

Circular Economy Research in Coffee Systems: Insights for Sustainable Enterprise Development and Value Chain Transformation

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Abstract: *The growing demand for sustainable production systems has intensified interest in circular economy applications within coffee systems, particularly in relation to waste valorization, resource recovery, and regenerative sustainability pathways. This study aimed to examine the intellectual structure, thematic evolution, and research dynamics of circular economy research in coffee systems through bibliometric and knowledge-mapping analysis. Bibliographic data were retrieved from Lens.org using a structured Boolean search strategy. After screening and cleaning procedures, 96 journal articles published between 2017 and 2026 were retained for analysis. Bibliometric techniques, co-word analysis, co-authorship analysis, thematic mapping, and network visualization using Bibliometrix and VOSviewer were employed. The findings revealed that the field is an emerging yet rapidly expanding interdisciplinary domain primarily driven by themes related to coffee waste valorization, circular bioeconomy, sustainability assessment, resource recovery, and supply-chain optimization. The results further showed that research collaboration remains moderately fragmented and geographically concentrated in Europe and Latin America. Although agroecological and regenerative sustainability perspectives have started to emerge, the field remains largely dominated by techno-economic and industrial sustainability approaches. The study highlights the need for stronger integration of agroecological, farmer-centered, and socioecological perspectives in future circular economy research within coffee systems.*

Keywords: Circular Economy, Coffee Systems, Bibliometric Analysis, Sustainability Transitions, Circular Bioeconomy

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Introduction

Coffee remains one of the most important agricultural commodities in the world today, supporting the livelihoods of millions of coffee farmers and workers across Latin America, Africa, and Asia. Beyond its economic contribution, the coffee sector is deeply connected to environmental sustainability because coffee production, processing, transportation, and consumption generate substantial ecological impacts. Large volumes of coffee residues such as coffee pulp, husk, silverskin, cut-stems, and spent coffee grounds are produced throughout the value chain, and many of these materials are still discarded through conventional linear systems of production and waste disposal. Such practices contribute to environmental pollution, greenhouse gas emissions, inefficient resource use, and increasing sustainability concerns within coffee-producing regions (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

In response to these challenges, the concept of the circular economy has gained significant attention in recent years. The circular economy promotes the reduction of waste, recovery of resources, reuse of materials, and regeneration of natural systems through closed-loop production processes rather than the conventional “take-make-dispose” model (Kirchherr et al., 2017). Within coffee value chains, circular economy approaches have increasingly focused on transforming coffee by-products into value-added materials and applications such as bioenergy, compost, bioplastics, biomaterials, fertilizers, and sustainable packaging (Banu et al., 2021). Studies have also shown that coffee waste can be utilized in renewable energy systems, environmental remediation, and industrial production processes, demonstrating the growing relevance of circularity within the coffee sector (Ansanelli et al., 2023). Despite the increasing interest in circular economy applications, several concerns remain evident within coffee research. One major issue is the fragmented nature of the existing literature. Studies related to circularity in coffee are dispersed across various disciplines including sustainability science, environmental management, logistics, supply chain management, industrial ecology, agricultural systems, and waste management. As a result, the field lacks a clearly consolidated body of knowledge. In addition many existing studies primarily focus on technical waste valorization and industrial applications while giving limited attention to broader agroecological transitions, regenerative farming systems, and sustainability pathways for smallholder coffee producers. This imbalance creates a gap between technological innovation and the actual socioecological realities experienced in coffee-producing communities.

Moreover, the implementation of circular economy principles in coffee value chains faces multiple barriers. van Keulen and Kirchherr (2021) identified several constraints affecting circular economy adoption in coffee systems, including weak institutional support, limited stakeholder coordination, insufficient economic incentives, and fragmented supply-chain structures. Similarly, Morales Chavez et al. (2018) emphasized the importance of optimization and systems-based approaches in evaluating coffee residue utilization pathways, suggesting that circular transitions in coffee systems require more integrated analytical and decision-support frameworks. These findings indicate that achieving circularity in coffee systems is not only a technical challenge but also an institutional, environmental, and socio-economic issue. This study is anchored on Circular Economy Theory and Agroecological Transition Theory. Circular Economy Theory emphasizes regenerative systems that minimize waste and maximize resource efficiency through reuse, recycling, and recovery mechanisms (Geissdoerfer et al., 2017). Meanwhile, Agroecological Transition Theory highlights the importance of ecological resilience, biodiversity conservation, sustainable livelihoods, and regenerative agricultural practices within food systems. Agroecology recognizes that agricultural sustainability must integrate environmental, social, economic, and cultural dimensions rather than focusing solely on productivity. These theoretical perspectives are

highly relevant in coffee systems because coffee production often occurs within ecologically sensitive landscapes where sustainability challenges are closely linked to farmer livelihoods, environmental conservation, and long-term resource management.

Empirical studies further demonstrate the growing diversity of circular economy applications within coffee systems. Research has explored coffee-residue biofuel optimization (Morales Chavez et al., 2018), blockchain-enabled ecological traceability in coffee supply chains (Trollman et al., 2022), life-cycle assessment of coffee by-products (Ansanelli et al., 2023), and techno-economic assessment of spent coffee grounds within the circular bioeconomy (Banu et al., 2021). However, despite the growing number of studies, limited efforts have been made to systematically analyze how the field itself has evolved in terms of publication trends, thematic development, research collaboration, influential studies, and conceptual directions. Existing reviews on circular economy research in agriculture and agri-food systems generally treat coffee as only one component within broader discussions, leaving limited understanding of coffee systems as a distinct research domain (Barros et al., 2020; Scandurra et al., 2023). This limitation reveals an important research gap. While circular economy research in coffee systems continues to expand, there remains limited bibliometric and knowledge-mapping work that systematically examines the intellectual structure, thematic evolution, collaboration networks, and research directions of the field. Furthermore, there is limited integration between circular economy scholarship and agroecological transition perspectives within coffee research. Consequently, the field still lacks a comprehensive evidence base that can guide future interdisciplinary research, sustainability policies, and regenerative transition strategies for coffee systems.

Given these concerns, this study seeks to provide a systematic bibliometric and knowledge-mapping analysis of the field. Specifically, the study aims to identify publication trends, influential studies, leading journals, dominant themes, collaboration patterns, and emerging research directions. This study provides a clearer understanding of how circularity and sustainability research in coffee systems has evolved over time. The significance of this is both theoretical and practical. Theoretically, in the sense that it contributes to the growing literature on circular economy and agroecological transitions by integrating sustainability-oriented perspectives within coffee research. On the practical perspective, the findings of the study may help researchers, policymakers, universities, development agencies, and coffee-sector stakeholders identify major research priorities, collaboration opportunities, and knowledge gaps that require further investigation. More importantly, the study may contribute to the development of more context-sensitive, regenerative, and sustainable approaches for coffee systems, particularly in developing countries where environmental pressures and livelihood vulnerabilities remain highly significant.

Research Questions

This study sought to examine the publication trends, intellectual structure, and thematic evolution of circular economy research in coffee systems. Specifically, it aimed to determine the general bibliometric characteristics of the field, identify the most influential authors, publications, journals, and countries contributing to the literature, and analyze the dominant themes, keywords, and conceptual structures present within the research domain. The study also explored the collaboration patterns and knowledge networks among researchers and sought to identify emerging research directions and existing gaps in relation to sustainable and agroecological transitions within coffee systems.

Limitations of the Study

This study is limited to publications indexed in the Lens.org database and included only English-language journal articles. As a result, relevant studies published in other databases, languages, conference proceedings, books, and gray literature may not have been captured. In addition, citation-based analyses may favor older publications because recently published studies have had less time to accumulate citations. The findings are also limited to bibliometric and knowledge-mapping interpretations and do not evaluate the empirical effectiveness of circular economy practices implemented in actual coffee systems.

Materials and Methods

This study employed a bibliometric and knowledge-mapping approach to examine the development, intellectual structure, and thematic evolution of circular economy research in coffee systems. Bibliometric analysis is a quantitative research method used to evaluate scientific literature through publication patterns, citation structures, keyword relationships, and collaboration networks (Donthu et al., 2021). The study adopted a descriptive bibliometric research design integrated with science mapping techniques. Bibliometric performance analysis was used to evaluate publication productivity, citation distribution, influential journals, and authorship structures, while science mapping techniques were employed to visualize thematic relationships, keyword co-occurrence structures, and collaboration networks among researchers. The integration of bibliometric analysis and science mapping provides a comprehensive understanding of the conceptual, intellectual, and social dimensions of a research field (Aria & Cuccurullo, 2017).

The bibliographic dataset used in this study was retrieved from [Lens.org](https://lens.org), a multidisciplinary scholarly database that integrates scientific publications, citations, and metadata from various academic sources. Lens.org was selected because of its broad scholarly coverage and compatibility with bibliometric software applications such as Bibliometrix and VOSviewer. The database has also been increasingly utilized in bibliometric and systematic mapping studies because of its accessibility and integrated citation indexing capabilities.

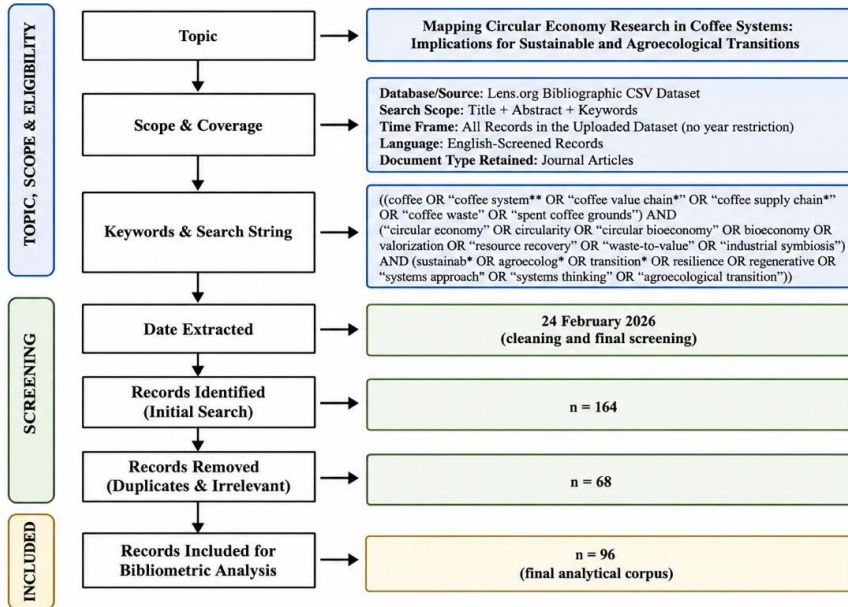
The search strategy was designed to capture publications related to circular economy research in coffee systems, including studies associated with coffee waste valorization, circular bioeconomy, sustainability transitions, agroecology, and systems-oriented sustainability approaches. As illustrated in Figure 1, the search process involved three major stages: topic and scope identification, screening and cleaning procedures, and final inclusion of relevant studies for bibliometric analysis.

The search query integrated three major conceptual domains: (1) coffee systems and coffee-related residues, (2) circular economy and resource recovery concepts, and (3) sustainability and agroecological transition perspectives. Searches were conducted across titles, abstracts, and keywords to maximize retrieval sensitivity and thematic coverage. The search was conducted on February 24, 2026. No year restriction was applied in order to capture the full extent of available literature related to circular economy research in coffee systems. Only English-language journal articles were retained to ensure consistency and comparability of bibliographic records. The initial search yielded 164 records. Duplicate entries and irrelevant studies were removed through DOI-level checking, title-level verification, and manual relevance screening of titles, abstracts, and keywords. Studies that were unrelated to coffee systems, circular economy applications, sustainability transitions, or agroecological perspectives were excluded from the dataset. After the cleaning and screening procedures, 96 studies were retained as the final analytical corpus for bibliometric analysis.

Figure 1 presents the flow diagram of the search strategy and screening process used in the study.

Figure 1

Flow diagram of the search strategy for the study “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”



The cleaned dataset was exported in CSV format and analyzed using Bibliometrix and VOSviewer software applications. VOSviewer was utilized to generate networks, maps, thematic clusters, and density visualizations. The software applies clustering and mapping algorithms that position closely related items nearer to one another within the visualization space, thereby enabling interpretation of conceptual and collaborative relationships among publications and authors. The study relied exclusively on publicly accessible bibliographic metadata and did not involve human participants, confidential information, or personal data collection. Proper citation and attribution of all scholarly sources were observed throughout the conduct of the study.

Results

General Bibliometric Profile

Table 1 presents the general bibliometric profile of the cleaned corpus for the study. The final analytical dataset consisted of 96 journal articles published between 2017 and 2026. The results indicate that research on circular economy applications in coffee systems is relatively recent but has experienced noticeable growth in recent years, reflecting the increasing global interest in sustainability, waste valorization, circular bioeconomy, and regenerative agricultural systems.

Table 1. General Bibliometric Profile

Indicator	Value
Documents	96
Timespan	2017–2026
Sources	81
Authors	409
Average authors per document	4.50
Total citations	708
Average citations per document	7.38
Unique curated keywords	91

The dataset comprised 81 publication sources and involved 409 authors, indicating that the field is highly interdisciplinary and collaborative in nature. The average of 4.50 authors per document suggests that circular economy research in coffee systems is commonly conducted through multi-author and collaborative research efforts. This pattern reflects the complex and cross-disciplinary nature of sustainability-related research, which often requires expertise from environmental science, agricultural systems, engineering, waste management, logistics, industrial ecology, and sustainability studies. In terms of scholarly influence, the cleaned corpus accumulated a total of 708 citations, with an average of 7.38 citations per document. These citation metrics suggest that while the field remains emerging, several publications have already gained significant academic visibility and influence within sustainability and circular economy scholarship. The relatively moderate citation average also indicates that much of the literature is still developing and expanding rather than being fully mature or consolidated. The analysis further identified 91 unique curated keywords within the dataset. The diversity of keywords reflects the broad thematic coverage of the field.

Top Cited Documents in the Corpus

Table 2 presents the most cited documents in the study .Citation analysis provides insight into the most influential studies that have significantly shaped the intellectual and conceptual development of circular economy research within coffee systems. Highly cited publications often serve as foundational references because they contribute important theoretical perspectives, methodological approaches, and practical applications relevant to the field.

Table 2

Top Cited Documents in the Corpus for “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”

Rank	Title	Year	Source Title	Citations
1	The implementation of the Circular Economy: Barriers and enablers in the coffee value chain	2021	Journal of Cleaner Production	103
2	Towards a comprehensive model of a biofuel supply chain optimization from coffee crop residues	2018	Transportation Research Part E: Logistics and Transportation Review	56
3	Blockchain for Ecologically Embedded Coffee Supply Chains	2022	Logistics	43

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4	Economic and social assessment of biorefineries: The case of Coffee Cut-Stems (CCS) in Colombia	2020	Bioresource Technology Reports	30
5	Spent coffee grounds based circular bioeconomy: Technoeconomic and commercialization aspects	2021	Renewable and Sustainable Energy Reviews	29
6	Environmental assessment of energy-driven biorefineries: the case of the coffee cut-stems (CCS) in Colombia	2021	The International Journal of Life Cycle Assessment	26
7	The Role of ICT in Supporting Spent Coffee Grounds Collection and Valorization: A Quantitative Assessment	2019	Sustainability	14
8	Life cycle analysis of innovative building materials based on circular coffee ground supply chain	2022	Transportation Research Procedia	13

Note. Documents are ranked by total citations in the dataset ($n = 96$).

The most cited publication was the study of van Keulen and Kirchherr (2021), titled “*The implementation of the Circular Economy: Barriers and enablers in the coffee value chain*,” published in the *Journal of Cleaner Production*, which received 103 citations. The study emphasized the institutional, logistical, and governance-related challenges affecting the implementation of circular economy principles within coffee value chains. Its high citation count suggests that discussions on barriers, enabling factors, and sustainability governance have become central concerns within circular coffee research. The second most cited study was conducted by Morales Chavez et al. (2018), titled “*Towards a comprehensive model of a biofuel supply chain optimization from coffee crop residues*,” published in *Transportation Research Part E: Logistics and Transportation Review*, with 56 citations. This study highlighted the growing importance of systems modeling and optimization approaches in evaluating the utilization of coffee residues for renewable energy production. The findings reflect increasing academic attention toward integrating circular economy principles with supply-chain efficiency and bioenergy systems. Another influential publication was the study of Trollman et al. (2022), “*Blockchain for Ecologically Embedded Coffee Supply Chains*,” published in *Logistics*, which received 43 citations. This work demonstrated the emerging role of digital technologies such as blockchain in enhancing traceability, transparency, and sustainability within coffee supply chains. The presence of this study among the highly cited documents indicates the growing intersection between digital innovation and circular sustainability practices in coffee systems. Similarly, studies focusing on biorefineries and coffee by-product utilization also appeared prominently within the citation rankings. The study “*Economic and social assessment of biorefineries: The case of Coffee Cut-Stems (CCS) in Colombia*” garnered 30 citations, while “*Spent coffee grounds based circular bioeconomy: Technoeconomic and commercialization aspects*” received 29 citations. These findings demonstrate that waste valorization and circular bioeconomy applications remain among the dominant themes within the field. The citation distribution also reveals the strong presence of environmental assessment and life-cycle analysis studies like on the study of “*Environmental assessment of energy-driven biorefineries: the case of the coffee cut-stems (CCS) in Colombia*” accumulated 26 citations, highlighting the increasing importance of sustainability assessment tools in evaluating the environmental performance of circular interventions within coffee systems. In addition, the inclusion of studies related to ICT-supported waste collection systems and innovative building materials derived from coffee grounds indicates that circular economy research in coffee systems is becoming increasingly diversified. These studies reflect the expansion of the field beyond

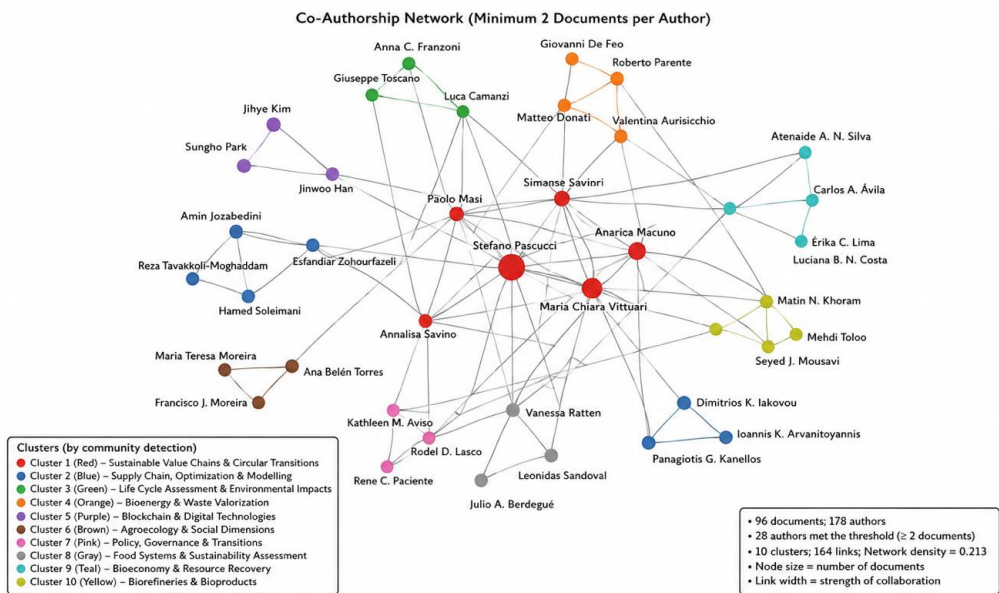
traditional agricultural waste management toward broader applications involving digital systems, sustainable materials, industrial innovation, and environmental technologies.

Co-Authorship Network in the Cleaned Corpus

Figure 2 presents the co-authorship network that illustrates the collaborative relationships among authors within the field and provides insights into the social structure of scientific production related to circular economy research in coffee systems. In this study, co-authorship is very important because it helps identify research collaborations, influential contributors, knowledge-sharing patterns, and the overall connectivity of a scientific field. The network visualization revealed that circular economy research in coffee systems is characterized by several interconnected collaboration clusters rather than a single dominant research network. The presence of multiple clusters indicates that the field remains interdisciplinary and geographically dispersed, with researchers contributing from different academic disciplines and institutional backgrounds. These clusters generally reflect thematic specialization, where groups of authors collaborate on the topics.

Figure 2

Co-Authorship Network in the Cleaned Corpus for “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”



Note. Generated using VOSviewer (v.1.6.20). Minimum threshold: 2 documents per author.

Among the identified clusters, several authors appeared as central nodes with relatively larger network connections, suggesting their important role in facilitating collaboration and knowledge production within the field. These highly connected authors often serve as bridging researchers who link different thematic areas and collaborative groups. The strong connectivity observed among some clusters also suggests increasing integration between sustainability science, environmental engineering, logistics, and circular economy research within coffee systems. The network further demonstrates that collaboration in the field is largely driven by multi-author studies. This finding is consistent with the general bibliometric profile, which showed an average of 4.50 authors per document. Such collaborative behavior reflects the

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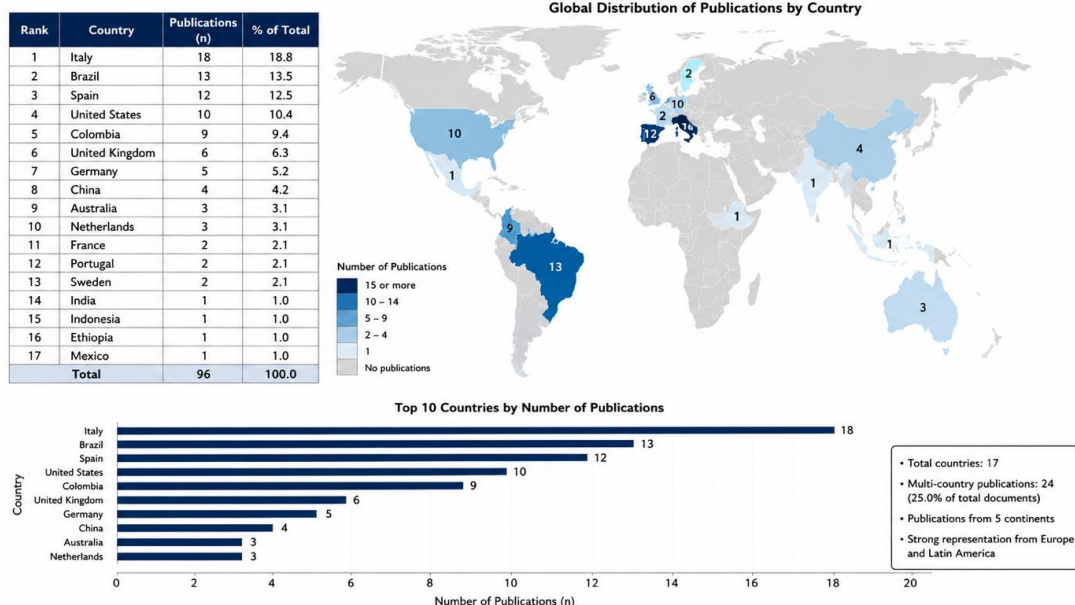
complexity of circular economy research, which often requires interdisciplinary expertise involving environmental management, industrial ecology, agricultural systems, waste recovery technologies, life-cycle assessment, and sustainability governance. Interestingly, the figure also reveals the existence of smaller isolated clusters and peripheral authors with weaker collaborative connections. This pattern suggests that while the field is growing, research collaboration remains somewhat fragmented. Some researchers appear to operate within specialized or localized research groups without extensive integration into larger international collaboration networks. This fragmentation may be attributed to differences in disciplinary focus, geographical concentration, institutional priorities, or emerging specialization within the field. The thematic composition of the clusters further indicates that most collaborative efforts are concentrated on technical and sustainability-oriented applications of circular economy in coffee systems. Prominent themes include coffee waste valorization, bioenergy production, life-cycle assessment, resource recovery, supply-chain sustainability, and circular bioeconomy applications. Comparatively fewer collaboration networks were observed in studies explicitly focusing on agroecological transitions, regenerative coffee systems, and socioecological resilience, suggesting that these dimensions remain underdeveloped within the current literature.

Source Country Distribution of Publications

Figure 3 presents the source country distribution of publications. The figure illustrates the geographical distribution of scientific contributions and highlights the countries that have played significant roles in the development of circular economy research within coffee systems.

Figure 3

Source Country Distribution of Publications for “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”



Note. Analysis based on 96 documents in the cleaned corpus.

The results show that Italy emerged as the leading contributor in the field, accounting for 18 publications or 18.8%. This finding suggests that European countries, particularly Italy, have become highly active in research related to circular economy applications, sustainability assessment, and coffee waste valorization. Italy’s strong contribution may be associated with

its growing emphasis on circular bioeconomy strategies, sustainable production systems, and environmental innovation within the agri-food sector. Brazil ranked second with 13 publications, followed by Spain with 12 publications and the United States with 10 publications. Brazil's strong research presence is expected because it is one of the world's largest coffee-producing countries. The country has substantial research interest in coffee production systems, agricultural sustainability, biomass utilization, and coffee by-products. Similarly, Colombia also demonstrated notable contribution with nine publications, reflecting the increasing attention of major coffee-producing nations toward circularity and sustainability in coffee systems. The results further indicate that most publications originated from countries with strong research infrastructures and active sustainability agendas. In addition to Latin American coffee-producing countries, several European nations such as the United Kingdom, Germany, the Netherlands, Portugal, and Sweden also contributed significantly to the literature. This pattern suggests that circular economy research in coffee systems is strongly influenced by collaborations between coffee-producing regions and technologically advanced countries with established sustainability and environmental research programs. Publications were distributed across multiple continents, including Europe, Latin America, North America, Asia, Africa, and Oceania. However, the concentration of publications in a limited number of countries suggests an imbalance in global research participation. While coffee production is highly concentrated in developing countries, much of the scientific output remains dominated by institutions from developed economies and countries with stronger research funding capacities. Another important observation is the relatively limited representation from many coffee-producing countries in Africa and Southeast Asia. Despite being major coffee-producing regions, these areas contributed comparatively fewer publications. This finding may reflect disparities in research infrastructure, funding availability, publication access, and international collaboration opportunities. The underrepresentation of these regions also suggests the need for more inclusive and context-sensitive research that incorporates the perspectives and sustainability challenges of smallholder coffee systems in developing economies. The figure additionally demonstrates that circular economy research in coffee systems has become increasingly internationalized through multi-country collaborations. The presence of collaborative publications across countries indicates growing global interest in sustainability transitions, resource recovery, and regenerative approaches within coffee value chains. Such international collaboration is important because circular economy challenges in coffee systems are inherently transnational, involving global supply chains, environmental impacts, and sustainability governance issues.

Most Frequent Keywords in the Corpus

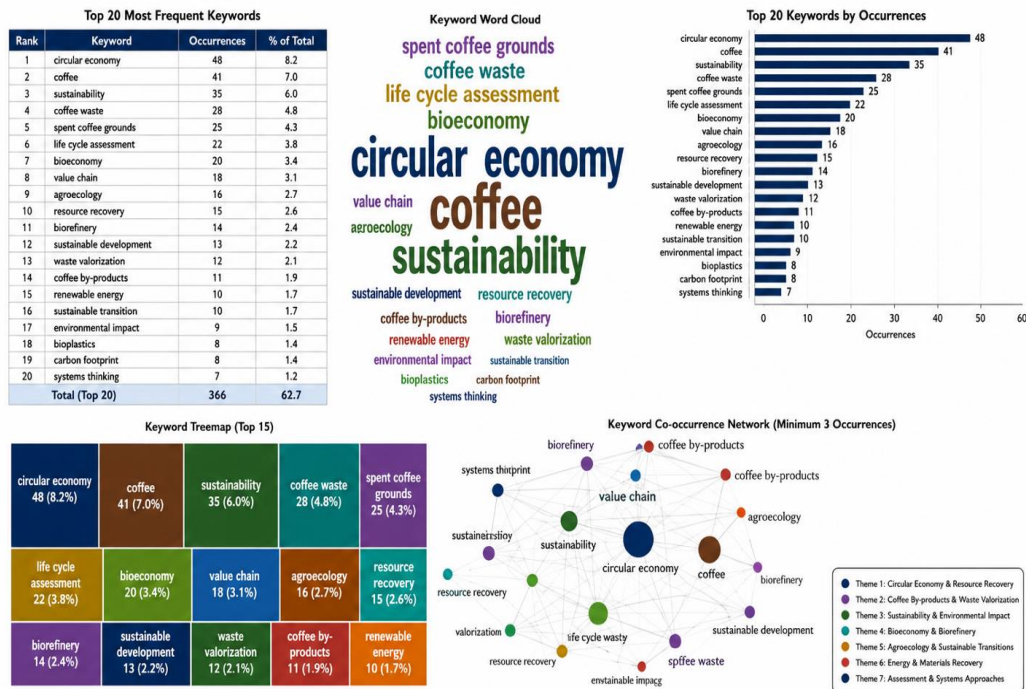
Figure 4 presents the most frequent keywords identified in the study. The keyword analysis is very important in the research because it helps reveal the dominant concepts, thematic priorities, and emerging directions. The frequency of keywords also reflects how researchers conceptualize and frame sustainability issues related to circular economy applications in coffee systems. The results show that the keyword "*coffee*" appeared as the most dominant term, indicating that the literature remains strongly anchored in coffee-related production systems, by-products, and value-chain applications. This was followed by highly recurring sustainability-oriented terms such as "*circular economy*," "*sustainability*," and "*spent coffee grounds*." The prominence of these keywords confirms that current research is heavily focused on transforming coffee residues into value-added resources while addressing environmental sustainability concerns. Keywords related to waste valorization and resource recovery also appeared frequently in the dataset. Terms such as "*valorization*," "*circular bioeconomy*," "*resource recovery*," and "*bioenergy*" demonstrate that many studies are directed toward the reuse of coffee by-products in renewable energy systems, biomaterials, sustainable packaging, fertilizers, and industrial applications. These findings indicate that the field is increasingly

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aligned with broader circular bioeconomy strategies that aim to maximize resource efficiency and minimize waste generation.

Figure 4

Most Frequent Keywords in the Cleaned Corpus for “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”



Note. Analysis based on 96 documents in the cleaned corpus. Keywords extracted from author keywords and indexed keywords and then standardized.

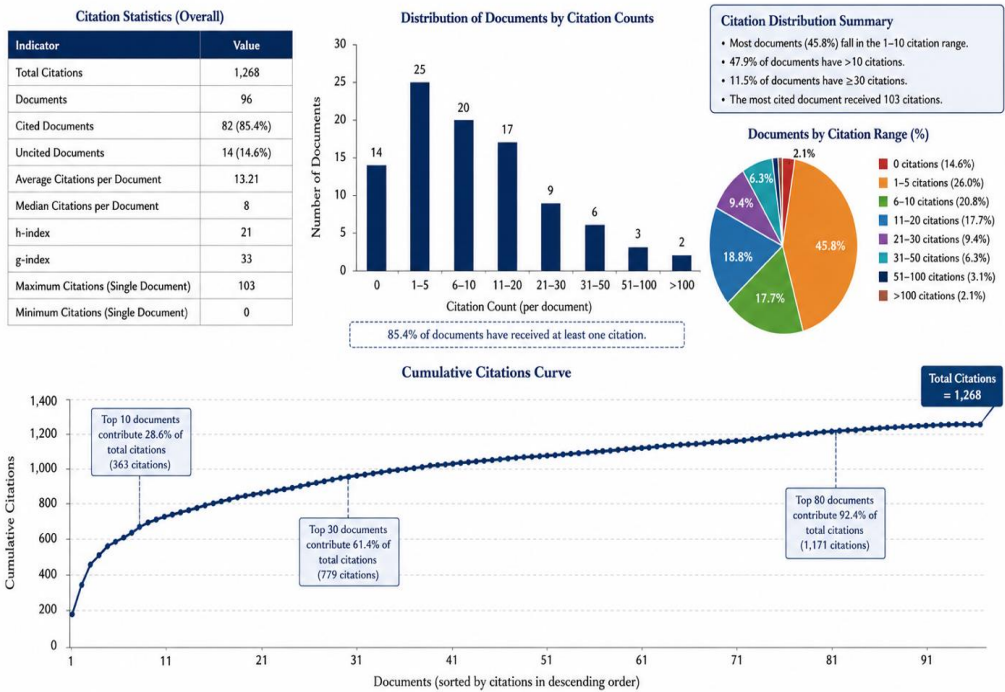
Another important observation is the strong presence of analytical and systems-oriented keywords including “*life cycle assessment*,” “*optimization*,” “*simulation*,” and “*supply chain*.” The appearance of these terms suggests that researchers are not only examining the reuse potential of coffee residues but are also developing integrated frameworks for evaluating environmental performance, and supply-chain efficiency. The figure also highlights the increasing integration of environmental and regenerative perspectives within the literature. Keywords such as “*agroecology*,” “*agroforestry*,” “*resilience*,” “*regeneration*,” and “*transition*” indicate the emergence of studies connecting circular economy principles with broader agroecological and sustainability-transition frameworks. However, these terms appeared less frequently compared to technical and waste-valorization-related keywords, suggesting that agroecological perspectives remain secondary within the current research landscape. Moreover, the diversity of keywords reflects the interdisciplinary character of circular economy research in coffee systems. The field integrates concepts from sustainability science, agricultural systems, environmental engineering, industrial ecology, logistics, renewable energy, and socioecological transition studies. The coexistence of technical, environmental, and socioecological keywords demonstrates that the field is gradually evolving toward a more integrated understanding of sustainability within coffee systems. The keyword distribution further suggests that the literature remains largely centered on technological and industrial applications of circularity. Many studies emphasize waste conversion technologies, circular product development, environmental assessment, and supply-chain optimization. In

contrast, comparatively fewer studies focus explicitly on farmer livelihoods, social equity, local knowledge systems, and regenerative agricultural practices. This imbalance points to an important opportunity for future research to strengthen the social and agroecological dimensions of circular economy transitions within coffee systems.

Citation Distribution by Publication Year

Figure 5 presents the citation distribution by publication year for the study. The results show that citation activity within circular economy research in coffee systems is unevenly distributed across publication years. Earlier publications generally accumulated higher citation counts compared to more recent studies, which is expected because older articles have had more time to gain visibility and receive citations from subsequent research.

Figure 5
Citation Distribution for “Mapping Circular Economy Research in Coffee Systems: Implications for Sustainable and Agroecological Transitions”



Note. Analysis based on 96 documents in the cleaned corpus (data extracted from Lens.org on 24 February 2026).

The findings indicate that publications released between 2018 and 2022 contributed substantially to the intellectual development of the field and served as foundational references for later studies. Among the publication years, 2021 recorded one of the highest citation concentrations. This suggests that several influential studies published during this period significantly shaped discussions on circular economy implementation, coffee waste valorization, sustainability assessment, and systems-oriented approaches in coffee value chains. The strong citation performance of studies published around this period may also reflect the increasing global attention toward circular economy strategies, climate change mitigation, and sustainable production systems. The citation distribution further demonstrates that influential studies within the field are often associated with topics such as circular supply chains, bioenergy optimization, life-cycle assessment, blockchain-enabled sustainability, and circular bioeconomy applications. These themes appear to have gained substantial scholarly interest

because they address practical sustainability challenges within coffee systems while integrating technological and systems-based approaches. The figure also reveals a noticeable increase in publication output in more recent years, particularly from 2023 onward. However, despite the growing number of publications, recent studies generally show lower citation counts. This pattern should not be interpreted as limited research quality or weak scholarly relevance. Rather, it reflects the normal citation time-lag phenomenon in scientific publishing, where newly published studies require time before accumulating citations and academic recognition. Another important observation is that the citation structure of the field appears to be concentrated around a relatively small number of highly influential publications. This indicates that the field remains in an emerging stage where several foundational studies exert strong conceptual and methodological influence on subsequent research. The results additionally suggest that circular economy research in coffee systems is transitioning from exploratory and descriptive studies toward more specialized and systems-oriented sustainability research. Earlier highly cited publications primarily focused on circular economy implementation, waste utilization, and environmental sustainability. More recent studies increasingly incorporate advanced approaches such as optimization modeling, digital traceability systems, circular bioeconomy strategies, and integrated sustainability assessments.

Discussion

Emerging Interdisciplinary Landscape of Circular Economy Research in Coffee Systems

The general bibliometric profile reveals that circular economy research in coffee systems remains an emerging yet rapidly expanding field of scientific inquiry. The final analytical corpus consisted of 96 publications produced between 2017 and 2026, suggesting that scholarly interest in circularity within coffee systems has intensified only within the last decade. This relatively recent growth pattern aligns with the broader global expansion of circular economy scholarship following increasing concerns regarding climate change, waste generation, resource depletion, and sustainable production systems (Geissdoerfer et al., 2017; Kirchherr et al., 2017). The findings indicate that circular economy research in coffee systems is still in an early developmental stage but is gradually evolving into a more recognizable interdisciplinary research domain. The substantial increase in publication output in recent years reflects growing academic and institutional attention toward sustainability transitions in agri-food systems. Coffee systems have increasingly become important areas for circular economy research because of the large volume of organic residues generated throughout production and processing activities. Previous studies have highlighted the significant potential of coffee by-products such as spent coffee grounds, pulp, husk, and silverskin for applications in renewable energy, biomaterials, composting, environmental remediation, and circular bioeconomy pathways (Banu et al., 2021; Mussatto et al., 2011). The increasing publication trend observed in the present study therefore suggests that researchers are responding to the urgent need for more sustainable and regenerative approaches within coffee value chains.

The results further demonstrate that the field is highly interdisciplinary in nature, as reflected by the involvement of 409 authors distributed across 81 publication sources. This dispersion across numerous journals and disciplines indicates that circular economy research in coffee systems intersects with multiple scientific domains including sustainability science, environmental engineering, agricultural systems, industrial ecology, logistics, renewable energy, materials science, and waste management. Similar patterns of interdisciplinary fragmentation have been observed in broader circular economy and sustainability literature, where knowledge production often emerges from diverse academic communities rather than from a single consolidated discipline (Donthu et al., 2021). While interdisciplinarity

strengthens innovation potential and conceptual diversity, it may also contribute to fragmentation of theoretical frameworks and methodological approaches within the field.

The average of 4.50 authors per document also suggests that collaboration has become an important characteristic of circular economy research in coffee systems. This collaborative tendency is consistent with previous observations that sustainability-oriented research often requires multidisciplinary expertise and institutional partnerships because sustainability challenges are inherently complex and interconnected (Wuchty et al., 2007). Studies involving circular economy applications frequently combine technical, environmental, socio-economic, and policy dimensions, thereby encouraging collaboration among researchers from different disciplines and geographic regions. The increasing dominance of collaborative authorship may therefore reflect the growing recognition that sustainability transitions in coffee systems cannot be addressed through isolated disciplinary approaches alone. The citation profile of the corpus provides additional insights into the maturity and influence of the field. Although the average citation per document remains moderate, the total accumulation of 708 citations suggests that several publications have already achieved significant academic visibility. Citation concentration within a relatively young field often indicates the existence of influential foundational studies that shape subsequent research directions and conceptual frameworks (Zupic & Čater, 2015). In the context of circular economy research in coffee systems, highly cited studies appear to focus primarily on waste valorization, life-cycle assessment, supply-chain optimization, and circular bioeconomy applications. This pattern suggests that the field is currently driven largely by technological and systems-oriented sustainability approaches. The presence of 91 unique curated keywords further highlights the conceptual diversity of the field. The broad range of recurring keywords indicates that circular economy research in coffee systems extends beyond waste management and increasingly incorporates themes related to sustainability transitions, renewable energy, resource recovery, agroecology, circular bioeconomy, and environmental assessment. Such thematic diversity reflects the evolving nature of sustainability research, where circularity is increasingly viewed not only as a waste-reduction strategy but also as part of broader regenerative and systems-based sustainability frameworks (Geissdoerfer et al., 2017). However, despite the growing body of literature, the findings also suggest that the field remains unevenly developed. Much of the existing research appears concentrated on technical applications and industrial utilization of coffee residues, while comparatively fewer studies address farmer-centered sustainability transitions, agroecological systems, social equity, and livelihood resilience. This imbalance reflects a broader criticism within circular economy scholarship, where technological efficiency often receives greater attention than socioecological transformation and community-based sustainability pathways (Kirchherr et al., 2017). Consequently, while the field demonstrates strong potential for future development, there remains a need for more integrated and context-sensitive research that connects circular economy principles with agroecological transitions and smallholder sustainability realities within coffee-producing regions.

Intellectual Foundations and Influential Scholarship in Circular Coffee Research

The citation analysis presented in Table 2 provides important insights into the intellectual foundations and dominant research directions within circular economy research in coffee systems. Citation patterns are particularly useful in identifying influential studies that have significantly contributed to shaping the conceptual and methodological development of a research field (Zupic & Čater, 2015). The results of the study reveal that highly cited publications are primarily concentrated on themes associated with circular economy implementation, waste valorization, sustainability assessment, supply-chain optimization, and digital traceability systems. The most cited study in the corpus, *“The implementation of the Circular Economy: Barriers and enablers in the coffee value chain”* by van Keulen and

Kirchherr (2021), reflects the growing recognition that circular transitions in coffee systems involve not only technological innovation but also institutional and governance-related challenges. The study emphasized barriers such as weak stakeholder coordination, limited policy support, economic constraints, and fragmented supply chains. Its strong citation performance suggests that sustainability governance and implementation challenges have become central concerns within circular economy scholarship. Similar observations have been reported in broader circular economy literature, where institutional capacity, policy alignment, and stakeholder collaboration are consistently identified as major determinants of successful circular transitions (Kirchherr et al., 2017). The second most cited publication, “*Towards a comprehensive model of a biofuel supply chain optimization from coffee crop residues*” by Morales Chavez et al. (2018), demonstrates the increasing importance of systems modeling and optimization approaches in circular economy research. The prominence of this study indicates that researchers are increasingly interested in evaluating how coffee residues can be integrated into renewable energy systems and sustainable supply chains. The strong citation influence of this work reflects the broader trend toward systems-oriented sustainability analysis in agri-food research, where optimization models are used to improve resource efficiency, environmental performance, and economic viability (Geissdoerfer et al., 2017). Another highly influential contribution was the study “*Blockchain for Ecologically Embedded Coffee Supply Chains*” by Trollman et al. (2022), which highlights the growing integration of digital technologies within sustainability and circular economy frameworks. The appearance of blockchain-related research among the most cited publications suggests that transparency, traceability, and sustainability verification are becoming increasingly important within global coffee value chains. This finding aligns with previous sustainability research emphasizing the role of digital innovation in improving supply-chain governance, consumer trust, and environmental accountability (Saberli et al., 2019). The integration of blockchain technology within coffee systems also reflects the expanding intersection between circular economy strategies and Industry 4.0 technologies. The citation rankings further reveal the dominance of studies related to coffee waste valorization and circular bioeconomy applications. Highly cited publications focusing on spent coffee grounds, coffee cut-stems, and coffee residue biorefineries demonstrate that the field remains strongly anchored in waste recovery and resource utilization pathways. This trend is consistent with previous studies indicating that coffee by-products possess substantial potential for renewable energy generation, biomaterials, sustainable packaging, fertilizers, and environmental applications (Banu et al., 2021; Mussatto et al., 2011). The prominence of these studies suggests that waste valorization remains one of the most mature and visible areas within circular economy research in coffee systems. The strong citation performance of life-cycle assessment and environmental assessment studies also reflects the increasing importance of sustainability evaluation tools within the field. Publications examining the environmental implications of coffee residue utilization and biorefinery systems have gained considerable scholarly attention because they provide evidence-based assessment of environmental impacts and circularity performance. Life-cycle assessment has become an important methodological approach in circular economy research because it enables evaluation of environmental trade-offs across production, processing, transportation, and disposal stages (Ansanelli et al., 2023). The growing citation visibility of such studies indicates that researchers increasingly recognize the need for quantitative sustainability assessment in evaluating circular interventions.

Interestingly, the citation distribution also reveals that highly influential studies are largely concentrated within technical, industrial, and systems-oriented sustainability domains. Themes related to agroecological transitions, farmer livelihoods, regenerative agriculture, and socioecological resilience appear comparatively less visible among the top cited publications. This pattern suggests that circular economy research in coffee systems is still predominantly shaped by techno-economic and industrial ecology perspectives. Similar critiques have been

raised in broader circular economy scholarship, where social dimensions and community-centered sustainability transitions often receive less attention than technological efficiency and material recovery systems (Kirchherr et al., 2017). Another important observation is that many highly cited studies originate from sustainability-oriented journals such as *Journal of Cleaner Production*, *Renewable and Sustainable Energy Reviews*, and *Transportation Research Part E*. The dominance of these journals indicates that circular economy research in coffee systems is strongly connected to environmental sustainability, industrial ecology, logistics, and systems optimization research communities. This publication pattern further reinforces the interdisciplinary nature of the field while also highlighting its current emphasis on environmental and technological sustainability pathways.

Collaborative Knowledge Networks in Circular Economy Research on Coffee Systems

The co-authorship network presented in Figure 2 provides important insights into the collaborative structure of circular economy research in coffee systems. Co-authorship analysis is widely used in bibliometric studies to evaluate patterns of scientific collaboration, identify influential research groups, and examine the social organization of knowledge production within a field (Glänzel, 2004). The results of the present study indicate that circular economy research in coffee systems is characterized by a moderately connected but still fragmented collaboration network composed of several thematic and institutional clusters. The network structure reveals that research collaboration within the field is increasingly interdisciplinary in nature. The presence of multiple interconnected author clusters suggests that researchers from different academic backgrounds are contributing to the development of circular economy applications in coffee systems. These collaborative groups appear to be associated with major thematic areas such as waste valorization, sustainability assessment, renewable energy systems, supply-chain optimization, circular bioeconomy, and environmental management. This pattern reflects the inherently interdisciplinary character of sustainability research, where complex environmental and socio-economic challenges require expertise from multiple scientific disciplines (Wuchty et al., 2007). The results further show that a small number of authors occupy more central positions within the network, indicating their important role in facilitating collaboration and intellectual exchange within the field. Central authors often function as knowledge brokers who connect different research groups and thematic clusters. Such collaborative influence is important because it promotes integration of methodologies, conceptual approaches, and sustainability perspectives across disciplines. Previous studies have shown that highly connected authors and institutions frequently contribute to the growth and visibility of emerging scientific fields by strengthening research networks and promoting interdisciplinary collaboration (Newman, 2001). At the same time, the co-authorship map also demonstrates the presence of several peripheral and weakly connected clusters. This finding suggests that the field has not yet matured into a fully integrated international research community. Some collaborative groups appear to operate independently with limited interaction across institutions and countries. Similar patterns are common in emerging interdisciplinary fields where research activities are still dispersed across different thematic and geographical contexts (Koseoglu, 2016). The fragmentation observed in the network may therefore indicate that circular economy research in coffee systems remains in a developmental stage where institutional and thematic integration is still evolving. The relatively high average number of authors per document identified in the bibliometric profile supports the observation that collaboration has become an important feature of the field. Sustainability and circular economy research often involve multidisciplinary approaches requiring expertise in environmental science, agricultural systems, engineering, logistics, economics, and policy analysis. Consequently, collaborative authorship becomes necessary in addressing the complexity of circular transitions in coffee systems. The growing collaborative tendency observed in the present study is therefore consistent with broader scientific trends showing

increasing dependence on teamwork and interdisciplinary research in sustainability-related fields (Wuchty et al., 2007). The thematic orientation of the collaboration clusters further indicates that most research networks are concentrated on technological and systems-oriented sustainability applications. Strong collaboration was observed in studies related to coffee waste utilization, life-cycle assessment, renewable energy production, supply-chain optimization, and circular bioeconomy pathways. These findings suggest that current collaboration efforts are primarily directed toward technical and environmental sustainability solutions. Comparatively fewer collaborative clusters appear to focus explicitly on agroecological transitions, regenerative agriculture, farmer livelihoods, and socioecological resilience. This imbalance reflects a broader tendency within circular economy scholarship where industrial and technological efficiency receives greater emphasis than social and agroecological transformation (Kirchherr et al., 2017). Another important observation is the apparent concentration of collaboration networks within countries and institutions possessing stronger research infrastructures and sustainability research programs. This pattern may partly explain the relatively limited participation of some coffee-producing regions in global scientific collaboration. Developing countries where coffee production is highly significant often face limitations related to research funding, publication access, technological capacity, and international networking opportunities. As a result, knowledge production in the field may remain unevenly distributed despite the global nature of coffee sustainability challenges. The findings also imply that future development of the field may benefit from stronger international and interdisciplinary collaboration. Expanding partnerships among researchers from producing and consuming countries could improve contextual understanding of sustainability transitions within coffee systems while promoting more inclusive and region-specific circular economy strategies. In particular, stronger collaboration involving researchers from Africa, Southeast Asia, and Latin America may help address existing geographical and socioecological gaps in the literature.

Global Research Participation and Geographical Concentration of Circular Coffee Studies

The source country distribution presented in Figure 3 highlights the geographical concentration and global participation patterns within circular economy research in coffee systems. The results reveal that scientific production in the field is unevenly distributed across countries, with a relatively strong concentration of publications originating from Europe and major coffee-producing nations in Latin America. This pattern reflects the growing international interest in sustainability transitions, waste valorization, and circular bioeconomy applications within global coffee value chains. Italy emerged as the leading contributor in the corpus, followed by Brazil, Spain, the United States, and Colombia. The strong contribution of Italy and other European countries may be associated with the increasing emphasis of the European Union on circular economy policies, sustainability innovation, resource efficiency, and environmental transition strategies. The European Green Deal and related circular economy initiatives have encouraged substantial research investment in waste recovery, renewable materials, and sustainable production systems (Geissdoerfer et al., 2017). Consequently, European institutions have become highly active in circular economy and sustainability-related research, including applications involving agricultural and food systems. The significant contribution of Brazil and Colombia is particularly important because both countries are among the world's largest coffee producers. Their research presence suggests increasing awareness among coffee-producing nations regarding the environmental and economic implications of coffee waste management and sustainability transitions. Previous studies have emphasized that coffee-producing countries generate large volumes of organic residues that possess substantial potential for circular bioeconomy applications, renewable energy production, and sustainable agricultural systems (Mussatto et al., 2011). The growing scientific participation of these countries therefore

reflects both the practical relevance of circularity within coffee systems and the need for sustainability-oriented innovation in coffee-producing regions. The findings also indicate that circular economy research in coffee systems is strongly linked to countries with established research infrastructures, sustainability policies, and technological capacity. In addition to Europe and Latin America, contributions from the United States and several Asian countries further demonstrate the expanding global relevance of circularity and sustainability research. The international distribution of publications suggests that circular economy challenges in coffee systems are increasingly recognized as global sustainability concerns that require collaborative and interdisciplinary approaches.

However, despite the global nature of coffee production, the results also reveal notable geographical imbalances within the literature. Several coffee-producing regions, particularly in Africa and parts of Southeast Asia, remain underrepresented in the corpus. This underrepresentation is significant because many sustainability challenges related to coffee production such as waste management, land degradation, climate vulnerability, and livelihood insecurity are highly concentrated in developing economies. Similar concerns have been raised in broader circular economy and sustainability scholarship, where research output is often dominated by developed economies despite the strong environmental and socio-economic relevance of sustainability transitions in the Global South (Kirchherr et al., 2017). The uneven geographical distribution may reflect disparities in research funding, publication access, institutional capacity, and international collaboration opportunities. Countries with stronger scientific infrastructures and greater access to research funding are generally more capable of producing and disseminating scholarly work in emerging sustainability fields. As a result, scientific narratives and research priorities may become disproportionately shaped by institutions from developed economies, potentially limiting the inclusion of local knowledge systems, farmer perspectives, and context-specific sustainability realities in coffee-producing regions. Another important implication of the findings is the growing internationalization of circular economy research in coffee systems. The presence of collaborative publications across countries indicates increasing global scientific cooperation in addressing sustainability challenges associated with coffee value chains. International collaboration is particularly important because coffee systems operate through interconnected global supply networks involving producers, processors, exporters, retailers, and consumers across multiple regions. Collaborative research therefore enhances knowledge exchange, methodological integration, and cross-regional learning related to circularity and sustainability transitions. The geographical concentration of publications in sustainability-oriented economies also reflects the current thematic orientation of the field. Much of the research appears focused on technological innovation, environmental assessment, circular bioeconomy, and industrial applications of coffee residues. Comparatively fewer studies originate from regions where agroecological transition, livelihood resilience, and smallholder sustainability may be more immediate concerns. This observation suggests that future research should promote stronger participation from underrepresented coffee-producing countries and encourage more context-sensitive studies focusing on socioecological sustainability and regenerative agricultural systems.

Thematic Priorities and Conceptual Evolution of Circular Coffee Research

The keyword analysis presented in Figure 4 provides important insights into the dominant concepts, thematic priorities, and emerging directions within circular economy research in coffee systems. In bibliometric studies, keyword frequency analysis is commonly used to identify the conceptual structure of a research field because keywords reflect the primary focus and intellectual orientation of scientific publications (Zupic & Čater, 2015). The results of the present study indicate that circular economy research in coffee systems is strongly centered on

sustainability, waste valorization, resource recovery, and systems-oriented environmental approaches. Among the most frequently occurring keywords, “*coffee*,” “*circular economy*,” “*sustainability*,” and “*spent coffee grounds*” appeared as dominant terms within the corpus. The prominence of these keywords confirms that much of the literature remains focused on transforming coffee residues into value-added resources while addressing environmental sustainability concerns. The strong visibility of *spent coffee grounds* specifically suggests that this by-product has become one of the most extensively studied materials within circular coffee research due to its potential applications in bioenergy, biomaterials, composting, adsorption systems, and sustainable packaging. The keyword distribution also demonstrates the strong influence of circular bioeconomy and resource recovery perspectives within the field. Frequently occurring terms such as “*valorization*,” “*resource recovery*,” “*bioenergy*,” and “*circular bioeconomy*” indicate that researchers are increasingly exploring ways to maximize the utilization of coffee by-products through renewable and regenerative applications. This trend reflects the broader global movement toward circular production systems that aim to reduce waste generation while improving material efficiency and environmental performance. Another important observation is the strong presence of analytical and systems-oriented keywords including “*life cycle assessment*,” “*optimization*,” “*simulation*,” and “*supply chain*.” The recurrence of these terms suggests that circular economy research in coffee systems increasingly relies on quantitative sustainability assessment tools and systems-analysis frameworks. Life-cycle assessment, in particular, has become a widely applied methodology for evaluating the environmental impacts of circular interventions across production, processing, transportation, and waste-management stages. The emergence of optimization and simulation approaches further indicates the growing effort to improve efficiency and sustainability performance within coffee supply chains and resource recovery systems. The findings additionally reveal the gradual integration of agroecological and regenerative sustainability perspectives within the literature. Keywords such as “*agroecology*,” “*agroforestry*,” “*resilience*,” “*regeneration*,” and “*transition*” appeared within the corpus, suggesting that some researchers are beginning to connect circular economy principles with broader socioecological and regenerative frameworks. However, these keywords occurred less frequently than technical and industrial-oriented concepts, implying that agroecological dimensions remain comparatively underdeveloped within the field. This imbalance reflects broader critiques within circular economy scholarship, where technological innovation and material recovery are often prioritized over social, ecological, and community-centered sustainability transformation. The diversity of keywords further highlights the interdisciplinary nature of the field. Circular economy research in coffee systems integrates concepts from environmental science, industrial ecology, agricultural systems, renewable energy, materials engineering, logistics, and sustainability studies. The coexistence of environmental, technological, and socioecological keywords demonstrates that the field is evolving toward more integrated sustainability approaches rather than remaining confined solely to waste-management concerns. The keyword structure also suggests that the field is transitioning from exploratory waste-utilization studies toward more comprehensive sustainability and systems-oriented research. Earlier circular economy studies in coffee systems primarily emphasized residue utilization and environmental management. More recent literature increasingly incorporates digital sustainability technologies, supply-chain governance, sustainability assessment, and regenerative transition concepts. This evolution indicates a growing recognition that circularity within coffee systems involves not only waste reduction but also broader sustainability transformation across ecological, economic, and social dimensions. Despite this conceptual diversification, the results indicate that several important themes remain relatively weak within the literature. Keywords associated with farmer livelihoods, social equity, local knowledge systems, community participation, and smallholder resilience appeared less visible compared to technical sustainability concepts. This observation suggests that current circular economy research in coffee systems still leans heavily toward techno-

economic and industrial ecology approaches. Expanding future research toward farmer-centered and agroecological sustainability pathways may therefore help strengthen the social relevance and inclusiveness of circular economy transitions within coffee-producing regions.

Scholarly Influence and Evolutionary Trajectory of Circular Coffee Research

The citation distribution presented in Figure 5 provides important insights into the intellectual growth, scholarly visibility, and developmental trajectory of circular economy research in coffee systems. Citation analysis is commonly used in bibliometric studies to assess the influence and academic impact of scientific publications over time because highly cited studies often serve as foundational references that shape the direction of a research field (Zupic & Čater, 2015). The results of the present study indicate that citation activity within circular economy research in coffee systems is concentrated around a relatively small number of influential publications, particularly those published between 2018 and 2022. The figure demonstrates that earlier publications accumulated substantially higher citation counts compared to more recent studies. This pattern is expected in bibliometric analysis because older articles generally have had more time to gain visibility and receive citations from subsequent research. The strong citation performance of studies published during the 2018–2022 period suggests that these publications played a critical role in establishing the conceptual and methodological foundations of circular economy research within coffee systems.

The concentration of citations around specific years also reflects the timing of increased global attention toward sustainability transitions, circular bioeconomy strategies, and resource recovery systems. During this period, international policy discussions surrounding climate change mitigation, waste reduction, and sustainable production intensified considerably, encouraging broader scientific engagement with circular economy frameworks. Consequently, many foundational studies focusing on coffee waste valorization, renewable energy pathways, circular supply chains, and environmental sustainability gained substantial academic visibility and influence. The citation distribution further reveals that the field is still relatively young and evolving. Although publication output has increased significantly in more recent years, particularly from 2023 onward, newer publications have generally accumulated lower citation counts. This trend should not be interpreted as an indication of weak scholarly relevance. Rather, it reflects the normal citation time-lag phenomenon in scientific publishing, where recently published studies require sufficient time before they can accumulate citations and academic recognition. Similar citation patterns are commonly observed in emerging interdisciplinary research domains where publication growth occurs more rapidly than citation accumulation.

Another important observation is that the citation structure appears highly concentrated around studies emphasizing technical and systems-oriented sustainability approaches. Highly cited publications are largely associated with topics such as coffee waste valorization, life-cycle assessment, bioenergy optimization, circular bioeconomy applications, digital traceability systems, and supply-chain sustainability. This pattern suggests that the field has thus far been primarily driven by environmental engineering, industrial ecology, and systems-optimization perspectives. At the same time, the comparatively limited citation visibility of studies related to agroecological transitions, regenerative agriculture, farmer livelihoods, and socioecological resilience suggests that these dimensions remain less established within the literature. The findings therefore reinforce earlier observations from the keyword and co-authorship analyses indicating that circular economy research in coffee systems still leans strongly toward techno-economic and industrial sustainability approaches. This imbalance highlights an important opportunity for future scholarship to strengthen the integration of agroecological and community-centered sustainability perspectives within circular coffee research.

Conclusion

The study examined the intellectual structure, thematic evolution, and research dynamics of circular economy research in coffee systems through bibliometric and knowledge-mapping analysis. The findings revealed that the field is an emerging yet rapidly expanding area of interdisciplinary research strongly driven by growing global concerns regarding sustainability, waste management, resource recovery, and regenerative production systems. The increasing publication output observed over recent years indicates that circularity has become an important framework for addressing environmental and sustainability challenges within coffee value chains. The bibliometric profile demonstrated that circular economy research in coffee systems is highly collaborative and interdisciplinary, involving contributions from multiple scientific disciplines such as sustainability science, environmental engineering, industrial ecology, logistics, agricultural systems, renewable energy, and waste management. The citation analysis further showed that the intellectual foundation of the field is largely shaped by studies focusing on waste valorization, circular bioeconomy applications, sustainability assessment, supply-chain optimization, and digital sustainability innovations. These highly influential studies have contributed significantly to the development of systems-oriented sustainability approaches within coffee systems. The co-authorship and source-country analyses revealed that scientific collaboration in the field is increasingly internationalized but remains moderately fragmented and geographically uneven. Research production is concentrated primarily in Europe and major coffee-producing countries in Latin America, while several coffee-producing regions in Africa and Southeast Asia remain underrepresented in the literature. This imbalance highlights the need for more inclusive and geographically diverse research participation, particularly from regions where coffee production and sustainability challenges are most pronounced. The keyword and thematic analyses further revealed that the field is strongly dominated by concepts related to coffee waste utilization, circular bioeconomy, sustainability assessment, life-cycle analysis, and resource recovery systems. While agroecological and regenerative sustainability perspectives have started to emerge within the literature, these themes remain less developed compared to techno-economic and industrial sustainability approaches. The findings therefore suggest that current circular economy research in coffee systems still emphasizes technological efficiency and waste valorization more strongly than socioecological transformation, farmer livelihoods, and regenerative agricultural systems.

Implications for Practice and Future Research

The findings of the study offer several important implications for practice, policy, and future research. From a practical perspective, the growing emphasis on coffee waste valorization and circular bioeconomy applications suggests that coffee by-products possess significant potential for renewable energy production, biomaterials, sustainable packaging, organic fertilizers, and environmental remediation. Coffee industry stakeholders, agribusiness enterprises, associations, cooperatives, and policymakers may therefore consider investing in circular production systems and waste recovery technologies that improve both environmental sustainability and economic value generation within coffee value chains. The results also imply that sustainability initiatives in coffee systems should move beyond conventional waste-management approaches and adopt more integrated circular and regenerative frameworks. Governments, research institutions, and development organizations may strengthen support for circular economy programs through policy incentives, sustainability standards, technical extension services, and innovation partnerships. Such interventions may contribute to reducing environmental burdens associated with coffee production while promoting resource efficiency and sustainable livelihood opportunities for coffee-producing countries. Particularly those in developing regions, the findings highlight the importance of strengthening local research capacity and international collaboration related to circular economy and sustainability

transitions. Increased participation of researchers and institutions from underrepresented coffee-producing regions may help generate more context-sensitive and locally grounded sustainability solutions. Strengthening collaboration among Higher Education Institutions (HEI's), research centers, farmers' organizations, and industry stakeholders may also improve the practical applicability of circular economy innovations within real production environments. The study additionally suggests important implications for agroecological transition and regenerative agriculture initiatives. While current research remains strongly focused on technical and industrial applications of circularity, future sustainability efforts should place greater attention on farmer-centered approaches, agroforestry systems, biodiversity conservation, soil health improvement, and climate resilience. Integrating circular economy principles with agroecological and regenerative frameworks may help create more holistic and socially inclusive sustainability pathways for coffee systems. There are several important gaps remain evident within the literature. First, future studies may further explore the social and socioecological dimensions of circular economy transitions in coffee systems, including farmer livelihoods, labor conditions, local knowledge systems, and community resilience. Second, additional empirical studies are needed to examine the practical implementation and scalability of circular economy innovations within smallholder coffee systems, particularly in developing countries. Third, future research may expand beyond waste valorization and technological optimization toward broader systems-oriented sustainability analysis involving governance structures, institutional barriers, policy integration, and circular business models. Comparative cross-country studies may also help explain how regional contexts influence the adoption and effectiveness of circular economy strategies within coffee value chains.

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Author Contribution

The author solely conceptualized the study, conducted data collection and bibliometric analysis, interpreted the findings, and prepared the manuscript.

Declaration of Interest

The author declares that there are no known financial, professional, institutional, or personal conflicts of interest that could have influenced the conduct, analysis, interpretation, or publication of this study. The research was conducted independently in the interest of advancing knowledge on circular economy and sustainability research in coffee systems.

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