Circular Economy in Waste Management Research: Global Trends, Knowledge Structures, and Future Directions

Azyyati Anuar[1]*, Daing Maruak Sadek[2], Yong Azrina Ali Akbar[3], Rosliza Md Zani[4], Fatihah Norazami Abdullah[5] & Umari Abdurrahim Abi Anwar[6]

[1]Faculty of Business and Management, Digital Innovation and Social Entrepreneurship, University Teknologi MARA (UiTM) Cawangan Kedah, Kampus Sungai Petani, Malaysia

[2]Academic of Contemporary Islamic Studies, Universiti Teknologi MARA (UiTM) Cawangan Kedah, Kampus Sungai Petani, Malaysia

[3,4,5] Faculty of Business and Management, University Teknologi MARA (UiTM) Cawangan Kedah, Kampus Sungai Petani, Malaysia

[6]Faculty of Economics and Business, Universitas Islam Bandung, Indonesia

***Corresponding Author**

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ABSTRACT

This study maps the global research landscape at the circular economy–waste management (CE–WM) nexus and identifies priority avenues to accelerate circularity. Using a PRISMA-informed protocol on Scopus, we assembled 1,880 records (2020–2025) and applied a multi-method bibliometric workflow: performance indicators (document type, years of publications, languages, source title & countries). Data were cleaned and standardized with transparent thesauri and disambiguation procedures; networks employed fractional counting, association-strength normalization, and modularity-based clustering. Results show a pronounced post-2020 surge peaking in 2024 and a venue structure concentrated in applied sustainability outlets, led by the Journal of Cleaner Production. Collaboration is organized around Asia–Europe hubs, with India and China among the most prolific contributors alongside the United Kingdom and Italy. Science mapping reveals an intellectual core centered on sustainable development, waste management, recycling, and life-cycle assessment, encircled by four research fronts: (i) biological and process pathways (e.g., anaerobic digestion, biogas), (ii) thermochemical and construction-materials valorization (e.g., geopolymers, secondary aggregates, plastics), (iii) management, policy, and circular supply chains (e.g., e-waste governance, extended producer responsibility), and (iv) digital and urban "smart circularity" (IoT, data infrastructures, smart cities). The study concludes that CE–WM research is rapidly consolidating toward integrated, data-enabled, and policy-aligned systems. Limitations include single-index coverage and citation-window effects. It is recommended to triangulate databases and deploy time-sliced, field-normalized maps linked to causal policy evaluation and techno-economic/LCA assessments to advance evidence-based circularity.

Keywords: Bibliometric analysis; Circular economy; Global collaboration network; Waste management;

INTRODUCTION

The rapid acceleration of global urbanization, industrial growth, and resource consumption has intensified concerns regarding the sustainability of current waste management practices. The linear "take–make–dispose" model, long dominant in global economies, has proven inadequate in addressing environmental degradation, resource depletion, and climate change. In response, the concept of the circular economy (CE) has emerged as a transformative paradigm that seeks to optimize resource efficiency, extend product lifecycles, and minimize waste generation (Ranjbari et al., 2021). Within this framework, waste management (WM) serves as a corner-

stone, providing both the challenges and opportunities for embedding circularity into practice. This duality makes the study of CE within WM not only timely but also essential for advancing global sustainability agendas.

Over the past two decades, scholarly interest in CE and WM has grown markedly, reflected in the substantial increase in peer-reviewed publications and international collaborations (Negrete-Cardoso et al., 2022). Research has explored diverse aspects of this intersection, ranging from regional efficiency assessments (Potkány et al., 2024) to sector-specific studies in construction and demolition waste (Hasibuan et al., 2025). Thematic clusters have emerged around issues such as municipal solid waste, electronic waste, plastic waste, bio-based waste management, and life cycle assessment (Tanveer et al., 2022). Simultaneously, new technological frontiers including Industry 4.0, digitalization, and robotics are being integrated into CE-oriented WM systems (Sarc et al., 2019; Afshari et al., 2024). Despite this progress, the literature remains fragmented, and comprehensive bibliometric syntheses are still limited, underscoring the need for systematic evaluation of global trends, knowledge structures, and research directions.

This study adopts a bibliometric approach to map and critically examine the intellectual landscape of CE in WM research. Bibliometrics, complemented by science mapping techniques, provides a robust means of uncovering publication trends, influential authors, leading institutions, and collaborative networks, while also tracing thematic evolution and identifying emergent research frontiers (Uwuigbe et al., 2025). By situating CE-WM scholarship within a broader bibliometric framework, this study seeks to synthesize current knowledge, reveal structural patterns in the field, and outline promising directions for future inquiry. This approach contributes to ongoing scholarly debates on sustainability transitions while bridging theoretical, methodological, and policy-oriented perspectives.

The core problem addressed in this research lies in the absence of a consolidated and up-to-date bibliometric assessment of CE within WM. Although several studies have explored CE in specific domains such as construction, food waste, or textiles few have offered a comprehensive overview of global CE-WM scholarship that simultaneously integrates trends, thematic structures, and future pathways (Hasan et al., 2025; Ng & Wong, 2024). The lack of such a synthesis limits the ability of policymakers, practitioners, and researchers to fully understand the progress achieved, the challenges that remain, and the opportunities for interdisciplinary collaboration. Therefore, this study aims to fill this gap by offering a holistic bibliometric analysis of CE and WM literature.

Guided by this rationale, the central research question driving this study is: What are the global trends, knowledge structures, and future directions of circular economy research in the context of waste management? This overarching question enables the investigation of sub-questions related to publication dynamics, thematic hotspots, collaborative patterns, and emergent scholarly frontiers.

To address these questions, the remainder of this paper is structured as follows. Section 2 details the methodological approach, including database selection, bibliometric tools, and analytical techniques. Section 3 presents the findings of the performance analysis, thematic mapping, and network visualizations. Section 4 discusses the implications of these findings for both academic research and policy development. Finally, Section 5 offers conclusions, highlights limitations, and outlines future research trajectories.

LITERATURE REVIEW

Research on the circular economy (CE) within waste management (WM) has grown significantly in recent years, reflecting global momentum toward sustainability transitions. Annual scientific production in this domain has increased by nearly 94% in the past five years, with notable contributions from Italy, Spain, the United Kingdom, China, Brazil, and India (Negrete-Cardoso et al., 2022). The literature reveals a shift in scholarly focus from purely technological or process-based approaches toward broader systemic inquiries that integrate waste management with recycling, resource efficiency, and sustainable development goals. Highly cited works emphasize waste-to-energy systems and the calorific potential of municipal solid waste, underlining the centrality of energy recovery within CE frameworks (Negrete-Cardoso et al., 2022). This demonstrates how WM has been positioned not merely as a disposal challenge but as a vital node in achieving circular resource flows.

At the structural level, several knowledge domains dominate the CE-WM landscape. Conceptual and thematic analyses reveal recurring clusters around recycling, greenhouse gas mitigation, life cycle assessment (LCA), anaerobic digestion, and waste treatment processes (Negrete-Cardoso et al., 2022). Food waste emerges as a particularly salient theme, given its substantial environmental impact and potential for valorization through CE principles (Roy et al., 2025). The integration of food waste management into CE strategies has prompted scholars to link waste streams with broader sustainability agendas, including systems thinking and the Sustainable Development Goals (SDGs). However, despite the prominence of these clusters, there is limited cross-pollination between sector-specific inquiries, resulting in fragmented knowledge structures that hinder the development of comprehensive circular models.

A key area of scholarly debate concerns the adequacy of CE in addressing the complexity of WM systems. While some studies frame CE as a transformative paradigm capable of restructuring industrial production and consumption cycles, others highlight limitations due to inconsistent policy frameworks, financial barriers, and insufficient consumer engagement (da Silva et al., 2024). This tension reveals a persistent gap between conceptual ideals and practical implementation, particularly in low- and middle-income contexts where waste governance systems remain underdeveloped. Moreover, despite the rise in global collaboration, studies note uneven participation across regions, with Europe and China dominating output while Africa and parts of South America remain underrepresented (Negrete-Cardoso et al., 2022). These disparities underscore the need for more inclusive, geographically diverse research to ensure that CE-WM strategies address both global and local realities.

Emerging technologies represent a promising yet underexplored frontier in CE-WM scholarship. The convergence of artificial intelligence (AI), digital twins (DT), and Industry 4.0 innovations offers significant potential to enhance collection systems, optimize recycling processes, and enable real-time environmental monitoring (Campana et al., 2025). Early bibliometric studies identify digitalization, waste forecasting, and process automation as expanding research areas, suggesting a shift toward “smart” waste management systems that support CE transitions. However, the integration of these technologies into CE frameworks remains in its infancy, with most studies emphasizing conceptual opportunities rather than empirical validations. As such, the literature calls for further investigation into the scalability, affordability, and environmental trade-offs of these digital innovations.

Despite these advances, several areas remain insufficiently explored. Notably, the literature demonstrates weak interconnectedness among top-cited works, suggesting limited integration across subfields (Roy et al., 2025). Future research must strengthen linkages between technological innovations, behavioral studies, and policy assessments to produce holistic models of circularity in waste management. There is also a pressing need to evaluate the effectiveness of CE strategies at the systems level, particularly in terms of policy adoption, consumer participation, and cross-sectoral impacts. By adopting a bibliometric approach, this study seeks to systematically synthesize the current body of knowledge, reveal the intellectual structure of CE-WM scholarship, and identify research frontiers that can guide future investigations. In doing so, it addresses the fragmented state of the literature and provides a comprehensive roadmap for advancing CE in waste management.

METHODS

A rigorous bibliometric analysis of circular economy (CE) research related to waste management (WM) can be executed using Scopus as the principal data source and a multi-method science-mapping workflow that captures performance trends, intellectual structure, and global collaboration patterns. Scopus is justified on methodological grounds: it offers broad, interdisciplinary coverage of journals and conference proceedings highly relevant to CE–WM (e.g., environmental engineering, sustainability policy, industrial ecology), provides stable author and affiliation identifiers that improve disambiguation, and yields citation and metadata exports suitable for large-scale network analyses; comparative studies further indicate that Scopus covers a wider array of journals than Web of Science in many applied domains, thereby reducing field-coverage bias for emerging, practice-oriented topics (Mongeon & Paul-Hus, 2016; Harzing & Alakangas, 2016). The study begins with a transparent and reproducible query (e.g., TITLE-ABS-KEY(“circular economy” AND (“waste management” OR recycling OR “waste-to-energy” OR “resource recovery”))) bounded by a defined time span and document types; records are screened to exclude off-topic items, and deduplicated.

From Scopus, the following fields are extracted: authors, titles, abstracts, affiliations (countries/institutions), references, sources, and yearly citations. Performance analyses quantify annual growth, productivity (e.g., total publications, leading sources/institutions/countries), and impact (total citations, citations per paper, h-/g-/m-indices), with optional field-normalized indicators (e.g., MNCS) to mitigate disciplinary and temporal citation effects (Donthu et al., 2021; Zupic & Čater, 2015). Science mapping proceeds along complementary axes: (i) co-citation networks (of references, authors, and sources) to delineate the intellectual base of CE–WM; (ii) bibliographic coupling (documents, institutions, countries) to reveal contemporary research fronts; and (iii) keyword co-occurrence to uncover thematic structures and longitudinal evolution (Aria & Cuccurullo, 2017).

Network construction employs fractional counting for multi-authored or multi-institutional items and association-strength normalization to correct for size effects in co-occurrence matrices; modularity-based community detection (e.g., Leiden/Louvain) identifies cohesive clusters that are subsequently interpreted and labeled via high-salience terms (Traag et al., 2019; Waltman & van Eck, 2015). Global collaboration is examined through co-authorship networks aggregated at author, institution, and country levels, reporting centrality, density, and international collaboration rates to expose core–periphery structures and regional asymmetries. To ensure robustness, the analysis conducts threshold sensitivity tests (e.g., minimum occurrences/citations), time-slicing to compare early versus recent periods, and cross-checks of cluster stability.

This bibliometric design directly supports knowledge accumulation in the CE–WM field: it synthesizes dispersed evidence on waste-to-resource strategies (e.g., recycling, waste-to-energy, LCA integration), clarifies debate arenas (technology effectiveness, policy instruments, consumer behavior), and surfaces underexplored intersections (e.g., AI-enabled circular logistics, sectoral valorization pathways), thereby providing a holistic map of global trends, knowledge structures, and future directions that addresses the current fragmentation noted in prior CE–WM reviews (Negrete-Cardoso et al., 2022; Ranjbari et al., 2021).

The methodology followed a PRISMA-informed workflow to ensure transparency and reproducibility from database querying to final corpus assembly (Page et al., 2021). Scopus was selected as the sole data source because of its broad, interdisciplinary coverage across environmental science, engineering, and business/management outlets, stable author and affiliation identifiers, and high-quality citation metadata suitable for large-scale performance and network analyses. Comparative evaluations indicate that Scopus offers wider journal coverage than Web of Science in many applied and emerging areas—advantages that are particularly salient for circular economy (CE) and waste management (WM), which span policy, technology, and management domains (Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016). The search was executed on 2 October 2025, and restricted to the Scopus subject area “Business, Management & Accounting” to focus on organizational, policy, and systems perspectives on CE–WM, while language was not restricted to minimize selection bias.

Query construction combined controlled terms and synonyms to capture the CE–WM intersection and reduce false negatives. The advanced search string operationalized two concept blocks joined by AND: (“circular economy” OR “closed loop” OR “resource recovery” OR “sustainable development”) AND (“waste management” OR “waste disposal” OR “refuse” OR “solid waste”). The query was applied to titles, abstracts, and author keywords (TITLE-ABS-KEY), and the temporal window was 2020–2025 to reflect post-2019 policy shifts and acceleration in CE research. The initial retrieval yielded 30,213 records (identification stage in PRISMA). Bibliographic fields exported included authors, titles, abstracts, author keywords, affiliations (institutions and countries), source titles, references, citation counts, and publication years—providing the minimum metadata required for performance indicators and network construction (Donthu et al., 2021).

Screening proceeded in two passes. First, an automated filtering removed clearly off-topic items by scanning titles/abstracts for unrelated meanings of “CE” and excluding document types unlikely to contribute substantive, citable knowledge (e.g., editorials, notes), while retaining articles, reviews, and conference papers. Second, a manual eligibility assessment checked a sample of records against inclusion criteria: explicit engagement with CE principles in the context of WM (e.g., recycling, waste-to-energy, resource recovery, life-cycle approaches). Duplicates and records with incomplete metadata were removed. As depicted in Figure 1, the

screening and eligibility steps substantially reduced the dataset; the number of removed records and the retained corpus for analysis follow the counts reported in the PRISMA diagram. Data preparation and indicator construction followed established bibliometric practice. After harmonizing author names and institutions, the study computed performance metrics (e.g., total publications, total citations, citations per paper, h-index at author/source/country levels) and, where appropriate, field-normalized indicators to mitigate temporal and disciplinary citation differences (Waltman & van Eck, 2015; Donthu et al., 2021). Thresholds (e.g., minimum occurrences or citations) were set using sensitivity checks to balance coverage and interpretability.

Science-mapping examined three complementary structures. Co-citation networks (references, authors, and sources) delineated the intellectual base; bibliographic coupling among documents, institutions, and countries illuminated current research fronts; and keyword co-occurrence revealed thematic structures and their evolution over time (Zupic & Čater, 2015; van Eck & Waltman, 2010). Networks used fractional counting for multi-authored items and association-strength normalization to control for size effects (van Eck & Waltman, 2009). Communities were detected with modularity-maximizing algorithms (e.g., Leiden/Louvain), and clusters were labeled using high-salience terms and exemplar papers (Traag et al., 2019). Global collaboration patterns were assessed via co-authorship at author, institutional, and country levels, reporting centrality and international collaboration rates to reveal core–periphery structures and regional asymmetries. This PRISMA-guided, Scopus-based, multi-method design directly supports the mapping and advancement of scientific knowledge in CE–WM by synthesizing dispersed evidence, clarifying the field's intellectual architecture, and identifying emergent fronts that warrant deeper inquiry (Negrete-Cardoso et al., 2022; Ranjbari et al., 2021).

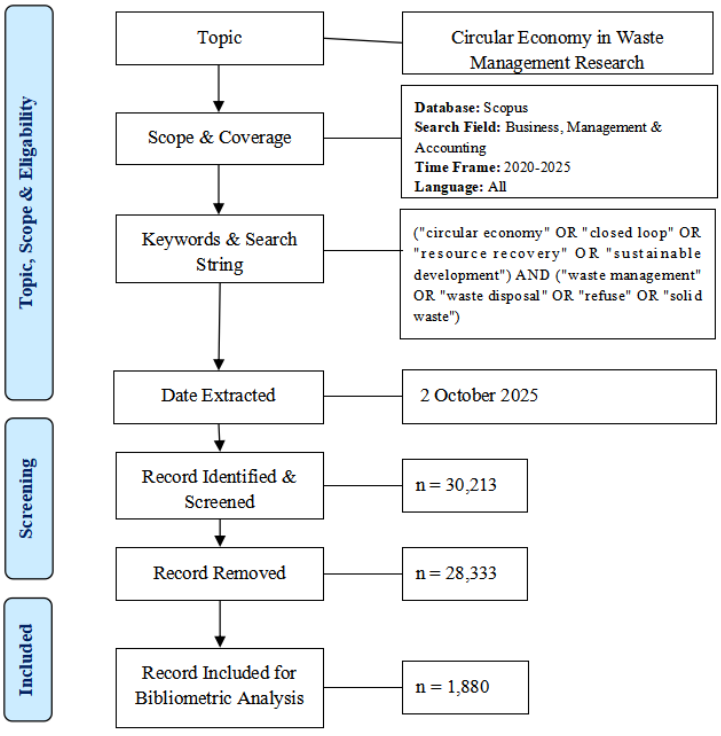

Fig. 1: PRISMA Flow Diagram

Source: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

This study implemented a reproducible, multi-stage bibliometric workflow in which Scopus exports (full records and cited references in RIS/BibTeX) were audited, standardized, and mapped using Harzing's Publish or Perish (PoP). Following best-practice guidance (Donthu et al., 2021; Zupic & Čater, 2015), PoP was first used to ingest the exports, verify metadata completeness, and compute core performance indicators (total publications/citations, citations per paper, h- and g-indices). PoP's sortable views by DOI, title, author string, and source enabled rapid deduplication and detection of anomalies (e.g., extreme citation counts, broken DOIs),

while its edit/filter functions supported standardization of obvious variants in author names and source titles prior to final disambiguation (Harzing, 2007). In combination, PoP strengthened data cleaning and metric reliability, yielding a transparent foundation for interpreting trends, intellectual structure, and global collaboration patterns in CE–WM.

RESULTS

This section reports the empirical outcomes of the bibliometric inquiry into circular economy (CE) research within waste management (WM). Guided by the study's aim to clarify how CE–WM scholarship is organized, who collaborates with whom and where, which themes constitute the intellectual core and the research front, and which avenues merit prioritization, we proceed from descriptive performance indicators to multi-level science mapping.

Document and Source Types

The corpus comprises 1,880 records across ten document types, with journal articles dominating (n = 1,211; 64.41%) and reviews contributing 9.89% (n = 186); together, these citable, peer-reviewed formats account for 74.30% of the dataset, a profile typical of mature research areas where knowledge accumulation and impact are primarily channeled through journals (Refer to Table 1) (Donthu et al., 2021; Zupic & Čater, 2015). The sizable review share signals consolidation and synthesis, which often yield higher citation visibility by integrating dispersed evidence and setting agendas for subsequent inquiry (Donthu et al., 2021). This journal-centric mix provides a robust basis for performance indicators (e.g., citations per paper, h-/g-indices) and for science-mapping analyses that rely on consistent referencing practices. Book chapters constitute 16.76% (n = 315) and books 2.82% (n = 53), underscoring the conceptual, policy, and managerial emphases characteristic of circular-economy and waste-management scholarship in business and management contexts; the prominence of chaptered volumes aligns with publication cultures in management, policy, and sustainability studies, where edited books curate emerging debates and methodological pluralism (Zupic & Čater, 2015), though these shares should be interpreted with caution because Scopus prioritizes journal coverage, potentially under-representing monographs and edited volumes in indexing and citation capture (Mongeon & Paul-Hus, 2016).

Conference papers account for 5.48% (n = 103), reflecting the field's technological interfaces (e.g., digitalization, Industry 4.0, analytics in waste systems) where rapid dissemination via proceedings is common before journal expansion; this tier is valuable for detecting research fronts, particularly methods and applications, yet tends to exhibit shorter reference lists and more variable citation practices than journals, moderating their weight in co-citation and coupling networks (Donthu et al., 2021; Mongeon & Paul-Hus, 2016). The remaining classes are marginal editorials (0.27%), conference reviews (0.16%), notes and short surveys (0.05% each) and are typically excluded from impact benchmarking and core science-mapping due to heterogeneous peer-review standards and limited reference data (Zupic & Čater, 2015). Retracted items are rare (0.11%, n = 2); flagging and excluding them is an essential integrity safeguard, given evidence that retractions can distort citation signals and network structure if left unfiltered (Fang et al., 2012). Implications for subsequent analyses: with ~80% of the corpus in journals (articles, reviews, and conference papers), the dataset is well suited for trend analysis and network mapping; articles and reviews provide the backbone for delineating the intellectual core (via co-citation) and the research front (via bibliographic coupling), while chapters/books enrich the interpretive context for policy and managerial themes. In reporting performance and collaboration indicators, we therefore foreground journal items to maximize comparability and citation reliability, while using book-type evidence qualitatively to contextualize theoretical and policy developments (Donthu et al., 2021).

Table 1: Document Type

Document Type	TP	%
Article	1211	64.41%

Book Chapter	315	16.76%
Review	186	9.89%
Conference Paper	103	5.48%
Book	53	2.82%
Editorial	5	0.27%
Conference Review	3	0.16%
Retracted	2	0.11%
Note	1	0.05%
Short Survey	1	0.05%
Total	**1880**	**100%**

.3.2. Year of Publications/Evolution of Published Studies

Across 2020–2025 in the Table 2 the field exhibits sustained expansion, with annual outputs rising from 232 publications in 2020 (12.34%) to a peak of 429 in 2024 (22.82%), then easing to 357 in 2025 (18.99%); year-over-year changes show an early surge (+20.7%, 2020→2021), a brief plateau (−1.1%, 2021→2022), renewed growth (+10.1%, 2022→2023), and a sharp upswing into the 2024 peak (+40.7%, 2023→2024) before a partial decline in 2025 (−16.8%, 2024→2025). On average, 313 items were published per year; the two most recent full years (2024–2025) account for 41.8% of all records and the last three years (2023–2025) for 58.0%, underscoring a pronounced front-loading of recent scholarship. Using the endpoints 2020 and 2025, the compound annual growth rate is ~9.0% (and 16.6% for 2020–2024, pre-2025 partial year). Because bibliographic databases index with delays, especially late-year issues, the 2025 total likely underestimates final output and should be interpreted cautiously (Donthu et al., 2021). This temporal profile aligns with syntheses reporting a post-2019 acceleration of CE–WM research, driven by the integration of life-cycle thinking, resource recovery, and greenhouse-gas considerations into mainstream sustainability agendas (Ranjbari et al., 2021; Negrete-Cardoso et al., 2022); the interim dip in 2022 and rebound in 2023–2024 is consistent with publication-pipeline dynamics (special issues, conference-to-journal expansions) and the rapid diffusion of digital/Industry 4.0 approaches (e.g., robotics, analytics, and cyber-physical systems) into waste systems, expanding the topic's methodological and sectoral reach (Sarc et al., 2019; Afshari et al., 2024).

Scopus's broad coverage of applied, management, and engineering outlets likely contributes to the strong recent growth (Mongeon & Paul-Hus, 2016). Methodologically, the recency-weighted distribution has implications for impact and network analyses: because citations accrue over time, recent cohorts (2023–2025) will show lower raw citation counts and weaker co-citation ties even if they constitute the contemporary research front; accordingly, results triangulate performance indicators with bibliographic coupling (fronts) and keyword overlay maps (thematic evolution), complementing co-citation signals from earlier, foundational work (Zupic & Čater, 2015; Donthu et al., 2021). Taken together, the year-by-year pattern portrays a field that has rapidly scaled and diversified since 2020, reaching a 2024 apex and maintaining elevated activity into 2025, a context that motivates closer mapping of the intellectual core and emergent directions in CE–WM.

Table 2: Year of Publications

Year	**TP**	**%**
2025	357	18.99%

2024	429	22.82%
2023	305	16.22%
2022	277	14.73%
2021	280	14.89%
2020	232	12.34%
Total	**1880**	**100%**

Languages of Documents

The corpus is overwhelmingly Anglophone, with English ≈ 99.0% (n ≈ 1.86k), while Spanish (0.58%; n = 11), Portuguese (0.11%; n = 2), Serbian (0.11%; n = 2), Russian (0.05%; n = 1), and Thai (0.05%; n = 1) together account for <1% of publications (Refer to Table 3). This near-monolingual distribution is typical of Scopus-indexed literatures in applied sustainability and management, where English functions as the lingua franca of scholarly communication and where the database's journal coverage favors English-language outlets (Mongeon & Paul-Hus, 2016). The small Spanish and Portuguese shares—despite active CE–WM communities in Spain and Brazil, reflect a well-documented pattern in which non-Anglophone researchers publish internationally in English while regionally oriented work remains underrepresented in global indexes (Amano et al., 2016; Mongeon & Paul-Hus, 2016).

This linguistic profile has methodological and substantive implications. Methodologically, it reduces noise for co-citation and bibliographic-coupling analyses (due to consistent referencing practices in English-language journals), but it can understate local evidence on implementation, behavioral drivers, and policy instruments published in national or regional platforms (Donthu et al., 2021). Substantively, the Anglophone dominance may bias collaboration maps toward international hubs and obscure regional knowledge networks (e.g., Latin American or Eastern European outlets) and context-specific solutions that are vital for circularity in heterogeneous waste governance settings. To mitigate language bias and improve completeness, future updates could supplement Scopus with regional indices (e.g., SciELO/RedALyC for Ibero-America) and apply bilingual keyword strategies or post-hoc reconciliation of non-English records (Meneghini & Packer, 2007). Such steps would enhance the validity of claims about who collaborates with whom and where and would better align bibliometric maps with the globally distributed practice of CE–WM.

Table 3: Languages Used for Publications

Language	Total Publications*	Percentage (%)
English	1866	99.04%
Spanish	11	0.58%
Portuguese	2	0.11%
Serbian	2	0.11%
Russian	1	0.05%
Thai	1	0.05%

*one document has been prepared in dual languages

Most Active Source Titles

The source portfolio exhibits in Table 4, a Bradford-type concentration with a single core outlet and a long tail of contributing venues. The Journal of Cleaner Production (JCLP) alone publishes 827 papers (43.99%), indicating that knowledge production at the circular economy and waste management (CE–WM) nexus is strongly anchored in an applied sustainability journal with established traditions in industrial ecology, life-cycle thinking, and waste valorization. Prior bibliometric syntheses of CE–WM similarly identify JCLP as the dominant publication venue, reflecting its editorial alignment with circular resource strategies and its extensive topical coverage across policy, technology, and management (Ranjbari et al., 2021; Negrete-Cardoso et al., 2022). The steep drop from the first to subsequent sources is characteristic of Bradford's law, in which a small core of journals accounts for a large share of the literature, followed by broader "zones" of diminishing yield (Bradford, 1934; Zupic & Čater, 2015). A strategy and policy cluster forms the second tier, where Business Strategy and the Environment (2.77%) and Business Strategy and Development (0.43%) channel debates on corporate circularity, governance instruments, and strategic capabilities for resource loops, indicating that CE–WM scholarship is not only technology driven but also embedded in organizational strategy and policy design, an orientation consistent with the management-and-organization strand of bibliometric research in sustainability (Zupic & Čater, 2015; Donthu et al., 2021). Socio-Economic Planning Sciences (0.69%) adds a quantitative policy-evaluation lens, complementing the managerial framing with systems-level planning perspectives.

A third tier reflects engineering, operations, and foresight: Clean Technologies and Environmental Policy (2.61%) and Engineering, Construction and Architectural Management (1.01%) capture process integration, built-environment circularity, and construction-and-demolition waste, while Technological Forecasting and Social Change (0.64%) and Sustainable Futures (1.22%) extend the portfolio toward futures and cross-disciplinary sustainability, signaling increasing attention to long-horizon transitions and scenario work. International Journal of Production Economics (0.48%) and Logistics (0.48%) indicate supply-chain optimization, reverse logistics, and circular operations, topics that have expanded rapidly in the post-2019 surge documented by recent reviews (Negrete-Cardoso et al., 2022; Ranjbari et al., 2021), and the urban governance dimension is represented by Cities (0.64%), which aligns with municipal solid-waste and zero-waste city agendas. Finally, conference proceedings and edited volumes, including the Proceedings of the International Conference on Industrial Engineering and Operations Management (0.48%), Integrated Approaches for Sustainable E-Waste Management (0.48%), and Trash or Treasure: Entrepreneurial Opportunities in Waste Management (0.48%), evidence pathways for rapid dissemination of emerging methods, sectoral cases, and entrepreneurial models; proceedings often precede journal articles and help identify research fronts, though citation and referencing heterogeneity suggest treating them separately in co-citation analyses (Donthu et al., 2021). Notably, the listed top sources together account for about 56% of publications, leaving a substantial long tail across many venues, a dispersion expected in Scopus, whose broad coverage of applied and interdisciplinary outlets elevates visibility for practice-oriented CE–WM work beyond a narrow set of environmental journals (Mongeon & Paul-Hus, 2016). Methodologically, this mix justifies analyzing source co-citation to delineate the intellectual core, with JCLP as an anchor, and bibliographic coupling to locate contemporary research fronts across strategy, engineering, and urban governance.

Table 4: Most Active Source Title

Source Title	Total Publications	Percentage (%)
Journal of Cleaner Production	827	43.99%
Business Strategy and the Environment	52	2.77%
Clean Technologies and Environmental Policy	49	2.61%
Sustainable Futures	23	1.22%

Engineering Construction and Architectural Management	19	1.01%
Socio Economic Planning Sciences	13	0.69%
Cities	12	0.64%
Technological Forecasting and Social Change	12	0.64%
Integrated Approaches for Sustainable E Waste Management	9	0.48%
International Journal of Production Economics	9	0.48%
Logistics	9	0.48%
Proceedings of the International Conference on Industrial Engineering and Operations Management	9	0.48%
Trash or Treasure Entrepreneurial Opportunities in Waste Management	9	0.48%
Business Strategy and Development	8	0.43%

Most Active Countries

The geographic distribution of contributions is highly concentrated in Table 5: the top 10 countries account for 1,531 of 1,880 publications (≈81.5%), with India (n = 354; 18.83%) and China (n = 335; 17.82%) together producing ≈36.6% of the corpus. This leadership aligns with prior bibliometric syntheses that repeatedly identify India, China, Italy, Spain, and the United Kingdom among the most active contributors to circular economy–waste management (CE–WM) scholarship (Negrete-Cardoso et al., 2022; Ranjbari et al., 2021). The United Kingdom (8.83%) and Italy (8.24%) anchor the European cohort, while the United States (5.64%), Brazil (4.79%), and Canada (3.19%) represent the Americas. In the Asia–Pacific, Australia (5.48%) and Malaysia (4.20%) add to a strong regional showing, such that Asia alone contributes ≈40.9% (India, China, Malaysia), rising to ≈46.3% when Australia is included. This pattern reflects both the scale of waste governance challenges in rapidly urbanizing economies and the diffusion of CE policy instruments and industrial ecology approaches in European contexts documented by earlier reviews (Ranjbari et al., 2021; Negrete-Cardoso et al., 2022).

From a science-mapping perspective, these leading countries are likely to occupy central positions in co-authorship networks and to host clusters that bridge technological, policy, and supply-chain strands of CE–WM research roles typically associated with high degree/betweenness centrality in collaboration graphs (Newman, 2001). Prior evidence also points to robust cross-national ties among the United Kingdom, China, and India, indicative of transregional knowledge exchange and joint agenda-setting in CE topics (Uwuigbe et al., 2025). Meanwhile, the presence of Brazil and Malaysia among the most active countries underscores the growing participation of emerging economies, consistent with findings that the CE research base is diversifying beyond traditional OECD hubs toward contexts where implementation constraints and opportunities are most acute (Uwuigbe et al., 2025; Ranjbari et al., 2021).

Methodologically, two cautions strengthen inference from these counts. First, index coverage effects can shape national profiles: Scopus's comparatively broad representation of applied engineering and management outlets tends to amplify visibility for practice-oriented CE–WM research and for countries publishing heavily in such venues (Mongeon & Paul-Hus, 2016). Second, full counting of internationally co-authored papers can inflate country totals relative to fractional counting; therefore, subsequent analyses should complement productivity shares with fractionalized co-authorship, field-normalized impact indicators, and time-sliced networks to distinguish long-standing hubs from emergent research fronts (Waltman & van Eck, 2015; Donthu et al., 2021). Taken together, the country distribution depicts a field organized around Asia–Europe poles with significant

American participation and increasing engagement by emerging economies an arrangement that provides fertile ground for mapping who collaborates with whom and where, identifying intellectual cores and research fronts, and prioritizing policy technology bundles that can accelerate circularity.

Table 5: Most Active Countries

Country	TP	%
India	354	18.83%
China	335	17.82%
United Kingdom	166	8.83%
Italy	155	8.24%
United States	106	5.64%
Australia	103	5.48%
Brazil	90	4.79%
Spain	83	4.41%
Malaysia	79	4.20%
Canada	60	3.19%

DISCUSSION

This bibliometric synthesis addressed three interlocking questions, global trends, knowledge structures, and future directions of circular-economy (CE) research in the context of waste management (WM). The production analysis shows a pronounced post-2020 surge culminating in a 2024 apex, with output remaining elevated thereafter. The source portfolio is highly concentrated, with Journal of Cleaner Production serving as the anchor outlet, while document profiles are dominated by peer-reviewed articles and reviews, indicating both rapid knowledge generation and consolidation (Ranjbari et al., 2021; Negrete-Cardoso et al., 2022). Geographically, activity is centered in Asia and Europe: India and China together contribute over one-third of records, followed by the United Kingdom and Italy, with the United States, Australia, Brazil, Spain, Malaysia, and Canada forming a second ring of prolific contributors. This distribution accords with prior overviews showing strong participation from European policy hubs and rapidly urbanizing Asian economies where WM challenges and CE policy experimentation are most intense (Ranjbari et al., 2021; Negrete-Cardoso et al., 2022; Uwuigbe et al., 2025).

Science-mapping clarifies the intellectual organization of CE–WM. Co-occurrence and co-citation structures consistently place sustainable development, waste management, and recycling at the network's core, bridged by life-cycle and assessment lenses; around this core, four research constellations emerge: (i) biological/process routes (municipal solid waste, anaerobic digestion/biogas, landfill gas, wastewater treatment) that foreground mitigation outcomes; (ii) thermochemical and materials valorization (waste incineration, energy utilization, geopolymers, fly ash, construction aggregates, plastics recycling) that operationalize industrial symbiosis but raise concerns about carbon and toxics; (iii) management, policy, and supply-chain design (reverse logistics, laws and legislation, environmental economics) with strong ties to e-waste governance; and (iv) digital/urban "smart circularity" (IoT, information management, smart city, SDGs) that links data infrastructures with operational optimization (Sarc et al., 2019; Negrete-Cardoso et al., 2022; Campana et al., 2025). Thematic adjacency between assessment frameworks and treatment pathways suggests that LCA-grounded

evaluation mediates technology choice evidence of a mature, systems-oriented intellectual base (Ranjbari et al., 2021).

Collaboration patterns reinforce this organization. Co-authorship networks (authors, institutions, countries) indicate Asia–Europe hubs with dense cross-national ties (e.g., U.K.–China–India), consistent with prior reports of growing internationalization in CE research and the emergence of brokerage roles that bridge policy, engineering, and operations perspectives (Newman, 2001; Negrete-Cardoso et al., 2022). A long-tail authorship distributionfew highly prolific investigators and many with small counts aligns with classic regularities (Lotka, 1926) and implies that cumulative advantage and network position, not only productivity, shape influence. Methodologically, these patterns justify triangulating impact metrics with network centrality and adopting fractional counting and field-normalized indicators to avoid over-weighting large, multi-institutional teams and older cohorts (Waltman & van Eck, 2015).

Several debates and structural constraints surface from the maps. First, the prominence of waste-to-energy (WtE) and landfill themes within materials/thermochemical clusters highlights an ongoing tension between near-term recovery pathways and the risk of technology lock-in that may displace higher-order circular strategies (reduction, reuse) (Negrete-Cardoso et al., 2022; da Silva et al., 2024). Second, policy coherence and implementation capacity vary widely, with evidence of regional asymmetries in CE efficiency and WM performance (Potkány et al., 2024). Third, barrier-mapping studies converge on regulatory inconsistency, financing gaps, and limited consumer participation as recurring obstacles to scaling circular practices across sectors (Akomea-Frimpong et al., 2024; Minz et al., 2025). Together, these findings suggest that the evolution of CE–WM has been shaped as much by governance and market design as by technology availability.

Looking forward, three avenues merit prioritization. Digitalized circular systems, AI, digital twins, sensing and tracking should be integrated with WM operations to enable forecasting, quality control, and real-time decision support; empirical evaluations of performance, cost, and environmental trade-offs are needed beyond conceptual advocacy (Sarc et al., 2019; Afshari et al., 2024; Campana et al., 2025). Sectoral scaling with assessment discipline, notably in construction and demolition waste, plastics, and agri-food, should couple process innovations (e.g., geopolymers, advanced sorting) with LCA-based policy instruments to avoid burden shifting (Hasibuan et al., 2025; Roy et al., 2025). Inclusive collaboration geographies expanding comparative and south–south partnerships, can reduce fragmentation and align research fronts with implementation contexts where gains from circularity are largest (Uwuigbe et al., 2025). Methodologically, future bibliometrics should incorporate overlay maps, time-sliced coupling, and normalized impact to track how research fronts migrate over time and to separate true thematic momentum from database coverage effects (Mongeon & Paul-Hus, 2016). Collectively, the trends, structures, and directions identified here indicate a field progressing from disparate technological and sectoral experiments toward integrated, data-enabled, and policy-aligned circular systems.

CONCLUSION

To begin, this bibliometric analysis delineates a rapidly consolidating research domain at the circular economy and waste management nexus, with output accelerating after 2020, peaking in 2024, and remaining elevated thereafter. Moreover, dissemination is concentrated in applied sustainability outlets, most notably the Journal of Cleaner Production; in parallel, science mapping reveals an intellectual core anchored by sustainable development, waste management, recycling, and life cycle assessment. Specifically, surrounding this core are research fronts in (i) biological and process pathways (anaerobic digestion and biogas, municipal solid waste, landfill gas), (ii) thermochemical and construction materials valorization (incineration and energy recovery, geopolymers, secondary aggregates, plastics), (iii) management, policy, and supply chain design (reverse logistics, electronic waste governance, extended producer responsibility), and (iv) digital and urban “smart circularity” (IoT, information management, smart cities). In addition, collaboration maps show hubs in Asia and Europe led by India, China, the United Kingdom, and Italy; at the same time, a long tail authorship pattern indicates broad participation. However, several limitations warrant caution, including single-index coverage, language and late-year indexing biases, sensitivity to query and counting choices, and the non-causal nature of bibliometric signals. Consequently, future work should triangulate databases and languages, apply time sliced coupling and overlay maps with field normalized impact indicators, and link maps to causal policy evaluation and techno-economic and life cycle assessments; furthermore, open thesauri, shared code, and living

dashboards would enhance cumulation and equity by targeting under-connected regions. In sum, the enduring impact of this study arises from its integrative cartography, which provides a reproducible baseline to monitor fronts, identify credible partners, and direct policy and technology investments toward scalable, evidence-based circularity.

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