

REVIEW

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Blockchain and sustainable finance as enablers of regenerative finance: a bibliometric and thematic review

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Abstract

Blockchain technology, sustainable finance, and regenerative finance are increasingly intersecting as vital research frontiers in addressing global environmental and social challenges. This study offers a comprehensive bibliometric and thematic analysis of the scholarly landscape at this intersection, aiming to illuminate how these domains are evolving and converging. Drawing on a curated dataset of 78 peer-reviewed articles sourced from Scopus and Web of Science, the research integrates quantitative bibliometric mapping with qualitative thematic insights to capture both the structural and conceptual dimensions of the field. The analysis employs co-word mapping to explore patterns of keyword co-occurrence and identify key intellectual linkages, thematic evolution analysis to track the development of major research themes over time, and factorial correspondence analysis to visualize the relationships among concepts within a multidimensional space. Findings reveal a rapidly growing and increasingly interdisciplinary body of work, with blockchain and sustainable finance serving as central pillars, while regenerative finance, though still emerging, shows strong conceptual potential. Notably, the appearance of AI-related themes suggests a nascent yet promising integration of intelligent systems with sustainability-focused finance. Together, these insights offer a nuanced understanding of the field's current dynamics and lay the groundwork for future research on regenerative, technology-enabled financial systems.

Keywords Blockchain, Sustainable finance, Regenerative finance, Bibliometric analysis, Thematic analysis

JEL Classification C89, G23, L86, O33

1 Introduction

The growing urgency of climate change and environmental degradation has prompted renewed attention to how financial systems can support sustainable development. In recent years, sustainable finance has moved from the margins to the mainstream, driven by increasing regulatory pressure, evolving investor expectations, and a broader understanding of fiduciary responsibility. In particular, regulations originating in Europe, and now influencing markets globally, require financial actors to incorporate environmental,



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social, and governance (ESG) risks and opportunities into their decisions. This shift reflects a fundamental change in how financial value and responsibility are understood (de Mariz et al. [5]; Redondo and de Mariz [20]). At the same time, technological innovation, especially in the form of blockchain and distributed ledger technologies, is reshaping the financial landscape. Blockchain offers a decentralized, transparent, and secure way of recording transactions, with growing applications in sustainability-related finance. These include traceable carbon markets, automated ESG reporting, and decentralized models of governance. While often promoted as a way to improve accountability and reduce reliance on intermediaries, blockchain is not without challenges: high energy consumption, regulatory uncertainty, and technological complexity all raise concerns, particularly in the context of climate-focused initiatives (Huseynov and Mitchell [9]; Ren et al. [21]; Yamahaki et al. [26]).

Emerging alongside these developments is the concept of regenerative finance, or ReFi. Unlike traditional sustainable finance, which focuses on reducing negative impacts, ReFi seeks to design financial systems that actively regenerate ecosystems and support community well-being. Often enabled by blockchain and other decentralized technologies, ReFi includes innovations such as tokenized carbon credits, nature-backed digital assets, and decentralized autonomous organizations (DAOs) that allow local participation in environmental finance. While still a relatively new area of research, ReFi introduces a more transformative vision of how finance can contribute to ecological and social repair (Lei et al. [16]; Asl et al. [3]; de Mariz [5]).

Despite growing interest in each of these areas, the academic literature that connects sustainable finance, blockchain, and regenerative finance remains limited and fragmented. Existing studies often focus on one or two of these concepts in isolation. For example, recent bibliometric reviews have mapped trends in sustainable finance (Roy and Vasa [22]; Kaura and Kumar [10]), while others have examined blockchain or artificial intelligence in ESG contexts (Arslan et al. [2]; Lăzăroiu et al. [15]; Nefla and Jellouli [19]). However, few studies integrate all three, and regenerative finance in particular remains underexplored in both conceptual and empirical terms. There is a clear need for a more integrated perspective that captures the intersections between these emerging domains. This review aims to fill that gap by offering a comprehensive analysis of the scholarly literature that connects blockchain, sustainable finance, and regenerative finance. Drawing on a curated dataset of 78 peer-reviewed articles published between 2021 and 2025; the study combines bibliometric mapping with thematic analysis to explore how these fields are evolving together. Unlike previous reviews, these work-places ReFi at the center of the analysis, offering a new perspective on how decentralized technologies can be used not only to mitigate harm but to actively support regeneration and equity. The review also considers how scholarly conversations have been shaped across disciplines, geographies, and institutional contexts, with attention to emerging challenges such as greenwashing, energy use, and the digital divide. To guide the analysis, we address the following three research questions:

RQ1: What does bibliometric analysis reveal about the scholarly landscape at the intersection of blockchain, sustainable finance, and regenerative finance?

RQ2: What are the dominant themes and knowledge structures shaping this field?

RQ3: What future research directions are needed to advance regenerative, blockchain-enabled financial systems in theory and practice?

These three questions are retained deliberately: while the first provides a structural, data-driven overview through bibliometric techniques, the second builds on this by identifying and interpreting key thematic patterns, both necessary steps before proposing meaningful directions for future research. Our findings show that the field is growing rapidly, with a sharp increase in publications since 2021. Research on blockchain and sustainable finance is expanding, especially in areas such as carbon markets, ESG verification, and financial inclusion. ReFi is beginning to emerge as a distinct concept, often connected to community-driven sustainability platforms and tokenized environmental assets. However, important limitations remain: there is still little agreement on standards for measuring impact, blockchain's environmental footprint raises concerns, and most projects remain concentrated in the Global North. These challenges highlight the need for deeper empirical research, clearer regulatory frameworks, and inclusive governance models.

This paper is organized as follows. Section 2 reviews the existing literature on blockchain, sustainable finance, and ReFi. Section 3 describes the methodology, including database selection and analytical tools. Section 4 presents the bibliometric results, while Sect. 5 explores key thematic patterns. Section 6 discusses implications for future research, and Sect. 7 concludes with reflections on policy and scholarly contributions.

2 Theoretical background: blockchain, sustainable finance, and regenerative finance

While each of the core concepts, blockchain, sustainable finance, and regenerative finance, has evolved from different intellectual traditions, they increasingly converge around shared objectives of transparency, accountability, inclusion, and ecological resilience. This section explores their intersections in more detail, showing how technological innovation and financial reorientation coalesce to support regenerative models of economic development.

2.1 Blockchain

Blockchain is a decentralized digital ledger technology designed to securely record and verify transactions across distributed networks. Its core attributes, immutability, transparency, decentralization, and consensus, have led to widespread applications, including cryptocurrencies, digital identity verification, and ESG-related financial services (Huseynov and Mitchell [9]). These applications extend into supply chains, carbon markets, and green bond issuance, where blockchain enables traceability, tokenization, and smart contract automation (Ren et al. [21]; Chen and Volz [4]).

Beyond infrastructure, blockchain's impact on financial modeling and forecasting is expanding rapidly. Deep learning innovations, such as transformer-based models and hybrid LSTM-GRU networks, have leveraged blockchain-generated financial data to improve prediction accuracy in crypto-finance and sustainability-linked asset markets (Kehinde et al. [11]; Kehinde et al. [12]). However, challenges persist. High energy use in Proof-of-Work blockchains raises environmental concerns, although newer consensus models (e.g., Proof-of-Stake) offer improvements (Sharma et al. [24]). Other concerns include privacy risks, interoperability limitations, and regulatory uncertainty. In low-trust or fragile contexts, blockchain can simultaneously reduce corruption and exclude marginalized groups due to technical barriers (Huseynov and Mitchell [9]). As

blockchain systems grow in complexity, questions of governance, AI integration, and algorithmic transparency will become central (Kehinde et al. [13]).

2.2 Sustainable finance

Sustainable finance involves integrating environmental, social, and governance (ESG) factors into financial decision-making to support long-term ecological and economic health. It encompasses responsible investment, climate-aligned lending, and green infrastructure financing, all tied to international frameworks like the UN SDGs and the Paris Agreement (Chen and Volz [4]). Over the past decade, it has moved from a niche concept to a core financial norm, supported by rising investor demand and tightening regulation. A major driver of this shift is the legal reinterpretation of fiduciary duty, which increasingly mandates that executives and asset managers incorporate ESG risks into financial governance (de Mariz et al. [5]). European regulatory leadership, particularly through the EU Taxonomy and Sustainable Finance Disclosure Regulation (SFDR), has global spillover effects on corporate ESG disclosure and investment flows (Redondo and de Mariz [20]).

Despite this momentum, concerns about greenwashing, where ESG claims lack substance, persist. A recent study shows that many thematic bond issuers fail to meet promised sustainability objectives, undermining trust and accountability in ESG-labelled instruments (Yamahaki et al. [26]). Moreover, inconsistent ESG ratings, fragmented data standards, and a lack of performance benchmarking hinder comparability across investments (Ante [1]; Lin et al. [17]). These shortcomings point to the need for digital tools that automate impact tracking and ensure regulatory alignment, areas where blockchain and AI hold promise.

2.3 Regenerative finance (ReFi)

Regenerative finance (ReFi) is a fast-evolving approach that builds upon sustainable finance principles but prioritizes ecosystem restoration and community empowerment as direct outcomes of capital allocation. Unlike ESG investing, which often seeks to “do less harm,” ReFi aspires to do net good by embedding circular economy logic, natural capital accounting, and decentralized governance directly into financial systems. It frequently leverages blockchain technologies, particularly for tokenized carbon credits, environmental DAOs, and nature-backed digital assets (Lei et al. [16]; Asl et al. [3]).

ReFi’s value proposition lies in making positive ecological externalities financially viable. Examples include platforms like KlimaDAO and Toucan, which tokenize carbon credits to enhance liquidity in voluntary carbon markets. Building on earlier FinTech-driven inclusion models, ReFi is increasingly being positioned as a tool to empower climate-vulnerable populations in the Global South, particularly through decentralized microfinance, blockchain-based climate registries, and community-governed environmental assets (De Mariz [6]; Lei et al. [16]). Yet, its growth is constrained by multiple systemic challenges: the lack of globally accepted MRV (monitoring, reporting and verification) standards for tokenized environmental assets; weak regulatory coordination; and distrust in on-chain ecological data. The integration of AI, such as remote sensing and smart contracts triggered by real-time environmental data, may offer solutions, but practical implementation remains uneven (Kehinde et al. [11]). Scaling ReFi will depend

on building trust, ensuring inclusivity, and aligning emerging digital tools with transparent governance mechanisms.

While blockchain, sustainable finance, and regenerative finance emerged from distinct intellectual lineages, technological innovation, institutional reform, and ecological economics, they are converging into a powerful composite framework. Blockchain acts as an enabler of traceability, automation, and decentralization; sustainable finance anchors ESG goals in capital flows and fiduciary practice; and ReFi proposes a regenerative logic that reframes value creation around planetary and social health. Their integration is not just additive, it's transformative. Together, these domains offer a new financial architecture capable of addressing structural inequalities, ecological degradation, and systemic accountability gaps in ways traditional systems have failed to achieve.

3 Research methodology

This study adopts a mixed-method bibliometric and thematic analysis to systematically map the scholarly landscape at the intersection of blockchain, regenerative finance (ReFi), and sustainable finance. By combining quantitative publication data with qualitative insights into thematic development, the methodology aims to offer both breadth and depth in understanding how these domains interact and evolve.

3.1 Data collection protocol

The data for this study were collected using a structured and replicable search protocol designed to capture relevant literature across major academic databases. Two prominent academic databases, Scopus and Web of Science (WoS), were selected due to their comprehensive coverage of high-quality scholarly journals in finance, technology, and environmental studies. The keyword strategy was designed to reflect both general and specific terminology associated with the topic. Figure 1 includes the keywords searched in the databases:

3.1.1 PICOS framework

To systematically categorize the collected data, a classification framework was developed based on the PICOS (Population, Intervention, Comparison, Outcomes and Study Setting) model. This framework facilitated the organization of research questions and guided the data classification process, ensuring alignment with the study's objectives. By applying PICOS, the research maintained methodological rigor, enabling the selection

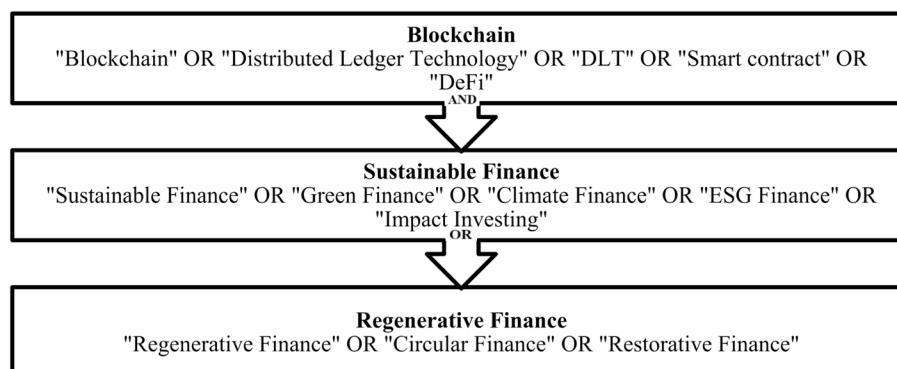


Fig. 1 Keywords search in scopus and web of science database. *Source* Authors' compilation

of relevant literature while excluding extraneous sources. This structured approach enhanced analytical precision, ensuring that the synthesized data directly contributed to addressing the study’s core research questions.

Table 1 presents the population criterion focused on peer-reviewed academic publications, while Intervention identified studies examining blockchain, ReFi, and sustainable finance applications. Comparison ensured the inclusion of empirical or theoretical analyses with meaningful contextual contrasts, and Outcomes prioritized research with measurable sustainability or financial impacts. Finally, Setting established linguistic (English-only) boundaries to capture the most recent and accessible scholarly contributions. Collectively, this framework strengthened the study’s validity by minimizing selection bias and reinforcing a systematic, replicable literature review process.

3.1.2 PRISMA framework

Figure 2 shows the PRISMA methodology for identifying relevant literature, we conducted a comprehensive search across the Scopus (n = 2,071) and Web of Science (n = 39) databases, yielding a total of 2,110 records. The search focused on peer-reviewed publications, a period marked from 2021 to early 2025 by rapid growth in interest and research output related to blockchain and sustainable finance innovations. After removing 529 duplicates and studies outside the selected subject areas (business, management, accounting, economics, econometrics, and finance), 1,581 records were screened. We then excluded 688 records based on document type (e.g., reviews) and language (non-English). The remaining 893 records were further evaluated based on study topic relevance, and 815 were excluded after assessing titles, abstracts, and keywords. This process resulted in 78 full-text peer-reviewed articles deemed eligible for bibliometric and thematic analysis.

All metadata, such as title, abstract, keywords, source, authorship, affiliations, and citations, were exported in BibTeX and CSV formats to ensure compatibility with bibliometric software.

3.2 Data analysis technique

The analysis was conducted in two main phases: bibliometric analysis and thematic mapping, following established practices in research synthesis (Zupic and Čater [27]).

Table 1 PICOS framework. *Source* Authors’ Compilation

Criteria	Inclusion	Exclusion
Population	Peer-reviewed academic articles, conference papers, and book chapters focusing on blockchain, ReFi, and sustainable finance	Non-academic sources (e.g., reports, blogs, news articles), studies unrelated to finance or sustainability
Intervention	Studies examining blockchain applications in sustainable finance, ReFi mechanisms, tokenization, decentralized finance (DeFi), ESG integration, or climate finance	Studies not involving blockchain or digital finance solutions
Comparison	Comparative studies (e.g., blockchain vs. traditional finance), case studies, empirical analyses, and theoretical models	Studies without a clear financial or sustainability context
Outcome	Research measuring impact on sustainability, financial inclusion, carbon markets, governance, or technological feasibility	Studies without measurable outcomes or purely speculative discussions
Study setting	English-language publications in Scopus and Web of Science (business, economics, finance, and environmental studies)	Non-English studies, reviews without original research

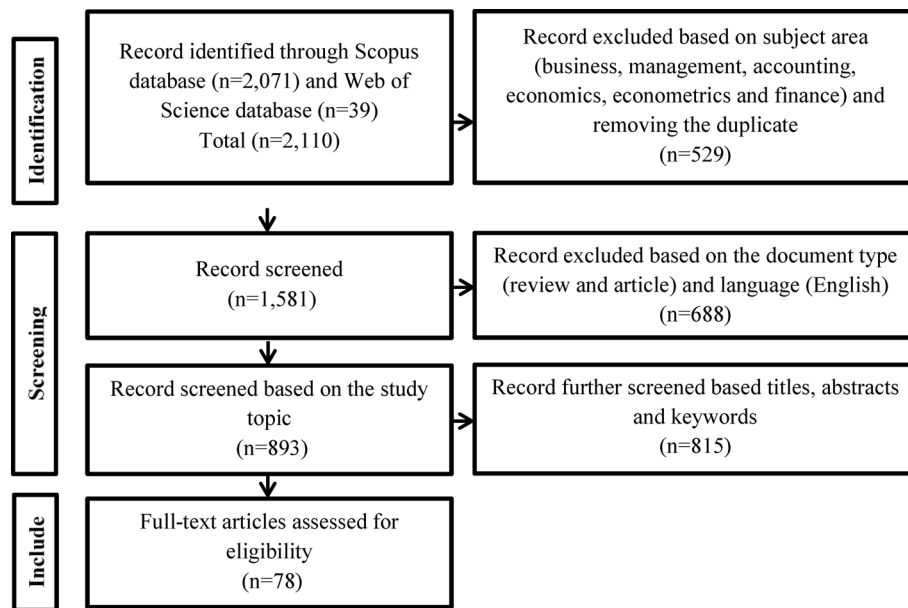


Fig. 2 PRISMA methodology. *Source* Authors' compilation

3.2.1 Bibliometric analysis

The bibliometric analysis was conducted using Bibliometrix, an R package, along with its web-based interface Biblioshiny, enabling a comprehensive exploration of academic output through sophisticated analytical tools. Key metrics examined included annual scientific production to track publication trends over time, the identification of the most productive authors and institutions, and the assessment of citation impact by country and source. Additionally, the analysis mapped co-authorship and collaboration networks to reveal scholarly partnerships and employed keyword co-occurrence and frequency analysis to uncover dominant themes and conceptual linkages within the field. Together, these metrics provided insights into influential contributors, prominent publication venues, geographic distributions of research activity, and the intellectual structure of the interdisciplinary domain under study.

3.2.2 Thematic analysis

The second phase of analysis employed thematic clustering and content mapping to derive nuanced insights into emerging research trends. This qualitative exploration was conducted through three complementary approaches: co-word analysis to map keyword co-occurrence patterns and reveal underlying intellectual structures; thematic evolution analysis to examine how dominant research themes progressed across distinct periods (2021–2022, 2023–2024, and 2025); and factorial correspondence analysis to systematically group related terms and documents within a multidimensional thematic framework. Together, these analytical techniques enabled a comprehensive examination of conceptual developments, temporal shifts in research focus, and the complex interrelationships among key themes in the literature.

4 Bibliometric analysis

To address research question one, we conducted a bibliometric analysis of seventy-eight peer-reviewed documents published between 2021 and 2025, using structured search queries applied across Scopus and Web of Science databases. The aim was to quantify research activity, identify influential contributors, and map collaboration patterns within the field connecting blockchain, regenerative finance (ReFi), and sustainable finance.

Figure 3 indicates a rapidly expanding research field, with an annual publication growth rate of 60.69%. Scholarly interest spiked in 2024 with thirty-five publications, a tenfold increase from 2021, signaling rising academic and institutional engagement. This surge aligns with post-pandemic momentum around climate action, digital innovation, and ESG mandates.

4.1 Geographic distribution and institutional productivity

The global distribution of research in the intersection of blockchain, sustainable finance, and regenerative finance reflects significant geographic concentration, with China and India emerging as the most prolific contributors. China leads with 40 publications, followed closely by India with 34, and then Australia (11), the United States (10), and the United Kingdom (9). However, impact does not strictly follow volume. India stands out for its scholarly influence, recording the highest total citations (294) and an impressive average citation count of 24.5 per article, surpassing all other countries. Smaller research communities such as Ireland and Romania also demonstrate high citation averages (28.0 and 23.0, respectively), underscoring the qualitative impact of select national contributions despite a lower overall publication count.

Institutional productivity further reveals the academic centers driving this emerging field. Hunan University in China tops the list with 20 published articles, significantly outpacing the second most active institution, RMIT University in Australia, which produced 6 articles. Other notable contributors include An Najah National University (5), Ningbo University (5), and several institutions with 3 or more publications, such as the University of Piraeus, Delhi University, and Széchenyi István University. These findings suggest a broadening engagement across continents, although the dominance of a few institutions signals an opportunity for further diversification and global academic collaboration.

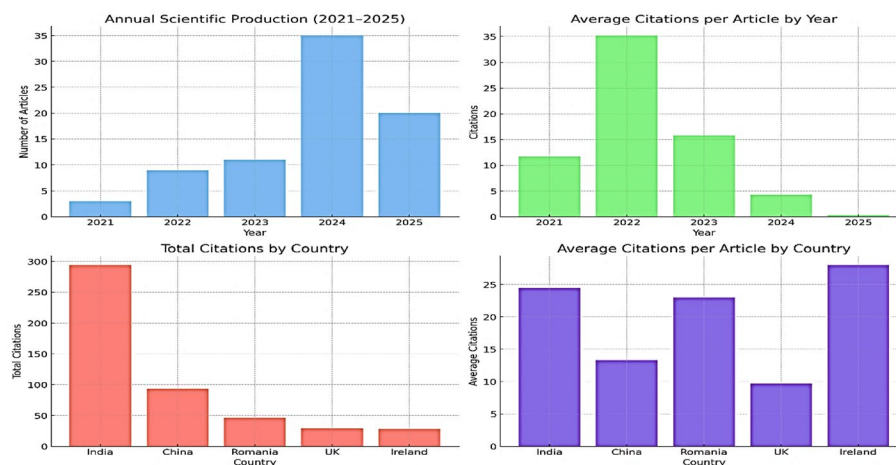


Fig. 3 Annual scientific production, average and total citations. *Source* Authors' compilation

4.2 Leading authors and sources

The scholarly discourse on blockchain, sustainable finance, and regenerative financial systems is being shaped by a small cohort of prolific and influential authors. Among them, S. Kumar, C. Ma, and Y. Ren stand out for both the number of publications and citation impact. Each of these authors has contributed significantly through three peer-reviewed outputs between 2022 and 2025, with a focus on ESG integration, bibliometric synthesis, and the intersection of FinTech and sustainability.

S. Kumar's landmark paper, *Past, Present, and Future of Sustainable Finance: Insights from Big Data Analytics through Machine Learning of Scholarly Research*, published in the *Annals of Operations Research* (2022), has amassed 233 citations to date, by far the highest in the dataset, reflecting its foundational role in mapping the intellectual terrain of sustainable finance using machine learning. Kumar also contributed a forward-looking book chapter in 2025 titled *Frontiers of Innovation: Unveiling the Future Opportunities in FinTech*, which further contextualizes financial transformation in a digital era. C. Ma and Y. Ren have frequently collaborated, co-authoring impactful articles such as *Sustainable Finance and Blockchain: A Systematic Review and Research Agenda* in *Research in International Business and Finance* (2023), each attracting 48 citations. Their 2025 joint article, *Decoding the Nexus: How FinTech and AI Stocks Drive the Future of Sustainable Finance*, while more recent, illustrates a pivot toward analysing digital asset ecosystems using econometric tools. Their bibliometric contribution in *Sustainability Accounting Management and Policy Journal* (2025) further extends the methodological scope of the field. Other notable contributors include A. Abdalnaser, whose 2023 article in the *Journal of Sustainable Finance & Investment* received 35 citations, and D. Mhlanga and Y. Liu, who have addressed emerging regional perspectives and the role of green technologies in ESG strategy, albeit with fewer citations due to more recent publication dates.

From a journal and source perspective, the field's output is highly interdisciplinary. The *Journal of Sustainable Finance & Investment*, *Research in International Business and Finance*, and the edited volume *The Sustainable FinTech Revolution* are among the most active and impactful platforms. Notably, *Research in International Business and Finance* leads in terms of h-index ($h = 3$) and total citations ($TC = 86$) across three contributions, underscoring its centrality to the discourse. Other key outlets include *Sustainable Finance*, *International Review of Economics & Finance*, and *Annals of Operations Research*, each contributing valuable empirical and theoretical work that spans economics, operations research, and digital innovation.

These patterns illustrate a maturing literature anchored by a few prolific scholars, with growing engagement across interdisciplinary journals. Together, this evolving authorship and source landscape signal the field's momentum toward conceptual consolidation and methodological diversity.

4.3 Collaboration networks and co-authorship patterns

The collaborative nature of research in sustainable finance and blockchain is evident through a notable concentration of co-authored works. Out of the seventy-eight documents analysed, a total of 202 unique authors contributed to the field, with only ten articles (representing approximately 12.8%) being single-authored. This figure not only illustrates a distinct inclination toward teamwork but also suggests that the complexity

of themes addressed demands collective academic effort. Collaboration thus emerges as a hallmark of this scholarly domain, reflecting the necessity of integrating diverse perspectives and expertise to address the multifaceted challenges of sustainability and digital finance.

International co-authorship further underscores the global character of the field. Approximately 22.06% of the publications involved cross-border collaboration, signaling a high level of engagement across national boundaries. Among the most frequently observed bilateral partnerships is the cooperation between India and Malaysia, which has emerged as a recurrent alliance in the corpus. Similarly, China and New Zealand demonstrate a particularly strong linkage, with multiple instances of co-authored work, indicating sustained academic dialogue between East Asia and Oceania. Additional noteworthy patterns include collaborations between the United Kingdom and several European countries, such as Germany, Denmark, and Greece, as well as Singapore. These connections point to the UK's central role in facilitating scholarly exchange across regional clusters. The United States also maintains dynamic research partnerships, particularly with the United Kingdom and Singapore, further reinforcing transcontinental engagement in the field. The global nature of these collaborations is visually represented in Fig. 4, which depicts a world map of co-authorship networks. This visualization highlights not only the volume but also the geographical diversity of joint research efforts. The connections mapped across Asia, Europe, and North America attest to a research ecosystem that is both inclusive and expansive. Indeed, scholars from a broad spectrum of disciplinary backgrounds come together in these networks, thereby enhancing the interdisciplinary depth of the literature. Such collaborative configurations are essential

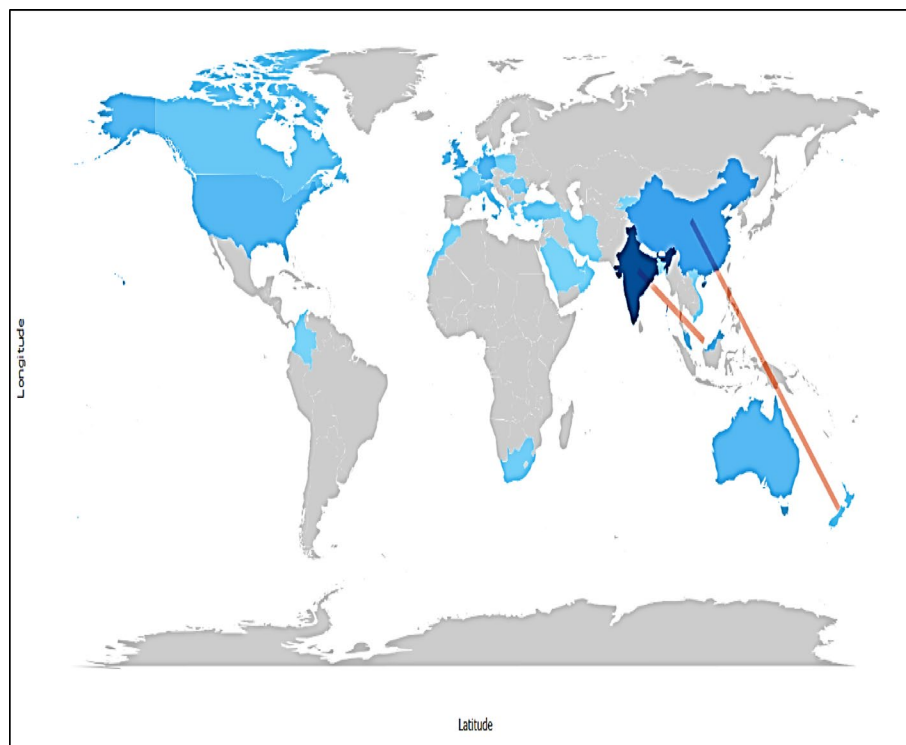


Fig. 4 Countries' collaboration world map. Source Bibliometrix Package of R

in a field that is inherently cross-cutting and responsive to real-world concerns such as climate change, digital disruption, and inclusive financial growth.

Ultimately, the patterns revealed in this analysis illustrate more than mere statistical co-authorship; they reveal a vibrant and interconnected academic community, unified by shared interests and mutual intellectual investment. The prominence of international collaboration not only strengthens the field's empirical and theoretical foundations but also contributes to its capacity for innovation and practical relevance. As sustainability and fintech continue to evolve in tandem, these scholarly alliances are likely to play a crucial role in shaping future research agendas and informing global policy dialogues.

5 Thematic analysis

To address research question two, this study applied thematic analysis to synthesize recurring patterns and conceptual clusters from the literature intersecting blockchain, regenerative finance (ReFi), and sustainable finance. Drawing from seventy-eight peer-reviewed documents published between 2021 and 2025, the analysis employed co-word mapping, keyword clustering and thematic evolution tracking to capture the intellectual structure of this emerging field. Table 2 provides the thematic analysis of Blockchain, Sustainable Finance and Regenerative Finance.

6 Keyword co-occurrence network

The keyword co-occurrence network was developed in the bibliographic corpus between 2021 and 2025. This visualization maps the frequency and strength of relationships between key concepts in the literature on blockchain, ReFi, and sustainable finance. Nodes represent keywords, and edges indicate co-occurrence strength, i.e., how often two terms appear together in the same studies.

Figure 5 displays a keyword co-occurrence network coloured by thematic clusters, while the table below quantifies node-level metrics such as betweenness centrality, closeness centrality, and PageRank. The network is organized into four thematic clusters, each representing distinct but interconnected research themes:

Cluster 1 (Red) centers around core terms like blockchain, finance, sustainable, financial, fintech, and study. This cluster anchors the discourse and reflects foundational work bridging fintech innovation with sustainable development paradigms. Terms like blockchain and finance have the highest PageRank and betweenness centrality, indicating they are conceptually dominant and frequently serve as bridges connecting other themes.

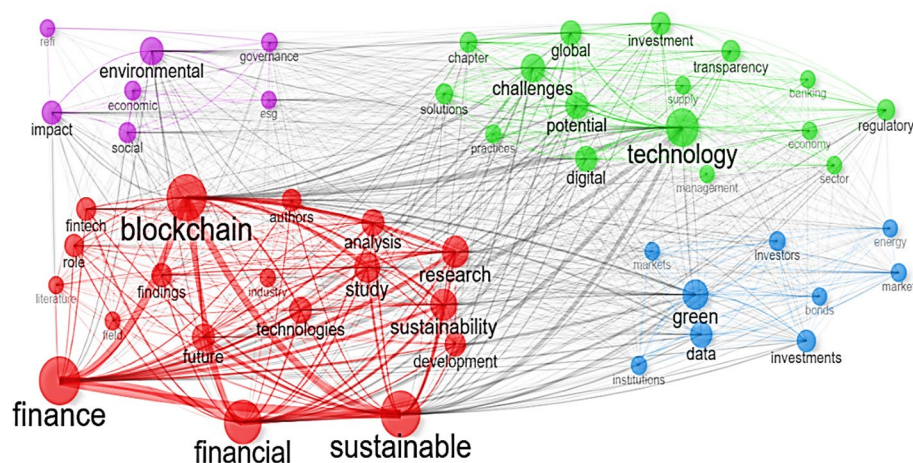
Cluster 2 (Blue) emphasizes terms such as green, investments, data, market, and investors. This group is more application-oriented and focused on financial instruments, investment behaviour, and ESG data infrastructures.

Cluster 3 (Green) includes technology, digital, transparency, global, and challenges. This thematic space explores the potential and limitations of technological adoption in financial and sustainability contexts. Technology holds a significant betweenness score (5.30) and is the most central node outside Cluster 1.

Cluster 4 (Purple) captures the social-environmental dimension with keywords like impact, governance, ESG, refi, and environmental. The presence of ReFi within this cluster, despite its low centrality and PageRank, suggests it is still emerging as a research focus but is tightly linked with impact-oriented finance and governance debates.

Table 2 Thematic analysis of blockchain, sustainable finance and regenerative finance. *Source* Authors' compilation

Authors, year	Theme	Key findings	ReFi focus	Blockchain applications	Sustainability link
Lei et al. (2024) [16], Chen and Volz (2022) [4]	Climate finance & carbon markets	ReFi tokens (e.g., KlimaDAO, Toucan) enable carbon credit tokenization, improving liquidity and transparency	ReFi bridges carbon markets with decentralized finance (DeFi), enabling fractional ownership of carbon credits	Smart contracts automate carbon credit issuance/trading; blockchain ensures immutable records	Reduces greenwashing; aligns with Paris Agreement goals
Ma et al. (2025) [18], Chen and Volz (2022) [4]	Energy transition	ReFi and blockchain facilitate renewable energy investments and decentralized energy trading	ReFi platforms fund clean energy projects via tokenized bonds or community-owned assets	Peer-to-peer (P2P) energy trading; IoT integration for real-time data	Lowens reliance on fossil fuels; supports SDG 7 (Affordable Clean Energy)
Sharma et al. (2024) [24], Kumar et al. (2025) [14]	Green bonds & sustainable investing	Blockchain enhances transparency in green bond issuance and impact reporting	ReFi democratizes access to green bonds for small investors via fractionalization	Smart contracts automate coupon payments; DLT ensures auditability	Combats greenwashing; aligns with ESG frameworks
Ren et al. (2023) [21], Ding et al. (2022) [7]	Supply chain sustainability	Blockchain tracks ESG compliance and carbon footprints across supply chains	ReFi incentivizes regenerative practices (e.g., fair-trade premiums via tokens)	Immutable tracking of materials (e.g., conflict-free minerals, organic farming)	Ensures ethical sourcing; reduces Scope 3 emissions
Sapra and Shaikh (2023) [23], Lei et al. (2024) [16]	Cryptocurrency & environmental impact	Proof-of-Stake (PoS) blockchains (e.g., Ethereum) reduce energy use vs. Bitcoin (PoW)	ReFi promotes low-carbon crypto projects (e.g., KlimaDAO's carbon-backed tokens)	Transition to PoS consensus cuts energy use by ~99%	Addresses critiques of crypto's carbon footprint
Drăgan et al. (2025) [8], Sharma et al. (2024) [24]	Financial inclusion	Blockchain and ReFi enable micro-loans/insurance for underserved communities	ReFi platforms offer decentralized credit scoring via on-chain data	Stablecoins and DeFi protocols reduce reliance on traditional banking	Supports SDG 1 (No Poverty) and SDG 10 (Reduced Inequalities)
Trotta et al. (2024) [25], Asl et al. (2024) [3]	Regulatory challenges	Lack of standardized frameworks for ReFi and blockchain in sustainable finance	ReFi requires interoperability with legacy financial systems	Regulatory sandboxes are needed for CBDCs and tokenized assets	Balancing innovation with investor protection

**Fig. 5** Keyword co-occurrence network. *Source* Bibliometrix Package of R

The network structure shows a high degree of interconnectivity, indicating a field that is both conceptually dense and increasingly interdisciplinary. The co-linking of “blockchain” with “study,” “sustainability,” and “technologies” demonstrates strong methodological emphasis, while keywords like “green,” “impact,” and “governance” point to practical and ethical dimensions gaining momentum.

From the thematic analysis, the centrality metrics help distinguish between conceptual hubs and thematic bridges:

High PageRank Nodes: Finance (0.045), sustainable (0.043), blockchain (0.043), and financial (0.041) are the most authoritative terms, indicating they are frequently connected to other influential nodes.

High Betweenness Nodes: Finance (14.23), blockchain (11.40), and technology (5.30) act as bridges between different thematic regions. These keywords facilitate interdisciplinary linkages, e.g., between technical innovation and sustainable economic frameworks.

Emergent/Niche Nodes: ReFi scores zero on betweenness and extremely low on closeness, reflecting its early-stage emergence and minimal integration into broader scholarly conversations, though its thematic clustering with governance and impact suggests strong potential for future interdisciplinary integration. Nonetheless, its presence in a distinct governance-impact cluster suggests future potential as the field matures.

6.1 Thematic evolution analysis

Figure 6 represents the period 2021 and 2022, the literature was anchored by two well-developed and highly relevant themes: one focused on sustainable development and global goals and the other on blockchain’s role in supply chain and sustainable financing. Basic themes such as sustainable finance, fintech solutions and crowdfunding platforms were central but less developed, indicating foundational relevance with scope for deeper inquiry. The emerging theme was data analytics in these years.

Figure 7 represents the period 2023–2024; the thematic landscape became more dynamic and diversified. “Sustainable finance,” “blockchain technology,” and “green finance” emerged as motor themes, showing high centrality and development, signaling their critical role in bridging theory and application. “Regenerative finance” and “finance refi,” although conceptually relevant, remained in the emerging quadrant, highlighting their underexplored but growing potential.

Figure 8 represents the period 2025, the thematic landscape showed further consolidation around “sustainable finance,” “blockchain technology,” and “sustainable

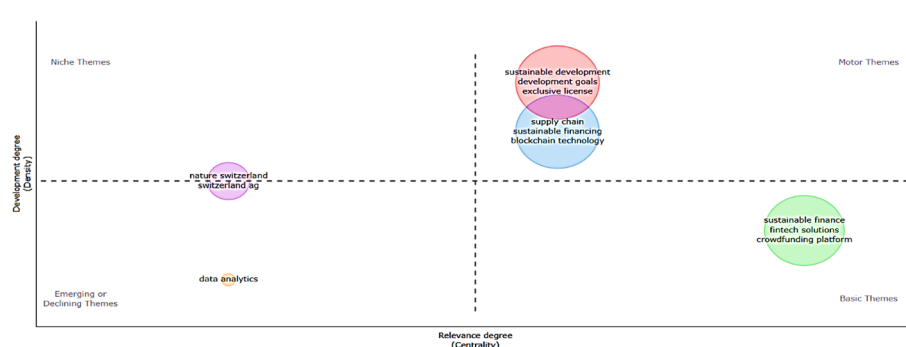


Fig. 6 Thematic evolution analysis from 2021 to 2022. Source Bibliometrix Package of R

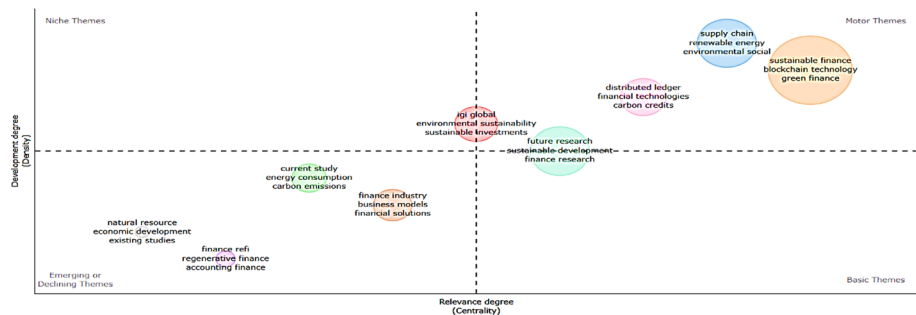


Fig. 7 Thematic evolution analysis from 2023 to 2024. *Source* Bibliometrix Package of R

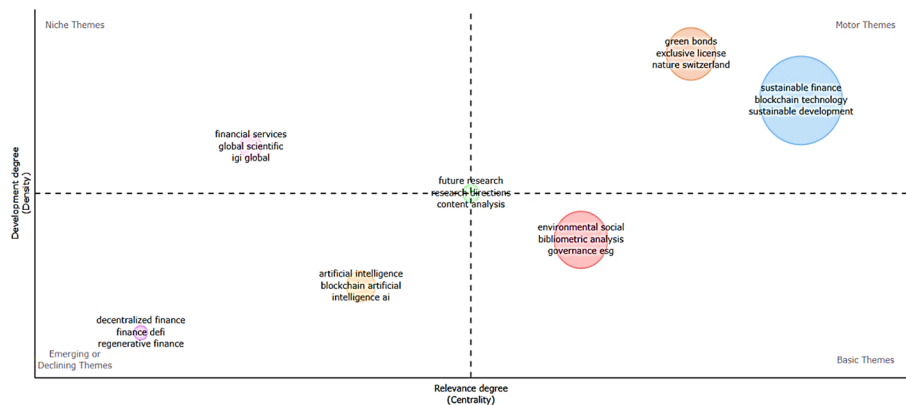


Fig. 8 Thematic evolution analysis of 2025. *Source* Bibliometrix Package of R

Table 3 Factorial correspondence analysis of keywords. *Source* R-Bibliometrix Biblioshiny

Keyword	Dim1	Dim2	Cluster
Sustainable finance	−0.34	−0.22	1
Blockchain technology	0.14	−0.11	1
Regenerative finance	0.52	0.54	1

development” as motor themes, reflecting their ongoing dominance and maturity in the research discourse. Meanwhile, topics like “artificial intelligence” and “blockchain AI” appeared with moderate centrality but lower development, suggesting growing interest in integrating emerging technologies with finance. “Environmental social” and “governance ESG” are positioned as basic themes, indicating foundational relevance but requiring more conceptual elaboration. Conversely, “Regenerative finance” and “decentralized finance” remained in the emerging quadrant, reflecting their current conceptual novelty and the need for further empirical development, rather than a lack of relevance.

6.2 Factorial correspondence analysis

Table 3 indicates the factorial analysis, which reveals that “sustainable finance” and “blockchain technology” are centrally located within the same thematic cluster, indicating their strong conceptual alignment in the literature. “Regenerative finance,” while in the same cluster, is positioned further away in both dimensions, suggesting it remains an emerging but distinct theme within the broader sustainable finance ecosystem. This

spatial differentiation highlights both integration and specialization across sustainability-oriented financial technologies.

7 Discussions and propositions for future research

This study reveals a rapidly evolving and increasingly interdisciplinary field that bridges technological innovation with sustainable financial practices. The bibliometric analysis demonstrated an exponential growth in scholarly output since 2021, with notable contributions from countries like India and China and strong international collaboration. Key research themes have matured over time, moving from conceptual discussions on sustainability and blockchain toward applied studies in tokenized carbon markets, green bonds, ESG fintech, and decentralized finance models.

Thematic mapping across multiple periods (2021–2025) has shown a dynamic transformation in research priorities. Early themes centered on sustainable development, green finance, and blockchain technology as motor themes, reflecting foundational interests in leveraging DLT for ESG objectives. In subsequent years, themes such as tokenization, supply chains, and financial inclusion gained prominence. ReFi appears in emerging or niche categories, reflecting its early-stage integration and growing relevance within academic discourse. Its current peripheral positioning suggests it is conceptually distinct and holds significant cross-cutting potential for future research.

Keyword co-occurrence and factorial analyses further reinforce this pattern. Central terms like “blockchain,” “sustainable finance,” and “green bonds” are densely interconnected, suggesting their role in anchoring the field’s intellectual structure. In contrast, terms like “regenerative finance,” “decentralized finance,” and “AI-blockchain integration,” though increasingly present, remain on the conceptual periphery. Notably, the factorial positioning of “regenerative finance” shows a spatial divergence from more mature themes, suggesting its distinctiveness and potential for deeper inquiry. To address research question three, the study prepares future research direction by indicating the following propositions.

7.1 Theoretical deepening of regenerative finance (ReFi)

Despite growing academic and practical interest, ReFi remains conceptually underdeveloped. It is often loosely aligned with sustainable or impact finance, lacking clear theoretical boundaries. The findings of this study, particularly the thematic maps and factorial positioning, show that ReFi appears on the research periphery, indicating its emergent but not yet central status.

Proposition 1: Future research should develop robust theoretical models that clearly define the normative foundations, mechanisms of value creation, and ecological principles that distinguish ReFi from mainstream ESG finance. This may include constructing typologies, conducting comparative theory-building, and engaging with ecological economics and systems thinking.

This proposition faces conceptual challenges due to the nascent and fragmented nature of ReFi, with no unified definition or theoretical consensus. Methodologically, building robust models may be difficult given the evolving nature of use cases and value systems. Resource-wise, comparative studies and interdisciplinary engagement require significant time, funding, and expert collaboration.

7.2 Governance and regulation of decentralized finance (DeFi)

The governance dimension, especially in relation to DAOs and decentralized climate finance, remains underexplored in both thematic and co-occurrence analyses. As ReFi platforms scale, questions of accountability, regulatory compliance, and stakeholder legitimacy become critical.

Proposition 2: Future studies should investigate governance models specific to decentralized regenerative finance systems. This includes exploring DAO design for ecological outcomes, analysing the role of digital identity and reputation systems, and conducting comparative legal studies on sandbox regulation and compliance architectures.

The technical complexity of DAO systems and their dynamic nature can hinder consistent governance assessment. Regulatory environments are highly fragmented and uncertain, varying drastically across jurisdictions. Accessing reliable data on decentralized ecosystems also presents a practical challenge.

7.3 Metrics and standards for impact assessment

Tokenized carbon credits, green assets, and nature-backed tokens are gaining traction, but their verification remains fragmented. The current literature lacks cohesive standards for measuring and reporting ecological outcomes, a gap visible in both keyword network and thematic density metrics.

Proposition 3: Researchers should focus on the development of interoperable and verifiable ESG and impact measurement systems. This includes the design of AI-enhanced data oracles, blockchain-integrated MRV (Monitoring, Reporting, and Verification) tools, and frameworks for evaluating regenerative outcomes using natural capital accounting and remote sensing technologies.

Developing interoperable MRV systems requires advanced technical infrastructure and coordination across stakeholders. There are methodological challenges in defining and validating ecological outcomes, especially in complex or remote environments. The lack of existing standards further complicates comparative assessments.

7.4 ReFi and financial inclusion in the global south

While financial inclusion is a recurring theme, most case studies are concentrated in developed regions. ReFi has the potential to empower climate-vulnerable and underbanked communities in the Global South, but this potential is still largely theoretical.

Proposition 4: Empirical studies should explore how blockchain-enabled regenerative finance tools (e.g., micro carbon markets, local DAOs, nature credits) can foster inclusive climate adaptation in low-income regions. Participatory action research, community-based pilots, and impact assessments in Africa, Asia, and Latin America are particularly needed.

Conducting research in underbanked and climate-vulnerable regions poses logistical and ethical challenges, including language, access, and trust. Resource constraints, digital literacy gaps, and regulatory hurdles may affect implementation. Long-term engagement is required for impact evaluation, which can be cost- and time-intensive.

7.5 Synergies between AI, blockchain and ESG

The emergence of AI-related keywords in recent factorial clusters suggests a nascent but promising integration of intelligent systems with sustainable finance. Yet, this area remains underdeveloped both theoretically and technically.

Proposition 5: Future research should investigate the synergistic potential of AI and blockchain in automating ESG reporting, optimizing carbon markets, and building adaptive financial instruments. Areas of interest include predictive modeling for environmental risk, generative ESG scoring systems, and AI-governed smart contracts for real-time ecological data.

The integration of AI and blockchain is still technically immature, with significant interoperability and scalability concerns. Ensuring data quality and bias mitigation in AI systems remains a challenge. Moreover, combining AI with ESG standards involves navigating both technical and normative uncertainties.

7.6 Longitudinal and impact-oriented studies

The field remains dominated by conceptual and bibliometric studies, with few longitudinal evaluations of real-world applications. The lack of long-term data impedes understanding of ReFi's actual impact on sustainability transitions.

Proposition 6: Researchers should prioritize longitudinal case studies and impact evaluations of implemented ReFi platforms. This could include ecosystem mapping, time-series analysis of governance shifts, and social-ecological outcome tracking in live ReFi ecosystems.

Longitudinal studies require sustained access to live ecosystems, which can be difficult due to platform discontinuities or changing stakeholder dynamics. There are methodological challenges in isolating causal impacts over time. Funding and institutional support for long-term projects may also be limited.

7.7 Interdisciplinary and transdisciplinary integration

The structural analyses show disciplinary clustering, with limited integration between finance, technology, ecology, and governance. However, systemic challenges like climate change and biodiversity loss require cross-disciplinary insights.

Proposition 7: Future research should be explicitly interdisciplinary, combining insights from finance, environmental science, law, political economy, and digital innovation. Research teams should co-develop frameworks with practitioners and policymakers, embedding real-world complexity into regenerative finance design.

True interdisciplinary collaboration is often hindered by disciplinary silos, differing epistemologies, and communication barriers. Coordinating researchers, policymakers, and practitioners across fields demands significant time and resources. There may also be resistance from traditional institutions to adopt systems-thinking approaches.

8 Conclusion

This study provides a comprehensive bibliometric and thematic analysis of the scholarly landscape at the intersection of blockchain technology, sustainable finance and regenerative finance (ReFi). Drawing from seventy-eight peer-reviewed publications retrieved from Scopus and Web of Science (WoS) between 2021 and 2025; after removing duplicates, the study mapped the intellectual structure, thematic development, and conceptual trends that define this emerging field.

The bibliometric results show a rapidly growing area of research, with an annual publication growth rate exceeding 60%. The geographic distribution indicates strong contributions from countries such as India and China, alongside growing institutional interest from both academia and practice. Collaborative networks among authors are expanding, but the field remains relatively fragmented, reflecting its interdisciplinary nature.

The thematic analysis revealed three distinct evolutionary phases. During the 2021–2022 periods, research was exploratory, centered on foundational themes such as sustainable development, green finance, and blockchain integration into environmental governance. By 2023–2024, the field matured with an increased focus on applied topics like tokenized carbon credits, decentralized finance, and ESG-aligned innovation. In 2025, the discourse further diversified as new clusters formed around artificial intelligence, impact evaluation tools, and blockchain-enabled ESG analytics; meanwhile, ReFi, despite its conceptual significance, remained peripheral in both density and centrality.

The co-occurrence and factorial analyses further confirm the significant role of blockchain and sustainable finance as intellectual anchors of the literature, while ReFi, financial inclusion, and decentralized finance continue to emerge as promising yet underdeveloped domains. Thematic maps and conceptual diagrams illustrate that while blockchain's utility for traceability, smart contracts, and carbon asset tokenization is widely explored, ReFi's transformative ambitions, centered on ecological regeneration and community empowerment, are still taking shape within academic research.

This study makes several important contributions. First, it maps and visualizes the field's structure using advanced bibliometric tools. Second, it identifies key thematic areas and tracks their evolution over time. Third, it synthesizes emerging trends and conceptual gaps, positioning the findings within a broader agenda for future scholarship. Finally, it provides a list of practical research ideas, including improving ReFi theory, designing governance for decentralized systems, and combining AI and blockchain for measuring ESG.

In conclusion, the intersection of blockchain, ReFi, and sustainable finance is still an emerging but high-potential research frontier. As the climate crisis accelerates and the demand for sustainable transformation grows, this convergence presents a timely opportunity for scholars to explore new paradigms of value creation, governance, and ecological restoration. However, realizing this potential will require continued empirical work, interdisciplinary collaboration, and inclusive innovation, especially in contexts where financial and ecological vulnerabilities intersect most acutely.

Finally, we emphasize that, while this review is comprehensive in scope, it is not without limitations. Our analysis is based on peer-reviewed articles published in English and retrieved from Scopus and Web of Science. These databases were chosen due to their high academic standards and broad disciplinary coverage; however, they may not capture every relevant contribution from emerging outlets or practitioner literature. In

addition, the study emphasizes structural and thematic insights drawn from bibliometric and content mapping techniques, which are well-suited for capturing field-level trends but do not aim to evaluate individual project outcomes. These choices reflect a deliberate focus on conceptual breadth and methodological rigor. Future research may complement this approach by exploring specific cases in more depth, incorporating practitioner perspectives, or expanding the dataset to include additional sources.

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Author contributions

Conceptualization [HFZ and JKR], data curation [HFZ and JKR], methodology [HFZ and JKR], formal analysis and discussion [HFZ and JKR], writing of original draft [HFZ and JKR], reviewing and editing [HFZ and JKR]. All authors have approved the final manuscript.

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