

Intellectual Evolution of Circular Economy Research in Sustainable Universities: A Bibliometric and Science Mapping Analysis

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Abstract

The intensifying global environmental crisis has positioned the circular economy (CE) as a regenerative alternative to the linear economic model, with universities serving as pivotal agents for embedding sustainability principles across research, education, operations, and community engagement. Despite growing interest, the scholarly landscape at the intersection of CE and sustainable universities remains fragmented. This study addresses this gap through a comprehensive bibliometric review of 233 empirical journal articles retrieved from Scopus (2003–June 2026). Employing PRISMA-guided screening, data harmonization via Bibliomagika, and analytical tools including Biblioshiny and VOSviewer, the research examined publication trends, collaboration networks, intellectual structures, and thematic clusters.

Results indicate exponential growth in publications since 2018, peaking in 2024–2025, reflecting heightened academic engagement aligned with global sustainability agendas. Collaboration networks reveal highly interconnected international communities, with prominent hubs in Europe and Asia facilitating knowledge exchange. Co-citation and bibliographic coupling analyses uncover an interdisciplinary intellectual foundation linking sustainability science, environmental management, and higher education studies. Keyword co-occurrence mapping identifies four major thematic clusters: educational and sustainability dimensions, operational resource recovery, institutional waste management and governance, and technological innovation with life cycle approaches. These findings position universities as living laboratories for circular practices while highlighting opportunities for deeper cross-regional collaboration and longitudinal impact studies. The review offers scholars, policymakers, and university administrators a structured roadmap to address research gaps and accelerate CE integration in higher education. By synthesizing evolutionary patterns, collaborative dynamics, and emerging frontiers, this study contributes to strengthening the theoretical and practical foundations for sustainable university transitions.

Keywords: Circular Economy, Sustainable Universities, Bibliometric Analysis, Higher Education, Sustainability Education, Resource Efficiency.

Introduction

The accelerating depletion of natural resources, increasing waste generation, climate change, and environmental degradation have intensified the global call for more sustainable patterns of production and consumption. These interconnected challenges have exposed the limitations of the prevailing linear economic model, which follows a "take–make–dispose" approach characterized by intensive resource extraction, short

product life cycles, and the continuous generation of waste. In response, the circular economy (CE) has emerged as a transformative paradigm that seeks to decouple economic growth from finite resource consumption by promoting the reduction, reuse, repair, remanufacturing, and recycling of materials throughout their life cycles. Rather than focusing solely on waste management, the circular economy advocates the design of regenerative systems that minimize resource inputs, waste, emissions, and energy losses while creating environmental, economic, and social value (Geissdoerfer et al., 2017). Consequently, the circular economy has become a cornerstone of global sustainability initiatives and is increasingly recognized as a strategic pathway for achieving sustainable development and building resilient societies.

The successful transition toward a circular economy depends not only on technological innovation and industrial transformation but also on institutions capable of generating knowledge, shaping future leaders, and demonstrating sustainable practices. In this context, higher education institutions (HEIs) have emerged as strategic actors in advancing circular economy transitions by integrating sustainability into education, research, governance, campus operations, and community engagement (Salas et al., 2021; Vergani, 2024). Beyond their traditional academic functions, universities are increasingly recognized as living laboratories where circular economy principles can be designed, tested, evaluated, and transferred to society through interdisciplinary collaboration and stakeholder engagement (Vergani, 2024). Their campuses provide real-world environments for implementing resource-efficient systems, sustainable infrastructure, waste minimization strategies, circular procurement, and responsible consumption practices while simultaneously cultivating the competencies required to support sustainable development (Mendoza et al., 2019; Salas et al., 2021). Consequently, universities are increasingly viewed not merely as institutions that teach sustainability but as organizations that actively model and accelerate the transition toward more circular and resilient societies (Vergani, 2024).

Reflecting the expanding role of universities in advancing sustainability, scholarly interest in the intersection of circular economy and higher education has grown considerably over the past decade. The literature has progressively evolved from conceptual discussions of circularity toward more application-oriented investigations that examine how higher education institutions operationalize circular economy principles through curriculum integration, campus resource management, institutional governance, sustainable infrastructure, waste valorization, stakeholder engagement, and innovation ecosystems (Mendoza et al., 2019; Salas et al., 2021; Vergani, 2024). More recent studies have further broadened the discourse by exploring the contributions of universities to the attainment of the United Nations Sustainable Development Goals, emphasizing their role in promoting sustainable consumption and production, fostering interdisciplinary research, and strengthening partnerships that facilitate circular transitions. Collectively, these studies demonstrate that circular economy research within higher education has developed into a multidisciplinary field that integrates perspectives from environmental science, engineering, management, education, architecture, and public policy, reflecting the increasing recognition of universities as drivers of sustainable transformation rather than merely venues for sustainability education (Geissdoerfer et al., 2017; Vergani, 2024).

Despite the growing body of literature on circular economy and sustainability in higher education, the existing evidence remains fragmented. Previous bibliometric studies have primarily examined circular economy as a broad multidisciplinary research domain encompassing diverse industrial, environmental, and business contexts (Geissdoerfer et al., 2017; Goyal et al., 2021; Camón Luis & Celma, 2020). Conversely, studies focusing on higher education have largely synthesized sustainability initiatives, green campus practices, or the role of universities in advancing sustainable development (Salas et al., 2021; Vergani, 2024). While these investigations have substantially advanced understanding within their respective domains, limited attention has been devoted to comprehensively examining the convergence of circular economy and sustainable universities as a distinct and evolving field of research. Consequently, the scientific development, intellectual structure, collaboration patterns, and thematic evolution of research at this intersection remain insufficiently synthesized.

Addressing this gap is important for both research and practice. From a scholarly perspective, a comprehensive synthesis of the literature provides a clearer understanding of the field's intellectual foundations, leading contributors, collaboration networks, and emerging thematic directions, thereby enabling researchers to identify underexplored areas and establish more meaningful research agendas. From an institutional perspective, understanding how circular economy research has evolved within higher education can assist university leaders and policymakers in designing evidence-informed strategies that strengthen sustainability governance, curriculum innovation, research collaboration, campus operations, and stakeholder engagement. Such evidence is particularly valuable as higher education institutions increasingly position themselves as strategic contributors to the achievement of the United Nations Sustainable Development Goals through the adoption of circular and sustainable practices (Salas et al., 2021; Vergani, 2024).

In response to these gaps, this study presents a comprehensive bibliometric analysis of empirical journal articles on circular economy and sustainable universities indexed in the Scopus database from 2003 to June 2026. Guided by the PRISMA framework and employing Bibliometrix/Biblioshiny, VOSviewer, and Bibliomagika, the study examines the evolution of scientific production, identifies the leading authors, institutions, countries, and journals, analyzes collaboration networks and the intellectual structure of the field through co-authorship, co-citation, and bibliographic coupling analyses, and explores the thematic landscape using keyword co-occurrence analysis. By integrating performance analysis and science mapping techniques, this study provides a comprehensive synthesis of the evolution of circular economy research within higher education, offering evidence that can inform future research, institutional sustainability initiatives, and policy development. Moreover, by focusing exclusively on empirical journal articles, the study provides a more robust synthesis of the evidence base underpinning the development of this emerging research field.

Methodology

Research Design

This study employed a descriptive bibliometric research design complemented by science mapping techniques to systematically examine the evolution of research on circular economy and sustainable universities. Bibliometric analysis is a quantitative approach that evaluates scientific publications through the analysis of publication outputs, citation relationships, collaboration networks, and conceptual structures within a specific field of knowledge. Unlike traditional literature reviews, bibliometric analysis enables the objective and reproducible synthesis of large volumes of scientific literature, thereby revealing the intellectual development, influential contributors, knowledge structures, and emerging research frontiers of a research domain.

The methodological framework consisted of four major phases: (1) bibliographic data retrieval, (2) document screening and selection, (3) data cleaning and harmonization, and (4) bibliometric performance analysis and science mapping. The document selection process followed the four principal phases of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework—identification, screening, eligibility assessment, and inclusion—to ensure transparency and reproducibility. Although originally developed for systematic reviews, PRISMA has been widely adopted in bibliometric studies to document the systematic selection of publications. Bibliomagika, Bibliometrix/Biblioshiny, and VOSviewer were subsequently employed for data preprocessing, bibliometric performance analysis, and network visualization.

Data Source and Search Strategy

The Scopus database served as the sole source of bibliographic data because of its extensive multidisciplinary coverage, rigorous journal indexing standards, comprehensive citation metadata, and compatibility with leading bibliometric software. Compared with other bibliographic databases, Scopus provides broader coverage of peer-reviewed literature and standardized bibliographic information, making it one of the most widely used databases for bibliometric investigations.

A comprehensive search strategy was developed through an iterative process involving preliminary searches and refinement of keywords identified from seminal publications on circular economy and sustainable universities. The strategy was designed to maximize the retrieval of publications examining the intersection of three major concept groups: (1) circular economy, (2) higher education institutions, and (3) sustainability.

Synonymous terms, abbreviations, Boolean operators (AND, OR), and wildcard symbols (*) were incorporated to maximize retrieval sensitivity while minimizing the exclusion of potentially relevant studies. The final search string was executed in the Title, Abstract, and Keywords (TITLE-ABS-KEY) fields of the Scopus database to retrieve publications explicitly addressing the intersection of these three concepts. The search covered publications indexed from 2003 to June 2026, with the final search conducted on June 30, 2026. Restricting the search to a single, well-curated database ensured consistency in bibliographic records, minimized duplication across indexing platforms, and enhanced the reproducibility of the bibliometric analysis.

Table 1. Search Strategy and Eligibility Criteria

Category	Description
Time Period	2003–2026
Database	Scopus
Search String	((("circular economy" OR circularity OR "closed-loop economy" OR "circular business model*" OR "resource efficiency") AND (universit* OR "higher education" OR "higher education institution*" OR HEI* OR college* OR campus OR campuses) AND (sustainab* OR "sustainable development" OR "education for sustainable development" OR ESD OR "green campus" OR "sustainable university" OR "sustainable universities")))
Document Types	Journal Articles
Language	English
Inclusion Criteria	Empirical journal articles indexed in Scopus from 2003–2026, published in English, and classified under Social Sciences, Environmental Science, or Business, Management and Accounting.
Exclusion Criteria	Non-English publications, non-article documents, non-journal sources, articles in press, duplicate or incomplete records, and studies not relevant to the research topic.

Document Screening and Selection

The document selection process followed the PRISMA framework to ensure transparency and reproducibility. The initial database search yielded **1,551** records. During the identification and screening stages, publications were filtered according to the predefined eligibility criteria presented in Table 1. Records outside the selected subject areas, non-English publications, non-journal documents, and articles in press were excluded.

The remaining publications underwent eligibility assessment through title, abstract, and keyword screening. Duplicate records, incomplete bibliographic information, non-empirical publications, and studies that did not explicitly examine the intersection of circular economy, higher education, and sustainability were subsequently removed. After applying all inclusion and exclusion criteria, 233 empirical journal articles constituted the final dataset for bibliometric analysis. The complete document selection process is illustrated in Figure 1.

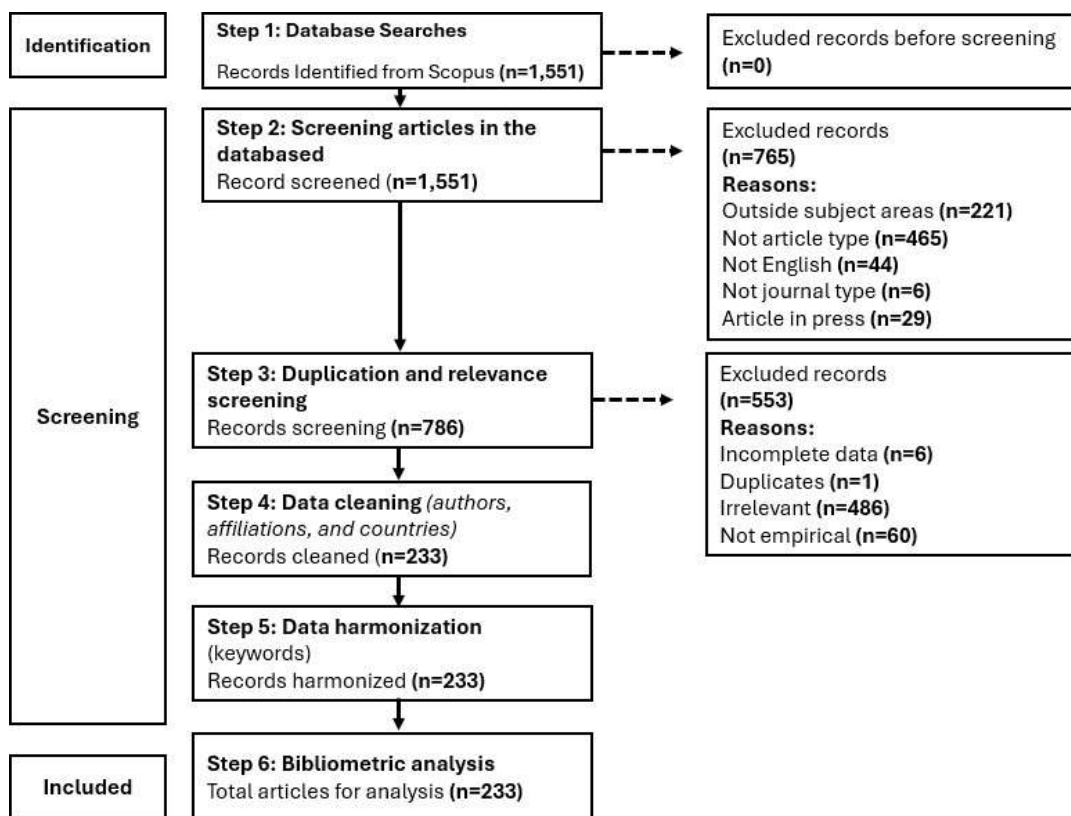


Figure 1. Screening process using key elements of PRISMA protocol

Data Cleaning and Harmonization

Prior to analysis, the final dataset was processed using Bibliomagika to improve the quality and consistency of bibliographic records. Data cleaning involved the standardization of author names, institutional affiliations, country names, and source titles to eliminate inconsistencies resulting from spelling variations, abbreviations, and duplicate entries. Keyword harmonization was likewise performed by merging synonymous terms and related expressions representing the same concept.

These procedures improved the accuracy of bibliometric indicators, collaboration networks, and thematic analyses by ensuring that conceptually equivalent entities were treated consistently throughout the science mapping process.

Bibliometric Analysis

The cleaned dataset was analyzed using the Bibliometrix package through the Biblioshiny web interface and VOSviewer. Biblioshiny was employed to perform descriptive bibliometric analyses, including annual scientific production, citation performance, source productivity, influential authors, institutional contributions, country productivity, and document impact. It was also used to generate thematic evolution, trend topics, and conceptual structure analyses.

To complement these analyses, VOSviewer was utilized for science mapping and network visualization, including co-authorship, co-citation, bibliographic coupling, and keyword co-

occurrence analyses. The combined use of Biblioshiny and VOSviewer enabled a comprehensive assessment of publication trends, collaboration patterns, intellectual structures, thematic development, and emerging research frontiers within the field of circular economy and sustainable universities.

Results

The following research questions guided the bibliometric analysis:

RQ1. How has the scientific literature on circular economy in higher education evolved in terms of publication output, citation impact, and growth trends over time?

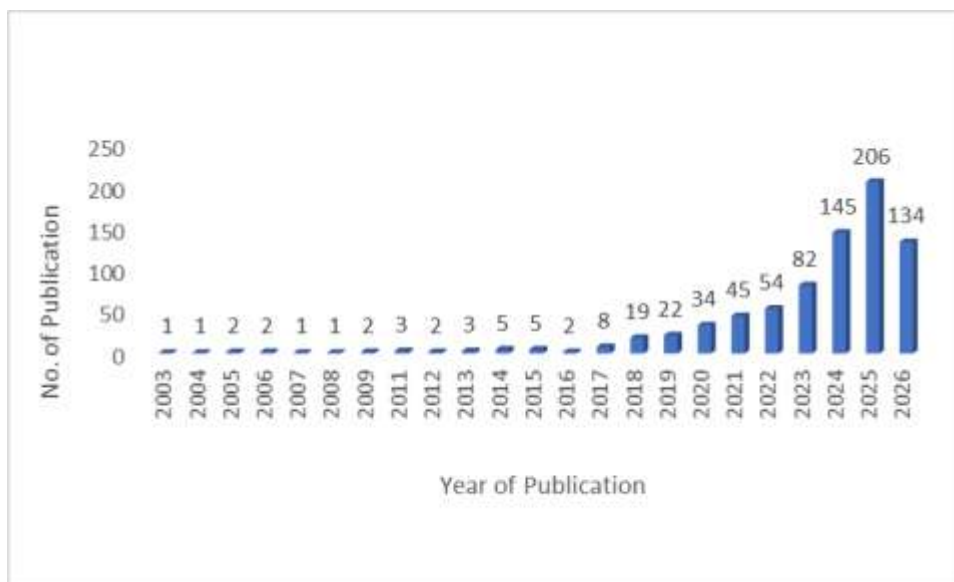


Figure 2. Annual Scientific Production Trend

Figure 2 shows the progressive development of research interest in the circular economy within higher education and sustainability contexts. The field experienced a prolonged formative stage characterized by limited research activity, indicating that the topic initially received relatively little academic attention. Over time, publication activity gradually expanded, reflecting increasing recognition of the role of higher education institutions in advancing circular economy principles and sustainable development.

A notable acceleration in research output emerged in recent years, suggesting that the topic has evolved into a rapidly growing area of research inquiry. This growth coincides with heightened global attention to sustainability agendas, resource efficiency, and the contribution of universities to sustainable transitions. The sharp increase in publications indicates expanding academic engagement, greater research investment, and the emergence of a more established research community.

The most recent years exhibit the highest levels of publication activity, highlighting the contemporary relevance and increasing maturity of the field. Although the latest year shows a

lower publication count than the preceding peak, this pattern is likely attributable to the incomplete indexing of publications and the fact that the year is still in its early stages rather than a decline in research interest. Notably, despite data collection occurring during the second quarter of the year, publication output has already reached a substantial level, indicated sustained research momentum and suggested that the total number of publications is likely to increase further as additional studies are published and indexed. Overall, the trend reveals a dynamic and expanding body of literature, underscoring the growing importance of circular economy research within higher education and sustainable university initiatives.

RQ2. Who are the leading contributors and how are scientific collaboration networks structured among authors, journals and countries in the field of circular economy and sustainable universities research?

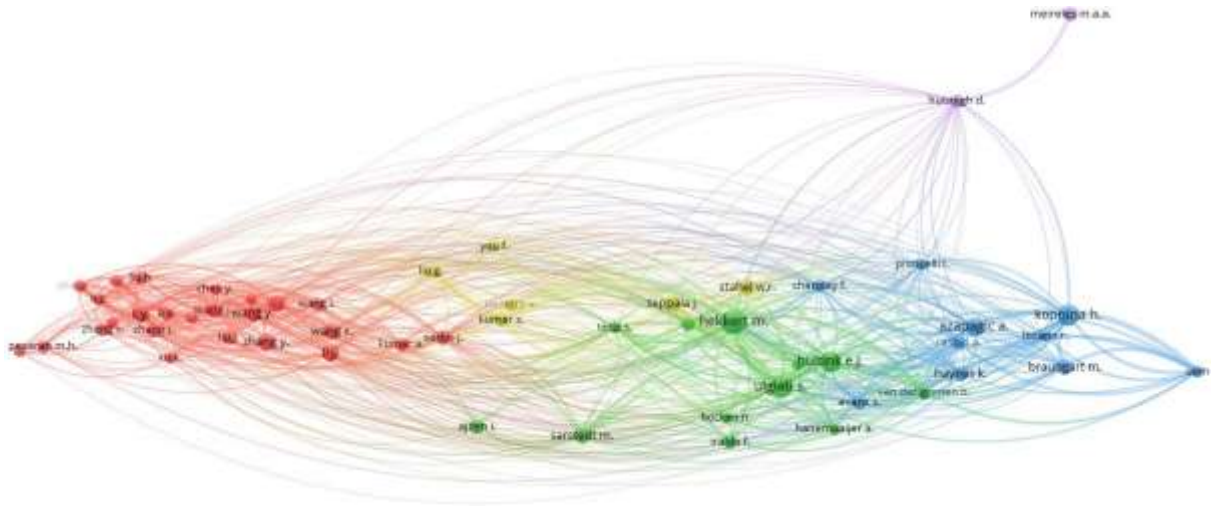


Figure 3. Co-authorship network of authors in circular economy and sustainable universities research.

Figure 3 reveals a highly interconnected network of authors, indicating active scholarly collaboration within the field. Several prominent authors occupy central positions in the network and serve as key connectors among multiple research clusters, suggesting their significant influence in knowledge production and dissemination. The presence of distinct clusters reflects the existence of specialized research communities that collaborate around common themes and interests. At the same time, the numerous links between clusters demonstrate a growing level of interdisciplinary collaboration, facilitating the exchange of ideas across different research groups. Overall, the network indicates that a diverse yet interconnected community of researchers supports the field and contributes to its continuous development.

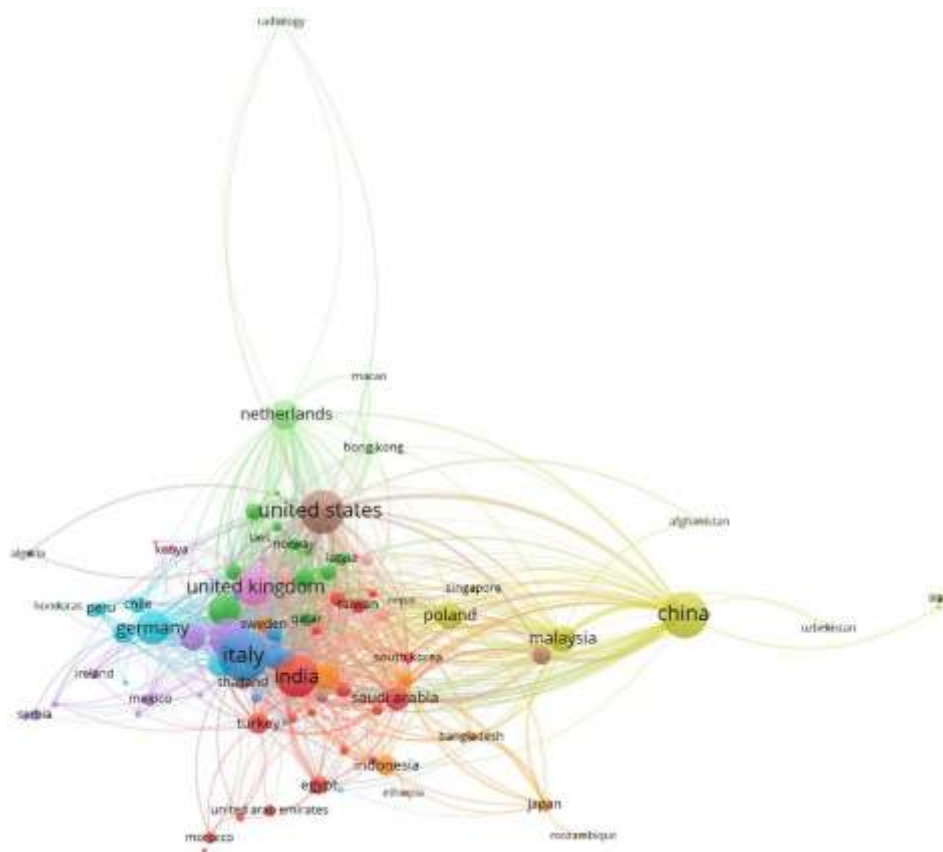
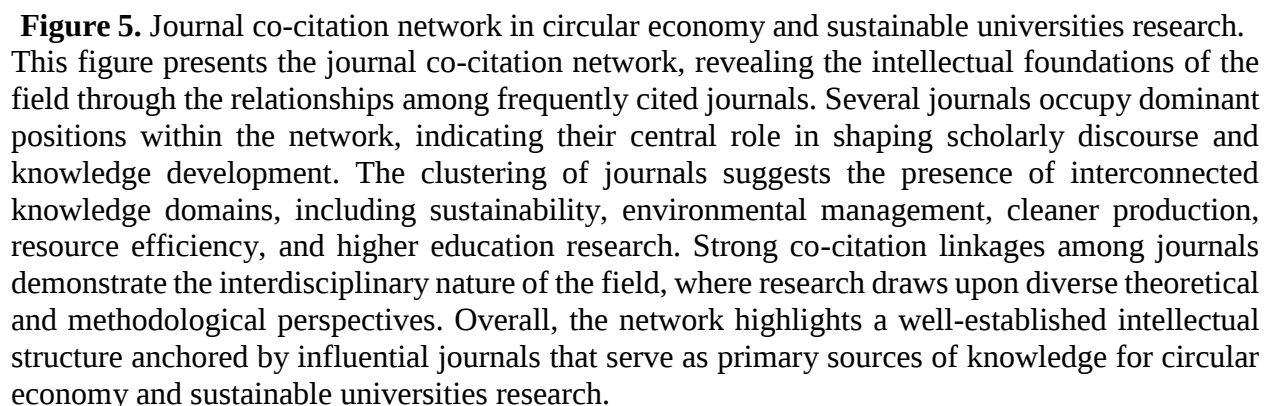


Figure 4. Country collaboration network in circular economy and sustainable universities research. Figure 4 shows extensive international collaboration among countries engaged in circular economy and sustainable university research. Italy, India, China, and the United Kingdom emerged as central collaboration hubs, indicating their significant role in facilitating international knowledge exchange. These countries play a crucial role in facilitating global knowledge exchange and fostering international research partnerships. The network also reveals multiple regional and cross-regional collaboration clusters, indicating that research in the field is not confined to a single geographic area but is supported by broad international participation. The strong interconnectedness among countries highlights the global nature of sustainability and circular economy challenges and emphasizes the necessity of collaborative efforts in advancing research and practice.



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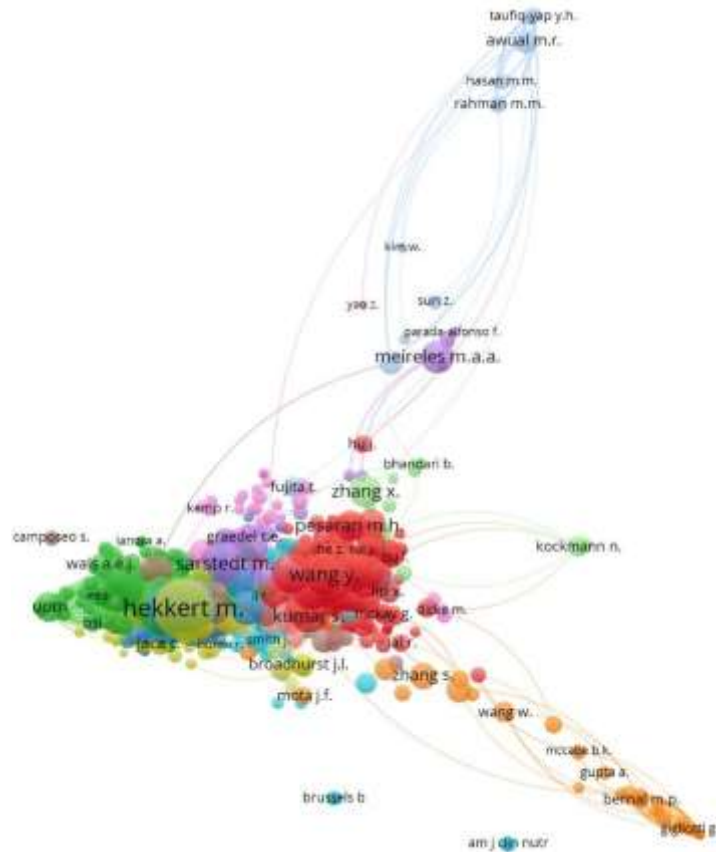


Figure 6. Author co-citation network revealing the intellectual structure of circular economy and sustainable universities research.

It shows the author co-citation network, revealing the intellectual foundations of circular economy and sustainable universities research. The network consists of several interconnected clusters, indicating that the field draws upon diverse yet related areas of knowledge, including sustainability, environmental management, circular economy, and higher education. The close proximity of the clusters suggests strong intellectual connections among these domains.

Authors occupy central positions within the network, highlighting their significant influence on the development of the field. These influential scholars serve as key intellectual anchors that connect different research areas and contribute to the formation of a cohesive knowledge base. Overall, the co-citation network demonstrates that the field is supported by an interdisciplinary and well-established intellectual structure.

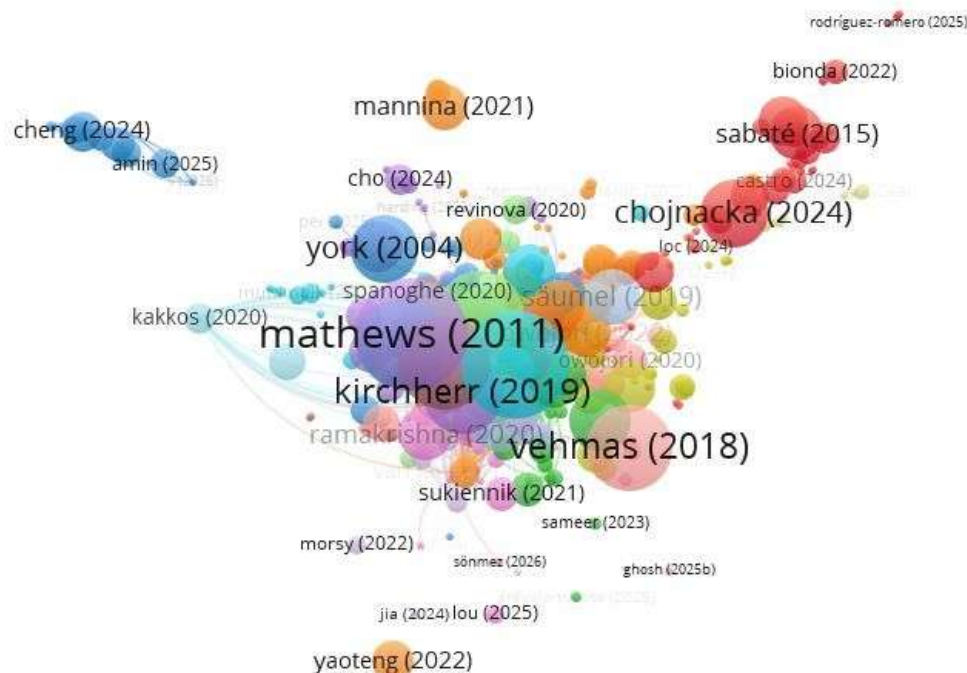


Figure 7. Document bibliographic coupling network illustrating contemporary research streams in circular economy and sustainable universities research.

It shows the document bibliographic coupling network, which reveals the current research streams shaping the field. The presence of multiple interconnected clusters indicates that recent studies share common reference foundations and are organized around related research themes. These clusters reflect growing scholarly interest in the application of circular economy principles within higher education and sustainability initiatives.

The network also shows a strong concentration of documents around several central studies, suggesting the emergence of a coherent body of contemporary research. At the same time, smaller peripheral clusters indicate developing and specialized topics that may represent future areas of investigation. Collectively, the findings suggest that the field continues to expand through interconnected research streams while maintaining a shared intellectual foundation.

RQ4. What are the major thematic clusters, knowledge domains, and emerging research frontiers in circular economy and sustainable universities research?

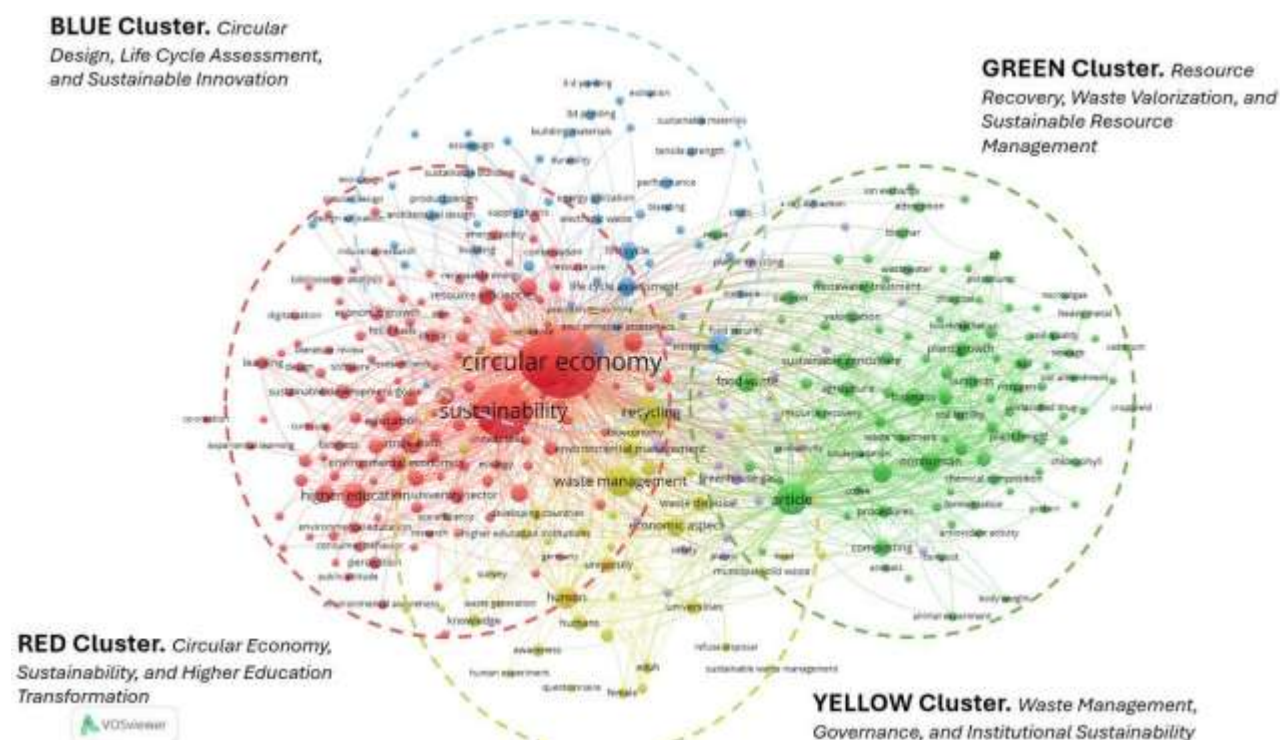


Figure 8. Keyword Co-occurrence Network of Circular Economy and Sustainable Universities Research

The red cluster represents the **core educational and sustainability dimension** of the field and is centered on the keywords *circular economy*, *sustainability*, *higher education*, *education*, *sustainable development goals*, *innovation*, *environmental education*, and *universities*. The cluster highlights the growing role of higher education institutions in promoting sustainability transitions through teaching, research, innovation, and stakeholder engagement. The strong association between the circular economy and educational concepts suggests increasing scholarly attention to integrating circular economy principles into curricula, institutional strategies, and sustainability-oriented learning environments. This cluster reflects the intellectual foundation of sustainable universities as catalysts for societal transformation toward circular and sustainable futures.

The green cluster focuses on the **operational and environmental management aspects** of circular economy implementation. Prominent keywords include *food waste*, *resource recovery*, *biomass*, *wastewater treatment*, *composting*, *sustainable agriculture*, *soil fertility*, and *nutrient recycling*. This cluster emphasizes practical approaches for closing material loops and improving resource efficiency through waste valorization and circular resource management strategies. The presence of agricultural and biological resource-related terms indicates that research increasingly explores how circular economy practices can contribute to environmental sustainability through

recycling, recovery, and regeneration processes. This cluster represents the environmental science and resource management knowledge domain underpinning circular economy applications.

The yellow cluster is characterized by keywords such as *waste management*, *waste disposal*, *economic aspects*, *environmental management*, *universities*, and *sustainable waste management*. This cluster bridges the educational and environmental dimensions of the field by focusing on institutional sustainability practices and governance mechanisms. Research within this cluster examines how universities implement circular economy principles through waste reduction programs, environmental management systems, and sustainability initiatives. Higher education institutions serve as living laboratories for testing and operationalizing circular economy strategies, as highlighted by the cluster. It also reflects increasing interest in measuring and managing sustainability performance at the institutional level.

The blue cluster encompasses keywords related to *life cycle assessment*, *ecodesign*, *sustainable building*, *product design*, *3D printing*, *building materials*, *resource use*, and *performance*. This cluster reflects the technological and innovation-oriented dimension of circular economy research. Studies within this domain focus on designing products, systems, and infrastructure that support circularity through resource efficiency, sustainable materials, and life-cycle thinking. The prominence of life cycle assessment indicates its importance as a tool for evaluating environmental impacts and supporting evidence-based decision-making. This cluster demonstrates how technological innovation and design strategies contribute to achieving sustainability objectives within higher education institutions and beyond.

Discussion

The bibliometric analysis reveals a dynamic and rapidly expanding body of literature on the intersection of circular economy (CE) principles and sustainable universities, confirming the field's emergence as a significant area within sustainability scholarship. The sharp growth in publications, particularly from 2018 onward, reflects increasing academic attention to the role of higher education institutions in advancing sustainability transitions. This finding is consistent with previous bibliometric studies on circular economy research, which reported substantial growth in scholarly output driven by global sustainability agendas, resource efficiency concerns, and the implementation of the United Nations Sustainable Development Goals (SDGs) (Goyal, 2021; Razalli, 2024). The sustained publication momentum observed in this study suggests that the integration of CE principles into higher education has become an increasingly important research priority.

The collaboration networks demonstrate a highly interconnected global research community characterized by active partnerships among authors and countries. This finding aligns with earlier studies that identified international collaboration as a key driver of innovation and knowledge exchange in sustainability and circular economy research. Similar to the observations of Camón Luis and Celma (2020), the present study found that research activity is concentrated around several collaborative hubs that facilitate the dissemination of knowledge across geographical boundaries. The presence of multiple collaboration clusters also highlights the interdisciplinary nature of the field, reflecting the need for collective efforts to address complex sustainability challenges within higher education institutions.

The co-citation and bibliographic coupling analyses reveal that the intellectual structure of the field is founded upon interconnected knowledge domains spanning sustainability science, environmental management, circular economy, and higher education studies. This finding supports previous bibliometric investigations that described circular economy research as inherently interdisciplinary and dependent on the integration of diverse theoretical perspectives (Dominko et al., 2023). The author co-citation network demonstrates the existence of influential scholars who serve as intellectual anchors, while the bibliographic coupling network highlights the emergence of coherent contemporary research streams. Together, these results suggest that the field has evolved from a fragmented body of literature into a more mature and structured area of inquiry.

The keyword co-occurrence analysis further reveals four major thematic clusters that characterize the field. The first cluster emphasizes sustainability education, higher education transformation, and the integration of circular economy principles into teaching and learning. This finding is consistent with studies highlighting universities as critical agents in promoting sustainability competencies and fostering environmental awareness among future professionals. The second cluster focuses on resource recovery, waste valorization, and circular resource management, reflecting the growing emphasis on practical applications of CE principles. Similar themes have been identified in broader CE literature, where waste reduction and resource efficiency remain dominant research priorities.

The third cluster centers on institutional sustainability, environmental management, and governance practices within universities. This finding reinforces the concept of universities as “living laboratories” where sustainability initiatives can be implemented, evaluated, and refined. Previous research has similarly emphasized the importance of institutional policies, governance frameworks, and sustainability performance assessment in advancing circular economy objectives within higher education settings. The fourth cluster highlights technological innovation, life cycle assessment, sustainable design, and resource-efficient technologies. Consistent with recent CE studies, this cluster demonstrates increasing scholarly interest in evidence-based approaches and technological solutions that support circular transitions and sustainable campus development.

Collectively, the findings indicate that research on circular economy and sustainable universities is progressing from conceptual discussions toward implementation-oriented and interdisciplinary approaches. The growing integration of educational, managerial, environmental, and technological perspectives suggests that future research will increasingly focus on translating circular economy principles into measurable institutional practices and long-term sustainability outcomes. This evolution reflects broader developments within circular economy scholarship, where attention is shifting from theoretical frameworks toward practical strategies that generate environmental, social, and economic value.

Implications

For scholars, this study provides a comprehensive map to identify gaps, such as limited longitudinal evaluations of CE implementation outcomes or integration with emerging technologies like digital twins for campus resource flows. Policymakers and university leaders can leverage these insights to prioritize investments in green campuses, faculty training, and cross-

institutional alliances that accelerate the transition to regenerative models. The findings reinforce universities' unique position as catalysts for systemic change, bridging theory and practice.

Limitations and Future Directions

This analysis is limited to Scopus-indexed English-language journal articles up to mid-2026, potentially excluding relevant gray literature, non-English publications, or conference proceedings. Future research should incorporate multiple databases, conduct meta-analyses of implementation efficacy, and explore emerging frontiers such as CE in digital education, equity in green transitions, and alignment with biodiversity goals. Thematic evolution mapping (as suggested in the draft tables) could further track shifts toward action-oriented and policy-integrated studies.

Conclusion

This bibliometric review synthesizes the evolutionary trajectory, collaborative dynamics, intellectual foundations, and thematic landscape of research on the circular economy and sustainable universities. The field's rapid growth, highly interconnected collaboration networks, and multifaceted thematic clusters underscore its vitality and increasing relevance in tackling global sustainability challenges. By mapping key contributors, influential research streams, and emerging frontiers, the study offers scholars, policymakers, and university leaders a clear roadmap to strengthen theoretical foundations, address critical gaps, and promote deeper integration of circular economy principles across higher education.

As universities continue to embrace regenerative practices, sustained scholarly attention remains essential to translate research into impactful action. The findings affirm the pivotal role of higher education institutions as living laboratories and catalysts for circular transitions. They also emphasize the need for enhanced international collaboration, longitudinal impact studies, and implementation-oriented research to accelerate the transformation toward truly sustainable universities. Ultimately, this work contributes to the broader mission of fostering resilient, resource-efficient, and environmentally responsible higher education systems for future generations.

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Author Contribution

All authors conceived of the work and contributed to writing the manuscript. Investigation: RJS, SACL, and MSS. Conceptualization and Methods: RJS, SACL and MSS. Literature review: RJS and SACL. Data analysis: RJS, SACL and MSS. Findings: RJS, MSS and SACL. Discussion and Conclusions: RJS and SACL.

AI Declaration

The authors used it solely to assist in refining grammar, improving sentence structure, enhancing readability, and providing suggestions for the organization and presentation of the manuscript. All research activities, including study design, data collection, bibliometric analysis, interpretation of

findings, and final content decisions, were conducted and validated by the authors, who assume full responsibility for the accuracy and integrity of the work.

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Declaration of Conflicting Interests

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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