of sustainable finance: understanding the state-mediated rent and value production through the Seychelles Blue Bonds. *Environ. Plan. A* 56 (2), 402–417. doi:10.1177/0308518x231201467
- Cruzes, D. S., Dybå, T., Runeson, P., and Höst, M. (2015). Case studies synthesis: a thematic, cross-case, and narrative synthesis worked example. *Empir. Softw. Eng.* 20, 1634–1665. doi:10.1007/s10664-014-9326-8
- Debrah, C., Darko, A., and Chan, A. P. C. (2023). A bibliometric-qualitative literature review of green finance gap and future research directions. *Clim. Dev.* 15 (5), 432–455. doi:10.1080/17565529.2022.2095331
- Deschryver, P., and de Mariz, F. (2020). What future for the green bond market? How can policymakers, companies, and investors unlock the potential of the green bond market? *J. Risk Financial Manag.* 13 (3), 61. doi:10.3390/jrfm13030061
- Dhutta, A., Bouri, E., Rothovius, T., and Uddin, G. (2023). Climate risk and green investments: new evidence. *Energy* 265, 126376. doi:10.1016/j.energy.2022.126376
- Douglas, T., Capra, L., and Musolesi, M. (2024). “A computational linguistic approach to study border theory at scale,” in *Proceedings of the ACM on Human-Computer Interaction* 8 (CSCW1), 159. doi:10.1145/3640998
- Edmans, A., and Kacperczyk, M. (2022). Sustainable finance. *Rev. Finance* 26 (6), 1309–1313. doi:10.1093/rof/rfac069
- Egger, R., and Yu, J. (2022). A topic modeling comparison between lda, nmf, top2vec, and bertopic to demystify twitter posts. *Front. Sociol.* 7, 886498. doi:10.3389/fsoc.2022.886498
- Elsayed, A. H., Naifar, N., Nasreen, S., and Tiwari, A. K. (2022). Dependence structure and dynamic connectedness between green bonds and financial markets: fresh insights from time-frequency analysis before and during COVID-19 pandemic. *Energy Econ.* 107, 105842. doi:10.1016/j.eneco.2022.105842
- Emmanuel, U., Das, N., and Nicholas, N. (2024). Green environments reimagined through the lens of green finance, green innovations, green taxation, and green energies. Wavelet quantile correlation and rolling window-based quantile causality perspective. *Renew. Energy* 228, 120650. ISSN 0960-1481. doi:10.1016/j.renene.2024.120650
- Fatica, S., and Panzica, R. (2021). Green bonds as a tool against climate change? *Bus. Strategy Environ.* 30 (5), 2688–2701. doi:10.1002/bse.2771
- Feng, W., Bilivogui, P., Wu, J., and Mu, X. (2023). Green finance: current status, development, and future course of actions in China. *Environ. Res. Commun.* 5 (3), 035005. doi:10.1088/2515-7620/acclc7
- Filho, W. L., Schmidberger, I., Sharifi, A., Vargas, V. R., Rampasso, I. S., Dibbern, T., et al. (2024). Design thinking for sustainable development: a bibliometric analysis and case study research. *J. Clean. Prod.* 455, 142285. doi:10.1016/j.jclepro.2024.142285
- Gao, Y., Li, Y., and Wang, Y. (2021). Risk spillover and network connectedness analysis of China’s green bond and financial markets: evidence from financial events of 2015–2020. *North Am. J. Econ. Finance* 57, 101386. doi:10.1016/j.najef.2021.101386
- Gianfrate, G., and Peri, M. (2019). The green advantage: exploring the convenience of issuing green bonds. *J. Clean. Prod.* 219, 127–135. doi:10.1016/j.jclepro.2019.02.022
- Grootendorst, M. (2022). BERTopic: neural topic modeling with a class-based TF-IDF procedure. *arXiv Prepr. arXiv:2203.05794*. doi:10.48550/arXiv.2203.05794
- Gupta, M., Taneja, S., Sharma, V., Singh, A., Rupeika-Apoga, R., and Jangir, K. (2023a). Does previous experience with the unified payments interface (UPI) affect the usage of central bank digital currency (CBDC)? *J. Risk Financial Manag.* 16 (6), 286. doi:10.3390/jrfm16060286
- Gupta, S., Kaur, G., Kumari, I., and Kalra, D. (2023b). Exploration of opportunities and challenges in green finance: a journey of sustainable development. *Sustain. Investments Green Finance*, 256–270. doi:10.4018/979-8-3693-1388-6.ch018

## Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. During the preparation of this work, the author(s) used ChatGPT for English editing and grammar checks. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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- Ha, S., Hale, T., and Ogden, P. (2016). Climate finance in and between developing countries: an emerging opportunity to build on. *Glob. Policy* 7 (1), 102–108. doi:10.1111/1758-5899.12293
- Haas, C., Jahns, H., Kempa, K., and Moslener, U. (2023). Deep uncertainty and the transition to a low-carbon economy. *Energy Res. & Soc. Sci.* 100, 103060. doi:10.1016/j.erss.2023.103060
- Hofmann, T. (2001). Unsupervised learning by probabilistic latent semantic analysis. *Mach. Learn.* 42, 177–196. doi:10.1023/a:1007617005950
- Huang, D. (2022). Green finance, environmental regulation, and regional economic growth: from the perspective of low-carbon technological progress. *Environ. Sci. Pollut. Res.* 29 (22), 33698–33712. doi:10.1007/s11356-022-18582-8
- Huang, L. (2024). Green bonds and ESG investments: catalysts for sustainable finance and green economic growth in resource-abundant economies. *Resour. Policy* 91, 104806. doi:10.1016/j.resourpol.2024.104806
- Huang, Y., Chen, C., Lei, L., and Zhang, Y. (2022). Impacts of green finance on green innovation: a spatial and nonlinear perspective. *J. Clean. Prod.* 365, 132548. doi:10.1016/j.jclepro.2022.132548
- Iacobuță, G. I., Brandi, C., Dzebo, A., and Duron, S. D. E. (2022). Aligning climate and sustainable development finance through an SDG lens. The role of development assistance in implementing the Paris Agreement. *Glob. Environ. Change* 74, 102509. doi:10.1016/j.gloenvcha.2022.102509
- Ibrahim, R. L., Al-mulali, U., Ozturk, I., Bello, A. K., and Raimi, L. (2022). On the criticality of renewable energy to sustainable development: do green financial development, technological innovation, and economic complexity matter for China? *Renew. Energy* 199, 262–277. doi:10.1016/j.renene.2022.08.101
- Kim, K. H., and Jung, K. J. (2024). Improvement of topic modeling and case analysis through convergence of Bertopic and TextRank. *J. Inf. Syst.*
- Kimura, T. (2024). Virtual teams: a smart literature review of four decades of research. *Hum. Behav. Emerg. Technol.* 2024 (1), 1–20. doi:10.1155/2024/8373370
- Kumar, B., Kumar, L., Kumar, A., Kumari, R., Tagar, U., and Sassanelli, C. (2024). Green finance in circular economy: a literature review. *Environ. Dev. Sustain.* 26 (7), 16419–16459. doi:10.1007/s10668-023-03361-3
- Kumar, S., Sharma, D., Rao, S., Lim, W. M., and Mangla, S. K. (2022). Past, present, and future of sustainable finance: insights from big data analytics through machine learning of scholarly research. *Ann. Operations Res.*, 1–44. doi:10.1007/s10479-021-04410-8
- Lee, C.-C., Li, X., Yu, C.-H., and Zhao, J. (2022). The contribution of climate finance toward environmental sustainability: new global evidence. *Energy Econ.* 111, 106072. doi:10.1016/j.eneco.2022.106072
- Lee, C.-C., Wang, F., and Chang, Y.-F. (2023). Does green finance promote renewable energy? Evidence from China. *Resour. Policy* 82, 103439. doi:10.1016/j.resourpol.2023.103439
- Lee, J. W. (2020). Green finance and sustainable development goals: the case of China. *J. Asian Finance, Econ. Bus.* 7 (7), 577–586. doi:10.13106/jafeb.2020.vol7.no7.577
- Leimbach, M., and Giannousakis, A. (2019). Burden sharing of climate change mitigation: global and regional challenges under shared socioeconomic pathways. *Clim. Change* 155 (2), 273–291. doi:10.1007/s10584-019-02469-8
- Li, W., Fan, J., and Zhao, J. (2022). Has green finance facilitated China's low-carbon economic transition? *Environ. Sci. Pollut. Res.* 29 (38), 57502–57515. doi:10.1007/s11356-022-19891-8
- Lin, B., and Bai, R. (2023). Nexus between green finance development and green technological innovation: a potential way to achieve the renewable energy transition. *Renew. Energy* 218, 119295. doi:10.1016/j.renene.2023.119295
- Liu, H., Liu, Z., Zhang, C., and Li, T. (2023a). Transformational insurance and green credit incentive policies as financial mechanisms for green energy transitions and low-carbon economic development. *Energy Econ.* 126, 107016. doi:10.1016/j.eneco.2023.107016
- Liu, M. (2022). The driving forces of green bond market volatility and the response of the market to the COVID-19 pandemic. *Econ. Analysis Policy* 75, 288–309. doi:10.1016/j.eap.2022.05.012
- Liu, N., Liu, C., Da, B., Zhang, T., and Guan, F. (2021). Dependence and risk spillovers between green bonds and clean energy markets. *J. Clean. Prod.* 279, 123595. doi:10.1016/j.jclepro.2020.123595
- Liu, Y., Cai, W., Lin, X., Li, Z., and Zhang, Y. (2023b). Nonlinear El Niño impacts on the global economy under climate change. *Nat. Commun.* 14 (1), 5887. doi:10.1038/s41467-023-41551-9
- Liu, Y., Dong, K., Wang, K., and Taghizadeh-Hesary, F. (2024). Moving toward sustainable city: can China's green finance policy lead to sustainable development of cities? *Sustain. Cities Soc.* 102, 105242. doi:10.1016/j.scs.2024.105242
- Long, S., Tian, H., and Li, Z. (2022). Dynamic spillovers between uncertainties and green bond markets in the US, Europe, and China: evidence from the quantile VAR framework. *Int. Rev. Financial Analysis* 84, 102416. doi:10.1016/j.irfa.2022.102416
- Lu, Y., and Xia, Z. (2024). Digital inclusive finance, green technological innovation, and carbon emissions from a spatial perspective. *Sci. Rep.* 14, 8454. doi:10.1038/s41598-024-59081-9
- Lyutov, A., Uygun, Y., and Hütt, M. T. (2024). Machine learning misclassification networks reveal a citation advantage of interdisciplinary publications only in high-impact journals. *Sci. Rep.* 14 (1), 21906. doi:10.1038/s41598-024-72364-5
- Ma, J., and Chang, C. P. (2023). The role of green finance in green innovation: global perspective from 75 developing countries. *Emerg. Mark. Finance Trade* 59 (10), 3109–3128. doi:10.1080/1540496x.2023.2210720
- Madaleno, M., Dogan, E., and Taskin, D. (2022). A step forward on sustainability: the nexus of environmental responsibility, green technology, clean energy and green finance. *Energy Econ.* 109, 105945. doi:10.1016/j.eneco.2022.105945
- Maria, M. R., Ballini, R., and Souza, R. F. (2023). Evolution of green finance: a bibliometric analysis through complex networks and machine learning. *Sustain. Switz.* 15 (2), 967. doi:10.3390/su15020967
- McInnes, L., Healy, J., and Melville, J. (2020). UMAP: uniform manifold approximation and projection for dimension reduction.
- Michaelowa, A., Hoch, S., Weber, A.-K., Kassaye, R., and Hailu, T. (2021). Mobilising private climate finance for sustainable energy access and climate change mitigation in Sub-Saharan Africa. *Clim. Policy* 21 (1), 47–62. doi:10.1080/14693062.2020.1796568
- Migliorelli, M. (2021). What do we mean by sustainable finance? Assessing existing frameworks and policy risks. *Sustain. Switz.* 13 (2), 117, 975. doi:10.3390/su13020975
- Mishra, P., Kumar, K., Fouzdar, A. S., and Singh, A. (2023). “Sustainability disclosure and green finance: driving the transition toward a sustainable future,” in *The sustainable fintech revolution: building a greener future for finance*, 20–36.
- Mohsin, M., Taghizadeh-Hesary, F., Panthami, N., Anwar, S., Abbas, Q., and Vo, X. V. (2021). Developing low carbon finance index: evidence from developed and developing economies. *Finance Res. Lett.* 43, 101520. doi:10.1016/j.frl.2020.101520
- Naeem, M., Karim, S., Rabbani, M., Bashar, A., and Kumar, S. (2023). Current state and future directions of green and sustainable finance: a bibliometric analysis. *Qual. Res. Financial Mark.*, 1755. doi:10.1108/QRFM-10-2021-0174
- Ngwenya, N., and Simatele, M. D. (2020). Unbundling of the green bond market in the economic hubs of Africa: case study of Kenya, Nigeria and South Africa. *Dev. South Afr.* 37 (6), 888–903. doi:10.1080/0376835x.2020.1725446
- Oh, Y. K., Yi, J., and Kim, J. (2023). What enhances or worsens the user-generated metaverse experience? An application of BERTopic to Roblox user eWOM. *Internet Res.* 34, 1800–1817. doi:10.1108/intr-03-2022-0178
- Olumekor, M., and Oke, A. (2024). Support for sustainable finance and investment in Europe. *J. Clean. Prod.* 449, 141769. doi:10.1016/j.jclepro.2024.141769
- Omukuti, J. (2024). The need for a climate-resilient development-aligned framing of innovative climate finance. *Curr. Opin. Environ. Sustain.* 66, 101400. doi:10.1016/j.cosust.2023.101400
- Ostergaard, P., Duic, N., Noorollahi, Y., and Kalogirou, S. (2022). Renewable energy for sustainable development. *Renew. Energy* 199, 1145–1152. doi:10.1016/j.renene.2022.09.065
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj* 372, n71. doi:10.1136/bmj.n71
- Pinsky, V. C., Kruglianskas, I., and Victor, D. G. (2019). Experimentalist governance in climate finance: the case of REDD+ in Brazil. *Clim. Policy* 19 (6), 725–738. doi:10.1080/14693062.2019.1571474
- Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., et al. (2006). Guidance on the conduct of narrative synthesis in systematic reviews. *A Prod. ESRC methods programme Version 1* (1), b92.
- Poyser, A., and Daugaard, D. (2023). Indigenous sustainable finance as a research field: a systematic literature review on indigenising ESG, sustainability and indigenous community practices. *Account. Finance* 63 (1), 47–76. doi:10.1111/acfi.13062
- Prasad, R. S., and Sud, R. (2019). Implementing climate change adaptation: lessons from India's national adaptation fund on climate change (NAFCC). *Clim. Policy* 19 (3), 354–366. doi:10.1080/14693062.2018.1515061
- Qin, M., Su, C.-W., Zhong, Y., Song, Y., and Oana-Ramona, L. O. B. O. N. T. (2022). Sustainable finance and renewable energy: promoters of carbon neutrality in the United States. *J. Environ. Manag.* 324, 116390. doi:10.1016/j.jenvman.2022.116390
- Raman, R., Gunasekar, S., Dávid, L. D., and Nedungadi, P. (2024a). Aligning sustainable aviation fuel research with sustainable development goals: trends and thematic analysis. *Energy Rep.* 12, 2642–2652. doi:10.1016/j.egy.2024.08.076
- Raman, R., Lathabhai, H., Mandal, S., Kumar, C., and Nedungadi, P. (2023a). Contribution of business research to sustainable development goals: bibliometrics and science mapping analysis. *Sustainability* 15 (17), 12982. doi:10.3390/su151712982
- Raman, R., Martin, H., Ray, S., Das, D., and Nedungadi, P. (2024b). Exploring sustainable development goal research trajectories in small island developing states. *Sustainability* 16 (17), 1–25. doi:10.3390/su16177463
- Raman, R., Nair, V. K., and Nedungadi, P. (2023b). Discrepancies in mapping sustainable development goal 3 (good health and well-being) research: a comparative analysis of Scopus and dimensions databases. *Sustainability* 15 (23), 16413. doi:10.3390/su152316413

- Raman, R., Nair, V. K., Prakash, V., Patwardhan, A., and Nedungadi, P. (2022). Green-hydrogen research: what have we achieved, and where are we going? Bibliometrics analysis. *Energy Rep.* 8, 9242–9260. doi:10.1016/j.egyr.2022.07.058
- Raman, R., Sreenivasan, A., Ma, S., Patwardhan, A., and Nedungadi, P. (2023). Green supply chain management research trends and linkages to UN sustainable development goals. *Sustainability* 15 (22), 15848. doi:10.3390/su152215848
- Raman, R., Sreenivasan, A., Suresh, M., and Nedungadi, P. (2024c). Mapping biomimicry research to sustainable development goals. *Sci. Rep.* 14 (1), 18613. doi:10.1038/s41598-024-69230-9
- Rasoulinezhad, E., and Taghizadeh-Hesary, F. (2022). Role of green finance in improving energy efficiency and renewable energy development. *Energy Effic.* 15 (2), 14. doi:10.1007/s12053-022-10021-4
- Ren, X., Zhang, X., Yan, C., and Gozgor, G. (2022). Climate policy uncertainty and firm-level total factor productivity: evidence from China. *Energy Econ.* 113, 106209. doi:10.1016/j.eneco.2022.106209
- Richardson, B. J. (2014). The evolving marketscape of climate finance. *Clim. Law* 4 (1–2), 94–106. doi:10.1163/18786561-00402008
- Rizzello, A., and Kabli, A. (2020). Sustainable financial partnerships for the SDGs: the case of social impact bonds. *Sustain. Switz.* 12 (13), 5362. doi:10.3390/su12135362
- Sachs, J., Lafortune, G., Kroll, C., Fuller, G., and Woelm, F. (2022). *From crisis to sustainable development: the SDGs as roadmap to 2030 and beyond. Sustainable development report 2022.* Cambridge: Cambridge University Press.
- Sengupta, R., and Patil, A. A. (2023). “Green finance products and investments in the changing business world,” in *Handbook of research on sustainable consumption and production for greener economies* (IGI Global Scientific Publishing), 344–357.
- Sharma, A., and Kautish, P. (2023). Measuring green finance. Recent developments in green finance. *Green Growth Carbon Neutrality*, 171–191. doi:10.1016/B978-0-443-15936-7.00008-6
- Singh, S., and Jayaram, R. (2021). Climate finance: a systematic literature review. *Int. J. Econ. Policy Emerg. Econ.* 14 (5–6), 566–580. doi:10.1504/ijepee.2021.118977
- Subramaniam, Y., and Loganathan, N. (2024). Does green finance affect renewable energy development in Singapore? *J. Asian Bus. Econ. Stud.* 31, 162–174. doi:10.1108/jabes-02-2023-0052
- Süer, S. (2020). “Developments on sustainable finance: a growth opportunity for global economy,” in *Handbook of research on creating sustainable value in the global economy* (IGI Global), 258–277.
- Taneja, S. (2024). “Sustainability-driven finance: reshaping the financial world,” in *Algorithmic Approaches to Financial Technology: Forecasting, Trading, and Optimization*. IGI Global, 74–92. doi:10.4018/979-8-3693-1746-4.ch005
- Tang, D. Y., and Zhang, Y. (2020). Do shareholders benefit from green bonds? *J. Corp. Finance* 61, 101427. doi:10.1016/j.jcorpfin.2018.12.001
- Tolliver, C., Keeley, A. R., and Managi, S. (2020). Policy targets behind green bonds for renewable energy: do climate commitments matter? *Technol. Forecast. Soc. Change* 157, 120051. doi:10.1016/j.techfore.2020.120051
- United Nations, Interagency Task Force on Financing for Development (2023). *Financing for sustainable development report 2023: financing sustainable transformations.* New York: United Nations.
- Van Eck, N. J., and Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84 (2), 523–538. doi:10.1007/s11192-009-0146-3
- van Niekerk, A. J. (2024). Economic inclusion: green finance and the SDGs. *Sustain. Switz.* 16 (3), 1128. doi:10.3390/su16031128
- Wang, J., Chen, X., Li, X., Yu, J., and Zhong, R. (2020). The market reaction to green bond issuance: evidence from China. *Pac. Basin Finance J.* 60, 101294. doi:10.1016/j.pacfin.2020.101294
- Wang, X., Zhao, H., and Bi, K. (2021). The measurement of green finance index and the development forecast of green finance in China. *Environ. Ecol. Statistics* 28 (2), 263–285. doi:10.1007/s10651-021-00483-7
- Wang, Z., Chen, J., Chen, J., and Chen, H. (2023). Identifying interdisciplinary topics and their evolution based on BERTopic. *Scientometrics* 129, 7359–7384. doi:10.1007/s11192-023-04776-5
- Wei, P., Qi, Y., Ren, X., and Gozgor, G. (2023). The role of the COVID-19 pandemic in time-frequency connectedness between oil market shocks and green bond markets: evidence from the wavelet-based quantile approaches. *Energy Econ.* 121, 106657. doi:10.1016/j.eneco.2023.106657
- Weikmans, R., and Roberts, J. T. (2019). The international climate finance accounting muddle: is there hope on the horizon? *Clim. Dev.* 11 (2), 97–111. doi:10.1080/17565529.2017.1410087
- Xu, J., Liu, Q., Wider, W., Zhang, S., Fauzi, M. A., Jiang, L., et al. (2024). Research landscape of energy transition and green finance: a bibliometric analysis. *Heliyon* 10 (3), e24783. doi:10.1016/j.heliyon.2024.e24783
- Yang, T., Sun, Z., Du, M., Du, Q., Li, L., and Shuwaikh, F. (2023). The impact of the degree of coupling coordination between green finance and environmental regulations on firms’ innovation performance: evidence from China. *Ann. Operations Res.* doi:10.1007/s10479-023-05704-9
- Yeow, K. E., and Ng, S.-H. (2021). The impact of green bonds on corporate environmental and financial performance. *Manag. Finance* 47 (10), 1486–1510. doi:10.1108/mf-09-2020-0481
- Yi, J., Oh, Y. K., and Kim, J. M. (2025). Unveiling the drivers of satisfaction in mobile trading: contextual mining of retail investor experience through BERTopic and generative AI. *J. Retail. Consumer Serv.* 82, 104066. doi:10.1016/j.jretconser.2024.104066
- Yu, X., Mao, Y., Huang, D., Sun, Z., and Li, T. (2021). Mapping global research on green finance from 1989 to 2020: a bibliometric study. *Adv. Civ. Eng.* 2021. doi:10.1155/2021/9934004
- Zakari, A., and Khan, I. (2022). The introduction of Green Finance: a curse or a benefit to environmental sustainability? *Energy Res. Lett.* 3 (3). doi:10.46557/001c.29977
- Zhang, D., Mohsin, M., and Taghizadeh-Hesary, F. (2022). Does green finance counteract the climate change mitigation: asymmetric effect of renewable energy investment and R&D? *Energy Econ.* 113, 106183. doi:10.1016/j.eneco.2022.106183
- Zhang, D., Zhang, Z., and Managi, S. (2019). A bibliometric analysis on green finance: current status, development, and future directions. *Finance Res. Lett.* 29, 425–430. doi:10.1016/j.frl.2019.02.003
- Zhou, M., and Li, X. (2022). Influence of green finance and renewable energy resources over the sustainable development goal of clean energy in China. *Resour. Policy* 78, 102816. doi:10.1016/j.resourpol.2022.102816
- Zhou, X., Tang, X., and Zhang, R. (2020). Impact of green finance on economic development and environmental quality: a study based on provincial panel data from China. *Environ. Sci. Pollut. Res.* 27 (16), 19915–19932. doi:10.1007/s11356-020-08383-2
- Ziolo, M., Bak, I., and Cheba, K. (2021). The role of sustainable finance in achieving sustainable development goals: does it work? *Technol. Econ. Dev. Econ.* 27 (1), 45–70. doi:10.3846/tede.2020.13863