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Circular Economy agriculture and supply chain: a literature review

La Economía Circular agrícola y la cadena de suministro. Una revisión de la literatura

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ABSTRACT

This study analyzes scientific production on the circular economy (CE) in the agri-food supply chain (AFSC), visualizing its future perspectives. A search was conducted in the Web of Science (WoS) and Scopus databases following the PRISMA methodology, resulting in 182 documents after applying inclusion and exclusion criteria. Scientific mapping was performed through citation analysis and annual production by journals and authors, also applying Tree of Science (ToS) methodology to study temporal contributions and cluster analysis in subareas. The results show a notable increase in scientific production, highlighting Italy, India, and China as the most productive countries, with the journals *Journal of Cleaner Production* and *Sustainability* leading in publications. Two relevant studies were identified: one introduces a new indicator to measure resource efficiency in the supply chain (SC), while the other proposes a model that integrates blockchain technology. Both studies are recognized for their high citation counts and impact in the field. There is also a call for more precise assessment tools, the exploration of innovative technologies, and the promotion of collaboration between academia and industry. Finally, we highlight the importance of investigating specific SCs, such as olive oil and meat, to generate effective strategies for the CE, underlining that this study provides a robust methodology for future analyses and public policy decisions.

Keywords: Circular economy, Supply chain, Scientometrics, Tree of Science.

RESUMEN

El presente estudio analiza la contribución científica a la economía circular (CE) en la cadena de suministro agroalimentaria (AFSC), visualizando sus perspectivas futuras. Se realizó una búsqueda en las bases de datos Web of Science (WoS) y Scopus siguiendo la metodología PRISMA, lo que resultó en 182 documentos tras aplicar criterios de inclusión y exclusión. Se llevó a cabo un mapeo científico mediante análisis de citas y producción anual por revistas y autores, utilizando también la metodología Tree of Science (ToS) para estudiar las contribuciones temporales y un análisis de clústeres en subáreas. Los resultados muestran un notable aumento en la producción científica, destacando a Italia, India y China como los países más productivos, en revistas Journal of Cleaner Production y Sustainability lidera las publicaciones. Se identificaron dos estudios relevantes: uno introduce un nuevo indicador para medir la eficiencia de recursos en la cadena de suministro (SC), y el otro propone un modelo que integra la tecnología blockchain. Ambos estudios son reconocidos por su alto conteo de citas y su impacto en el campo. Además, se resalta la necesidad de herramientas de evaluación más precisas, la exploración de tecnologías innovadoras, y fomentar la colaboración entre académicos y la industria. Finalmente, se subraya la importancia de investigar cadenas de suministro específicas, como el aceite de oliva y la carne, para generar estrategias efectivas hacia la CE, resaltando que este estudio proporciona una metodología robusta para futuros análisis y decisiones en políticas públicas.

Palabras clave: Economía circular, Cadena de suministro, Cienciometría, Tree of Science.

1. INTRODUCTION

The circular economy (CE) in the agri-food supply chain (AFSC) is becoming essential as the global population grows, from 1.6 billion in 1900 to nearly 8 billion in 2020, creating an unsustainable demand for food coverage (Yadav *et al.*, 2022). This supply chain (SC) encompasses all stages from agricultural production to consumption, involving various stakeholders such as farmers and food processors, thus constituting a complex system (Viswanadham & Kameshwaran, 2013). The sector generates 1.2 billion tons of waste annually, a figure that could nearly double by 2025, leading to economic losses of approximately USD 400 billion (Sinha & Tripathi, 2021). Looking ahead, it is crucial to address waste and post-harvest losses to ensure a sustainable agri-food supply chain (SAFSC) (Hertel, 2015). Additionally, current linear production and consumption models generate significant amounts of waste, highlighting the need to adopt circular approaches. Although there are limitations in global measurements, a study financed by the European Union (EU) estimated that households in the North produce between 1 and 2 tons of solid waste annually (Tisserant *et al.*, 2017). In 2007, global waste reached 3.2 gigatons, with only 1 gigaton being recycled or reused, indicating low resource efficiency. While attention to plastics is notable, construction and other materials constitute the largest sources of waste (Pacini & Golbeck, 2020). It is estimated that only 37% of materials are circular, and the factual figure for solid waste recycling could be as low as 15% (Pietzsch *et al.*, 2017).

The relationship between the CE and agriculture is fundamental for the agri-food system to evolve from a linear "extract-manufacture-dispose" model to a circular bioeconomy (CB) that prioritizes waste reduction and recycling, alongside the transition from fossil fuels to bio-based alternatives. This transformation is essential for sustainably meeting the increasing food and energy needs of a growing population. However, it is vital to adopt an approach that not only focuses on technology, but also considers economic value and distributive effects through a new social cost-benefit framework to guide the trajectory towards circularity. Additionally, the reuse of agricultural waste is being explored, such as in the olive oil industry, where research is being conducted on the production of lactic acid from olive leaves, despite challenges in fermentation. This approach not only validates the utilization of waste, but also promotes a greener economy by converting waste into valuable products (Gugel *et al.*, 2024; Khanna *et al.*, 2024).

To better understand the current state of research and identify gaps in this field, a comprehensive literature review was conducted. This review provides a foundation for analyzing the advancements and challenges in applying CE principles to the agriculture supply chain (ASC).

Of the 182 articles selected, we identified 17 related to the literature review. The originality of this analysis lies in its focus on research related to the CE applied to the ASC, specifically its first link, a critical sector due to its high waste generation and resource inefficiency. This differentiates it from previous studies that address the CE in sectors such as the biomass (Longo *et al.*, 2024) or meat SCs (Caccialanza *et al.*, 2023). Although many of the 17 references analyzed discuss the broader applications of CE, this study offers a more specialized approach, highlighting the role of blockchain technology and Industry 4.0 (I4.0) (A. Kumar *et al.*, 2024) in advancing the CE in the ASC. It identifies gaps in its adoption, especially in developing economies, an aspect not notably addressed in the existing literature. Additionally, it emphasizes the need for further research in specific SCs, such as olive oil (Stempfle *et al.*, 2021) and meat (Caccialanza *et al.*, 2023), to develop tailored CE strategies, providing a more structured call for future research compared to previous studies. Furthermore, it underscores the importance of more precise indicators and evaluation tools (Silvestri *et al.*, 2022) to measure the impact of CE initiatives, particularly in resource efficiency and waste reduction, offering a unique methodological approach.

While the reviewed references offer valuable insights into various aspects of CE, such as the biomass SC (BSC) (Longo *et al.*, 2024), meat SC (Caccialanza *et al.*, 2023), and blockchain applications (Sendros *et al.*, 2022), they often focus on specific sectors or technologies without the methodological rigor and holistic perspective of this review. For example, the review of the BSC by Longo *et al.* (2024) focuses on life cycle thinking (LCT) and CE principles but lacks the temporal and scientometric analysis provided herein; Caccialanza *et al.* (2023) review sustainability practices in the meat SC without integrating emerging technologies or offering comprehensive mapping of the field; and the scoping review by Sendros *et al.* (2022) explores the potential of blockchain applications in agriculture without situating it within the broader context of CE and the ASC as effectively as this study.

Another point that highlights the originality of this research lies in the combination of two methodologies: the Tree of Science (ToS) (Valencia-Hernandez *et al.*, 2020), which helps identify and organize the most influential articles on the CE and SC; and the PRISMA method (Moher *et al.*, 2009), which ensures a rigorous and transparent process in the selection and evaluation of scientific articles. By combining different methodologies, this approach effectively identifies relevant studies, particularly notable in their application to CE within the agricultural sector, facilitating the determination of research gaps and opportunities for improvement. Publications in this field were examined using Scopus and Web of Science (WoS), focusing on key contributions through scientometric techniques. Scientific mapping was conducted, including citation analysis and a description of the annual production of journals and researchers. After applying ToS methodology to review contributions to CE over time, cluster analysis was performed to study articles in different subfields. This work not only helps to highlight significant advances in CE and effective strategies for analyzing the literature and unstructured information but also introduces efficient methods for systematic literature reviews. The structure of the article is as follows: introduction, theoretical framework, definition of CE and its principles, methodology, results and discussion, conclusions, and implications.

2. THEORETICAL FRAMEWORK

The growing concern for sustainability in the ASC drives the adoption of the CE, although its implementation faces challenges (Schipfer *et al.*, 2024). The CE offers a framework to optimize resource use and reduce waste, particularly in food waste management, where losses are significant at all stages, from production to consumption (Kounani *et al.*, 2023). Traditional linear models have generated economic losses and food security issues, in addition to environmental impacts (Padthar *et al.*, 2024). The CE proposes solutions such as waste prevention, recycling, and biorefinery, transforming waste into valuable products (Medhekar, 2024). However, sustainability in the ASC requires a holistic approach, considering population growth, climate change, and resource depletion (Bigliardi *et al.*, 2024). Collaboration among multiple stakeholders, the implementation of green technologies, and sustainability assessment are crucial (Yaqot *et al.*, 2023). The CE presents opportunities through sustainable development goals (SDGs), value creation, efficient food distribution, and technological advancements (Sadh *et al.*, 2023).

3. DEFINITION OF THE CIRCULAR ECONOMY AND ITS PRINCIPLES

The concept of CE has recently emerged in the literature, gaining recognition through promotion by EU institutions as a key approach to mitigate the consumption of limited natural resources (Nikolaou *et al.*, 2021). After analyzing 221 definitions, a comprehensive definition was proposed that encompasses the principles, strategies, and drivers of CE, highlighting its contribution to environmental, economic, and social sustainability: "The circular economy is an economic system that entails a shift from a linear production model to a circular one, which involves eliminating the extraction of virgin resources through reduction, alternative reuse, recycling, and recovery of materials along the supply chain, aimed at promoting the maintenance of value and sustainable development (SD), creating environmental quality, economic development, and social equity, to benefit present and future generations. This is made possible through a coalition of stakeholders (industry, consumers, policymakers, and academia) and their innovations and technological capabilities" (Kirchherr *et al.*, 2023). The principles of CE are related to the so-called Rs, which range from the well-known 3 Rs to broader approaches that indicate up to 10 Rs: reject, rethink, reduce, reuse, repair, restore, remanufacture, repurpose, recycle, and recover (Korhonen *et al.*, 2018).

4. METHODOLOGY

4.1. Search strategy

We conducted a systematic literature review to identify relevant publications on CE in ASC, selecting the WoS and Scopus databases for their comprehensive coverage of high-impact research globally (Marín-Velásquez & Arrojas-Tocuyo, 2021; Moral-Muñoz *et al.*, 2020). The search was limited to the period 2010-2024 for two main reasons: first, the emerging research in CE, as CE only became a distinct area of study in 2010. By restricting the timeframe, the focus is guaranteed to be on current and relevant literature aligned with temporary interpretations of CE. Second, the quality and availability of data in Scopus and WoS are generally higher for recent publications, minimizing the risk of including limited or incomplete information when considering research prior to 2010. To optimize the collection of significant publications, various document types were included, such as articles, reviews, book chapters, and conference proceedings, acknowledging the diversity of approaches and contributions in the field of CE. The search strategy combined keywords and Boolean operators, employing terms such as CE, agriculture, and SC using the AND operator, as well as incorporating synonyms and related terms to broaden the search without sacrificing specificity. Table 1 presents a detailed list of terms and search parameters used in WoS and Scopus, with the results refined through a screening process following PRISMA guidelines.

Table 1
Parameters used in circular economy agriculture and supply chain

Databases	Web of Science	Scopus
Range	2010-2024	
Date	January 25, 2024	
Document type	Papers, books, chapters, and conference proceedings.	
Search fields	Title, abstract, and keywords	
Words	"circular" AND "economy" AND "agriculture" AND "supply" AND "chain"	
Results	190	140
Total (WoS + Scopus)	182	

Source: own elaboration.

Figure 1 illustrates the general procedure for identifying the most pertinent academic literature on the CE and ASC. The PRISMA method was employed to appraise only the most relevant literature (Moher *et al.*, 2009). The examination process was comprised of two main stages. Initially, the ToS metaphor was used to portray the progression of various contributions associated with the CE, resembling a tree structure. The ToS employs the SAP algorithm to select papers from a citation network (Valencia-Hernández *et al.*, 2020). Papers positioned in the roots signify seminal publications; those in the trunk support current literature and are substantiated by the roots; while those in the branches represent primary subtopics. ToS has been widely used to depict trends in diverse fields such as agriculture, business, and health. Subsequently, the second stage entails traditional scientometric analysis, amalgamating data from popular databases like Scopus and WoS.

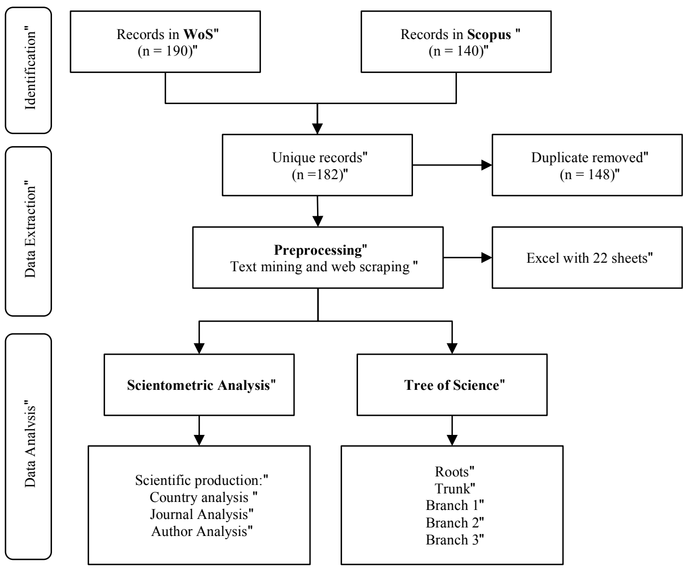

Figure 1
PRISMA diagram for preprocessing data
Source: own elaboration.

4.2. *Scientific mapping*

Belmonte and colleagues (Belmonte *et al.*, 2020) characterized scientific mapping as a method in scientometrics enabling the examination of academic literature by using bibliometric metrics related to authors and publications. For instance, scientometric analysis is commonly used for identifying groundbreaking innovations (Leydesdorff *et al.*, 2021) and evaluating the performance of universities (Al-Jamimi *et al.*, 2022). This research centers on four dimensions: scientific output, geographical origin, journal sources, and authorship examination. This approach offers readers a comprehensive view of a research topic, beginning with a broad summary and concluding with an in-depth exploration of collaborative networks. To leverage citation analysis, this study adopted the technique advocated by Hurtado-Marín *et al.* (2021). This innovative approach establishes a collaboration based on references, resulting in improved accuracy in discerning the network structures with scientometric data. These methods were developed using the statistical software Rstudio (version 2023.12.1+402), along with its supplementary package Bibliometrix (Aria & Cuccurullo, 2017). Visualizations were generated using the ggraph R package (version 2.0.6) (Si *et al.*, 2022) and Gephi (version 0.10.1) (Bastian *et al.*, 2009).

5. RESULTS AND DISCUSSION

This section provides a descriptive examination of CE in agriculture within SC using bibliometric methodologies. Four dimensions were examined: scholarly output, national contributions, journal output, and authorship patterns.

5.1. *Scientometric analysis*

5.1.1. Scientific production

Figure 2 illustrates the progression of article production in relation to this topic. The graph demonstrates a marked expansion of research activity in this area over the past 6 years, particularly evident in the substantial increase in articles indexed within the Scopus database. Notably, between 2019 and 2023, the annual growth rate in the number of publications in WoS amounted to 66%, while in Scopus, it reached 56%.

During the pandemic and post-pandemic period, scientific writing has undergone significant growth. During crises like the pandemic, the scientific community tends to intensify its research and publication efforts to address emerging challenges. This increase in scientific output has also been driven by the need to rapidly share relevant information to develop effective solutions. Furthermore, the digitization and accessibility of online platforms have facilitated collaboration among researchers and the rapid dissemination of new findings.

In the post-pandemic era, this momentum in scientific writing has persisted, as challenges related to CE, preparedness for future pandemics, and recovery from social and economic impacts remain. Additionally, awareness about the importance of scientific research and international collaboration has increased during the pandemic, which could continue to foster the production and dissemination of scientific knowledge in the future.

The annual scientific output within a particular subject serves as a barometer for tracking shifts in a research domain, while paper citations gauge its relative significance within the academic community. Moreover, comparing production figures between the Scopus and WoS databases is pivotal as it sheds light on the advantages and constraints associated with each database selection. Consequently, this study examined publications on CE in agriculture for SC spanning from 2010 to 2023, alongside the yearly citation counts to gauge the impact of the topic (see Fig. 2). Furthermore, the combined unique production from both datasets was assessed to discern the parallels and distinctions in CE in agriculture for SC production between Scopus and WoS. Finally, the evolution in production was categorized into three phases: initial growth, rapid expansion, and stability. These delineated stages help to better understand the various temporal dynamics within CE in agriculture for SC (Sun *et al.*, 2020).

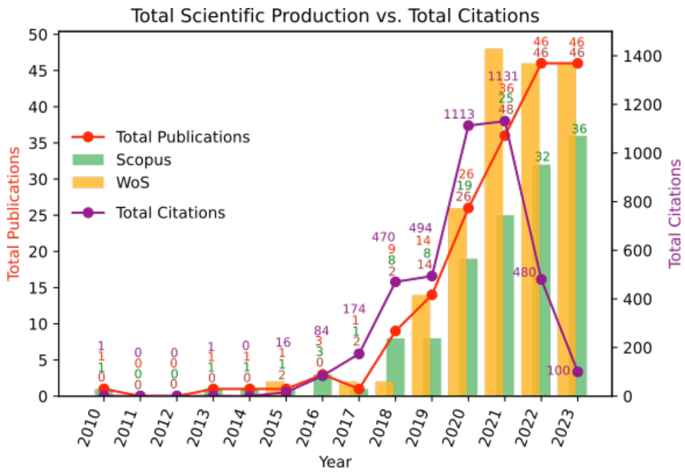

Figure 2
Total Scientific Production vs. Total Citations
Source: own elaboration.

Early growth phase (2010-2017): Within this timeframe, there were a total of 8 publications, constituting 4% of the overall output. WoS contributed 1 publication, while Scopus accounted for 7. This variability arises from WoS initiating publications on CE in agriculture for SC in 2014, whereas Scopus began in 2010. Citations garnered during this phase amount to 7% (276) of the total citations, reflecting the delayed impact of publications. Throughout this period, a consistent annual increase was observed in citation metrics. The most referenced study was by Di Maio *et al.* (Kulakovskaya *et al.*, 2023), which introduced a novel value-based indicator for evaluating the SC actor's performance concerning resource efficiency and CE principles.

Expeditious advancement phase (2018-2020): There was a marked annual surge in both total publications and citations during this period. This phase accounts for 25% (45) of all publications and 51% (2077) of citations. The increase in articles on CE is driven by various factors related to the European Green Deal, particularly the push for sustainability that began in 2019. This initiative has promoted research in CE as a strategy to combat climate change and biodiversity loss. Despite its goal to reduce pressure on EU ecosystems, there is a risk of transferring environmental damage to other countries through biomass imports, emphasizing the need for sustainable supply chains (SSC) at a global level (Henke *et al.*, 2024). The high consumption footprint of the EU, especially in resource-intensive products, and the dependence of the food industry on imports such as meat and palm oil, underline the urgency of exploring circular alternatives. Moreover, global competition in staple foods highlights the importance of sustainable sourcing policies that address environmental justice and food security. Thus, research in CE becomes essential for formulating policies that limit negative environmental and social impacts (Wei & Kallbekken, 2024). In conclusion, the growth in this field responds to the need for sustainability, impact mitigation, and the search for solutions for social justice and food security within the framework of the SDGs.

Stability phase (2021-2023): This phase has been condensed to 3 years as production levels remained consistent throughout. With a total of 124 publications, representing 68%, there was a growth rate of 12%. However, the total number of citations received declined due to the delayed impact of this factor.

5.1.2. Country analysis

The use of country analysis as a scientometric method to pinpoint the most prolific regions globally within a specific subject is increasingly prevalent (Chen, 2023). The productivity of a country reflects the government's investments in science aimed at fostering industrial innovation (Zanardello, 2023). A total of 53 countries are engaged in research on the CE for SC, with the top 10 outlined in Table 2.

The citation data column indicates the cumulative citations from both WoS and Scopus per country. Analogous to the production results, the top 10 countries accounted for 40.79% of the total citations. Notably, Malaysia, the Netherlands, and Pakistan, while absent from the list due to their relatively low production figures, demonstrate notable citation indices of 362, 260, and 141, respectively. Conversely, while China excels in scientific output, its impact is comparatively less pronounced.

Table 2
Top 10 most productive countries

Country	Production		Citation		Q1	Q2	Q3	Q4
Italy	31	14.69%	573	8.62%	10	1	3	0
India	18	8.53%	389	5.85%	5	1	0	1
China	16	7.58%	134	2.01%	1	4	2	1
United Kingdom	11	5.21%	583	8.77%	3	2	0	0
Germany	9	4.27%	269	4.04%	3	1	0	0
France	7	3.32%	433	6.51%	7	0	0	0
Greece	7	3.32%	106	1.59%	1	1	1	0
Turkey	6	2.84%	65	0.98%	3	1	0	0
USA	6	2.84%	84	1.26%	1	0	0	0
Australia	5	2.37%	77	1.16%	1	0	0	0

Source: own elaboration.

According to SCIMAGO, the countries listed in Table 2 are constantly researching current topics, making them the countries that generate the most articles. The increase in publications on CE in countries such as Italy, China, India, and the United Kingdom reflects the implementation of government policies that promote resource efficiency, resource scarcity in some cases (such as in Italy), strong industrial foundations (China), economic growth (India), and robust research infrastructure (United Kingdom). Government support, research funding, and regulatory frameworks, along with the need to optimize resources and manage waste, drive innovation and research in more efficient production processes. The presence of top-ranking universities and research institutions, as well as international collaboration and industry participation, significantly contributes to scientific output. While environmental awareness plays a role, the relative importance of each factor varies among countries, requiring specific contextual analyses for comprehensive understanding. Future studies should unravel the complex interplay of these factors for each nation (Banerjee *et al.*, 2024)

These findings illustrate the challenges in determining the ideal number of clusters within CE for SCs through an experiment employing newspaper data. Figure 3 displays six subgroups of countries. The inset figure illustrating clustering by size (top left) indicates comparable sizes among the five largest clusters, while the inset figure depicting nodes and links over time (bottom left) reveals the evolving interaction among new countries and relationships. Based on this representation, it is evident that new relationships have been steadily growing since 2016, leading to the establishment of a robust scientific community focused on CE for SC collaboration.

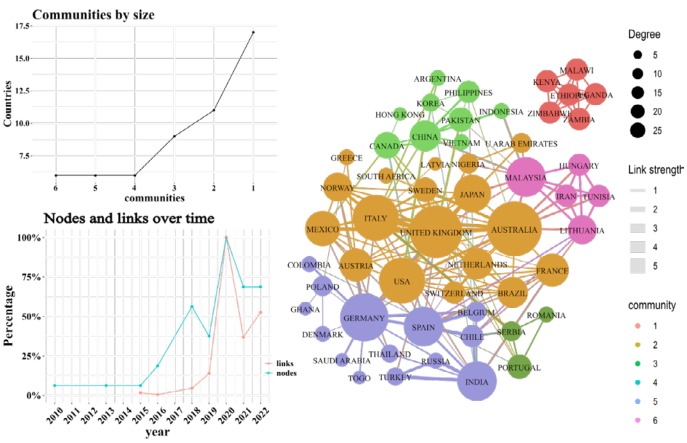

Figure 3
Country collaboration network
Source: own elaboration.

5.1.3. Journal analysis

The *Journal of Cleaner Production* boasts the largest volume of publications. *Sustainability* is also highlighted as a notable journal focusing on the environmental, cultural, economic, and social sustainability of humanity. Table 3 presents this data, revealing that the most influential journals in terms of impact factor include *Resources, Conservation and Recycling* (2.68), *Journal of Cleaner Production* (1.98), and *Science of the Total Environment* (1.95). Figure 3 illustrates the citation analysis using references retrieved from searches on Scopus and WoS. The citation network delineates various themes within a set of papers, with each node representing a journal and the links indicating references between the journals.

Table 3
Top 10 most productive journals

Journal	WoS	Scopus	Impact Factor	H-Index	Quartile
Journal of Cleaner Production	18	10	1.98	268	Q1
Sustainability (Switzerland)	0	10	0.66	136	Q1
Science of The Total Environment	8	9	1.95	317	Q1
Energies	10	2	0.63	136	Q1
Environmental Science and Pollution Research	8	3	0.94	154	Q1
Nongye Gongcheng Xuebao/Transactions of The Chinese Society of Agricultural Engineering	0	5	0.45	60	Q2
Sustainability	24	0	0.66	136	Q1
Circular Economy and Sustainability	0	3	—	—	—
Resources, Conservation and Recycling	0	3	2.68	170	Q1
Smart Innovation, Systems and Technologies	0	3	0.17	31	Q4

Source: own elaboration.

Figure 4 shows the citation network among journals, where three main groups are observed. In the first group, two studies published in *Science of the Total Environment* stand out. One paper discusses the challenges and barriers faced in on-farm composting and the application of compost derivatives, such as European regulations, variability in compost quality, and greenhouse gas emissions. It also presents recommendations, innovations, and future research directions to address these issues and promote a CE system in agricultural waste recycling (De Corato, 2020). The other discusses the potential for harvesting vegetation in wetland buffer zones to minimize phosphorus and promote CE value chains by using plant biomass for various purposes such as building materials, paper production, and bioenergy. This approach could provide compensation to landowners for restored land that is no longer suitable for conventional farming practices (Walton *et al.*, 2020). In the second group, the *Journal of Cleaner Production* is highlighted, with one particular study standing out that focuses on identifying the barriers to adopting I4.0 and CE in the ASC in India (S. Kumar *et al.*, 2021). Of note in the third group is the journal *Plos One* with a study that examines the knowledge, use, disposal, and local consequences of single-use plastics in remote island communities in southern Sulawesi, Indonesia, and identifies a complex set of factors contributing to extensive plastic leakage into the marine environment (Phelan *et al.*, 2020). The figure showing nodes and links over time reveals that the proportion of links compared to nodes (journals) has been higher in recent years. This means that CE for the SC has positioned itself as a topic of interest for research in the international context.

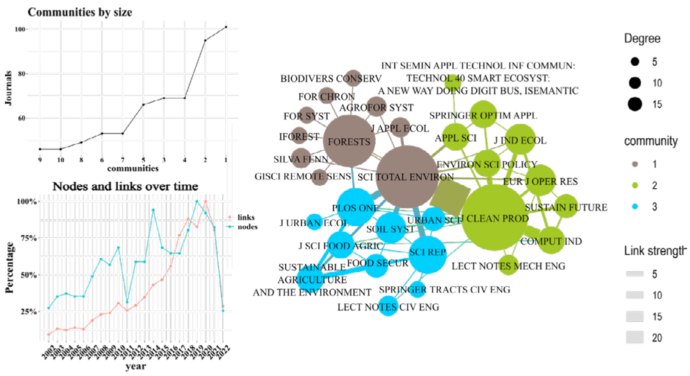

Figure 4
Journal collaboration network
Source: own elaboration.

5.1.4. Author Collaboration Network

Table 4 shows the ten most productive researchers on CE in agriculture for the SC. Professor D. Bochtis is among those who have authored the most articles on CE, with an h-index of 41. He recently published research that explores the practical implementation potential of carbon farming technologies in the agricultural sector, aligning them with EU policy frameworks (Kyriakarakos *et al.*, 2024). The researcher with the highest h-index is Professor S. Mangla. His latest study explores how digital traceability practices can improve sustainability performance in food firms, with sustainability-oriented innovation (SOI) mediating the relationship and supply chain learning (SCL) moderating the link between digital traceability and innovation (Zhou *et al.*, 2024). In this sense, there is a relationship between the quantity of publications and the quality of the scientific community regarding CE for the ASC.

Table 4
Production by Author

No.	Researcher	Total Articles	Scopus h-Index	Affiliation
1	Bochtis D	3	41	Centre For Research And Technology-Hellas, Thessaloniki, Greece
2	Kumar S	3	10	Indian Institute Of Management, Mumbai, India
3	Mangla S	3	62	O.P. Jindal Global University, Sonipat, India
4	Ram M	3	23	Graphic Era Deemed to be University, Dehradun, India
5	Zhang H	3	4	Ottawa Research and Development Centre, Ottawa, Canada
6	Achillas C	2	24	International Hellenic University, Thessaloniki, Greece
7	Agnusdei G	2	12	Universidad del Salento, Lecce, Italy

No.	Researcher	Total Articles	Scopus h-Index	Affiliation
8	Al-Ansari T	2	42	Hamad Bin Khalifa University, Doha, Qatar
9	Ashekuzzaman S	2	12	Munster Technological University (MTU), Bishopstown, Ireland
10	Bucea-Manea-Tonis R	2	9	National University of Physical Education and Sports, Bucharest, Romania

Source: own elaboration.

Figure 5 shows the scientific collaboration network among the authors in Table 4. This network is constructed based on their personal networks. The collaboration network shows two prominent groups, the first being a highly cohesive group where the main researchers appear. For example, researchers Achillas and Bochtis authored a study that aims to bridge the gap between theory and practice in supply chain management (SCM) for bioenergy and bioresources, suggesting innovative approaches and solutions to enhance efficiency in this field (Achillas & Bochtis, 2021). In the second group, researcher Dr. S. Ashekuzzaman appears with other authors of a paper that examines the nutrient and metal content of dairy processing sludge, which are bio-based fertilizers (Shi *et al.*, 2022).

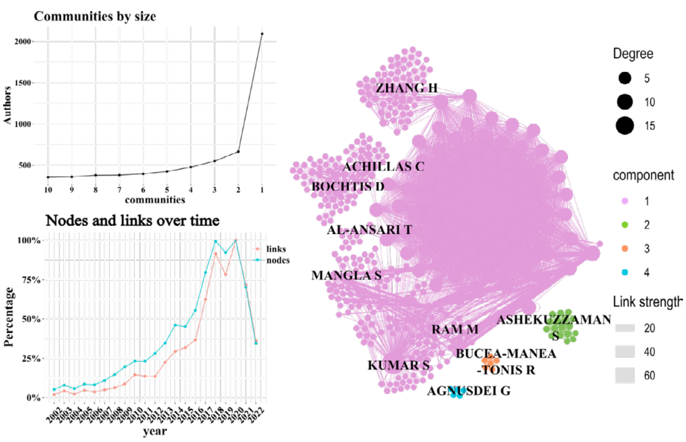

Figure 5
Author collaboration network
Source: own elaboration.

5.2. *Tree of Science*

The network analysis enabled us to identify the most significant documents (Figure 6). Records with the highest metrics were chosen for examination and arranged using the analogy of the ToS: foundational (roots), fundamental (trunk), and contemporary (leaves) categories (Valencia-Hernández *et al.*, 2020). To delineate subareas or shared research domains, we employed the clustering algorithm suggested by Blondel *et al.* (2008), resulting in the identification of the four primary groups visible in the leaf category.

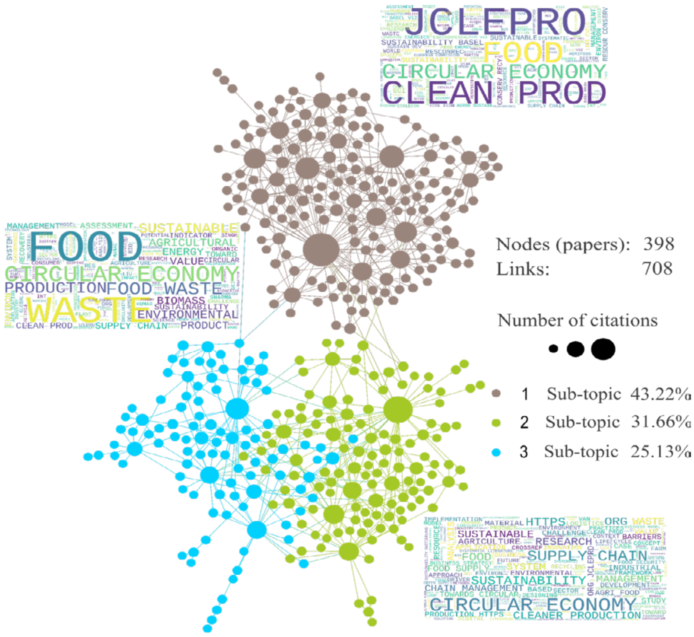

Figure 6
Internetwork with the three biggest clusters
Source: own elaboration.

5.2.1. Root

The foundational articles on CE for the ASC encompass various perspectives. The first delineates the CE goal of enhancing resource efficiency and achieving a harmonious balance between the economy, environment, and society. Despite its nascent stage, CE primarily emphasizes recycling over reuse (Ghisellini *et al.*, 2018). Another article seeks to disentangle the concepts of "CE" and "Sustainability," outlining eight distinct relationships between them based on a thorough literature review. It underscores the commonalities and disparities between CE and sustainability (Geissdoerfer *et al.*, 2017). Meanwhile, a third study aims to clarify the CE concept by examining 114 definitions, revealing a predominant focus on reduce, reuse, and recycle activities rather than systemic shifts and links to SD (Kirchherr *et al.*, 2017). The fourth paper delves into the origins and conceptualizations of CE, emphasizing process redesign and material cycling to foster sustainable business models. It calls for a revised definition of CE centered on maximizing ecosystem functioning and human well-being (Murray *et al.*, 2017). Additionally, a fifth article defines CE in the context of SD and explores its environmental sustainability, identifying six key challenges for achieving global net sustainability (Korhonen *et al.*, 2018). Finally, the need to transition to a CE in the agro-food sector is discussed in the sixth study, prompted by the unsustainability of current economic models, resource scarcity, and food loss and waste generation throughout the SC (Esposito *et al.*, 2020).

5.2.2. Trunk

The trunk hosts a series of noteworthy studies. One delves into leveraging big data to enhance sustainability management in the agricultural waste valorization SC. This study amalgamates concepts from I4.0, sustainability, and the agri-food sector to evaluate the environmental impacts of various pretreatment processes and technologies (Belaud *et al.*, 2019). Another study explores the sustainability dimensions of short supply chains (SCs) within the context of CE principles. It elucidates the interconnectedness of SCs with circularity and sustainability, considering factors like environmental impact, health, food quality, consumer behavior, producer-consumer relationships, and local economies (Joshi *et al.*, 2020). The CE paradigm finds application in agro-industrial systems to curtail losses and waste in food SCs, with precision agriculture and artificial intelligence assuming pivotal roles (Kiss *et al.*, 2019). The use of multifunctional computer models is advocated to facilitate monitoring, simulation, forecasting, and optimization in precision agriculture, with due consideration to the social and cultural aspects of human behavior. A separate endeavor aims to delineate key CE dimensions within the agri-tourism sector and evaluate their efficacy using the combined analytical hierarchy process (AHP)-TOPSIS method. This study underscores the significance of destination attractiveness, community contributions, and sustainable livelihoods in shaping CE decisions within agri-tourism clusters, with Pithoragarh emerging as a prominent cluster in Uttarakhand, India (S. Kumar *et al.*, 2021*;* Lal *et al.*, 2020). Furthermore, strategies targeting soil enhancement in local food production systems are outlined to bolster resilience and foster a CE ethos, focusing on soil restoration via carbon sequestration and on-farm cycling of nutrients. The integration of smart web-based geospatial decision support systems for sustainable land use planning and management is advocated, alongside the potential use of forensic soil science in cold case investigations (Mehmood *et al.*, 2021; Silvestri *et al.*, 2022). In a comprehensive review, the literature on CE in the ASC is examined, pinpointing the drivers and barriers to the adoption of CE practices in the ASC. Environmental, policy, and economic benefits are identified as prime motivators, while institutional, financial, and technological hurdles impede CE implementation. The study calls for globally accepted standards and frameworks, as well as government intervention to foster CE initiatives within the agriculture sector (Tseng *et al.*, 2019).

5.2.3. Branch 1

The texts reviewed encompass various aspects of CE and its application within different sectors, emphasizing the significance of LCT and assessment tools in enhancing sustainability. One paper focuses on the BSC, stressing the need for comprehensive tools to improve circularity and sustainability in bioenergy (Caccialanza *et al.*, 2023). Another study examines the interdependencies among the water, energy, and food sectors, encouraging CE approaches, especially in food waste management (Del Borghi *et al.*, 2020). Additionally, a proposed framework of environmental and energy performance indicators aims to evaluate the EU's Common Agricultural Policy in line with CE strategies (Feng & Lam, 2021). Other research explores sustainability within the meat SC and food waste management in India, emphasizing waste reduction and effective management practices (Ghisellini *et al.*, 2023). The importance of CE in mitigating environmental impacts, particularly in resource-intensive agricultural systems, is highlighted, along with the potential of the bioeconomy to facilitate circularity through renewable biological resources (Kharola *et al.*, 2022; Longo *et al.*, 2024). Moreover, an overview of the adoption of a CE in China underscores the need for comprehensive approaches to promote CE across various levels (Morales *et al.*, 2021). Finally, a study analyzes the relationship between sustainability and CE, emphasizing their integration into policy formulation and strategies to address SDGs, particularly in sectors like agriculture and innovation. Overall, these studies underscore the importance of CE principles and strategies in fostering sustainability across different sectors (Rodias *et al.*, 2020).

5.2.4. Branch 2

One study explores CE-based integrated farming systems for indigenous chicken, employing the triple bottom line (TBL) approach and sustainable agriculture to enhance food security efforts (Abbasi *et al.*, 2024). Through in-depth analysis and qualitative data gathering, valuable insights into the complexities of the indigenous chicken sector are obtained. Simulation and modeling reveal interactions within subsystems, leading to the development of a transformative indigenous chicken-based integrated farming system value chain framework (Deekonda, 2023). Additionally, the study emphasizes the importance of CE principles and integration of forward and reverse linkage to achieve sustainability across the value chain (Khan & Mahajan, 2023). Another study explores CE principles in the agri-food sector, highlighting the need for value optimization and collaboration to address inefficiencies and excessive waste. It presents empirical evidence on the adoption of CE practices within Indian agribusiness, identifying influencing factors and firm-level strategies (Matkerimova *et al.*, 2022). Finally, an analysis aims to evaluate the sustainability of circular agriculture, considering its impact on food security, circularity, environmental efficiency, and energy efficiency, aligning with SDGs and emphasizing the benefits of corporate social and ecological responsibility in promoting sustainable agricultural development (Poponi *et al.*, 2023).

5.2.5. Branch 3

Several papers examine the challenges and opportunities of transitioning the agricultural sector to a CE, emphasizing the importance of conversion technology, SSC, stakeholder involvement, and the use of analytical tools. Anaerobic digestion (AD) stands out as a critical organic waste conversion technology, its success reliant on feedstock properties and operational parameters (Ncube *et al.*, 2022). Additionally, agricultural waste biomass, including starch, cellulose, and protein, presents significant potential for the development of value-added products and bioenergy through biological and physiochemical processes (Haque *et al.*, 2023). The assessment of circularity within the agroindustry, particularly in sectors like the olive oil industry, underscores the need to monitor progress and enhance sustainability through the development of appropriate indicators (Kounani *et al.*, 2023). Furthermore, applying CE principles to the olive oil SC in Italy reveals opportunities for environmental improvement, particularly through waste valorization and the adoption of renewable energy sources, as evidenced by life cycle assessments and environmental impact evaluations (Sadh *et al.*, 2023).

CE is emerging as an effective solution to enhance sustainability in the ASC by addressing the interplay between economic, environmental, and social dimensions. While CE has emphasized the importance of recycling, a broader perspective that incorporates resource reduction and reuse is required to facilitate significant changes in the agricultural sector. Furthermore, technologies such as big data and artificial intelligence are crucial for managing agricultural waste and optimizing precision agriculture, helping to reduce waste and improve efficiency. However, there are institutional, financial, and technological barriers that hinder implementation, making it necessary to promote collaboration among stakeholders and government support. Case studies highlight the need for strategies tailored to local contexts, as evidenced in the poultry sector, which demonstrates how CE can enhance food security. The integration of sustainability indicators into policy formulation is key to advancing and aligning agricultural practices with the SDGs. In summary, adopting a CE model in agriculture can yield multiple benefits, with a collaborative approach being fundamental to enhancing its role in global sustainability.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The present research has provided a panoramic view of scientific contributions in the field of CE applied to the ASC. The ToS analysis has allowed us to identify seminal, fundamental, and contemporary studies, highlighting the main lines of research and trends in this area. Additionally, scientific mapping has revealed valuable information about scientific production in terms of the most prolific countries and journals, as well as collaboration networks among authors.

6.1. Findings

This review evaluates the relevance of academic works through methodologies such as citation counts and thematic clustering, highlighting two influential studies. The first, by Di Maio *et al.* (2017), introduced a new value-based indicator to measure performance in the SC, focusing on the CE, which boasts a high citation count, demonstrating its impact in the field. The second, by Casado-Vara *et al.* (2018) proposed an SC model using blockchain technology, also with numerous citations and essential for the adoption of innovations in the CE. While other studies are relevant, these two are notable for their significant influence and innovative approaches at various stages of research.

6.2. Research gaps

The relationship between I4.0 and the CE in SAFSC presents significant research gaps. Currently, few studies integrate these concepts, and there is a notable lack of research addressing the challenges of adopting I4.0 technologies that facilitate the CE, especially in developing economies (A. Kumar *et al.*, 2024). This review addressed the research gap regarding the CE for ASC, providing a comprehensive and updated overview of scientific contributions (Gallego-Schmid *et al.*, 2024).

6.3. Future research directions

This literature review on the CE in ASC highlights several key areas that are crucial for future research and development. First, there is a need to develop more precise indicators and assessment tools to measure the impact of CE initiatives, including more refined metrics for resource efficiency, waste reduction, and environmental sustainability. Additionally, the exploration of innovative technologies is emphasized, highlighting the importance of technological advancements such as AD for the valorization of agricultural waste and the generation of value-added products. There is also a need to foster closer collaboration among academics, policymakers, industries, and farmers, directing efforts toward creating effective partnerships that connect research with practice. The study identifies specific challenges in different sectors and regions, suggesting that future research should focus on tailored solutions to overcome barriers such as the lack of fiscal incentives and the implementation of environmental standards. Finally, there is a need for more specific research on certain SCs within the agricultural sector, such as olive oil and meat, to generate effective strategies for transitions toward the CE.

6.4. Limitations

This study, while providing valuable insights into the CE in ASC, faces several limitations: the analysis is based on data from Scopus and WoS, which although extensive databases, may not capture all relevant research, including gray literature and publications in lesser-known journals, potentially resulting in an incomplete representation of the research landscape. Furthermore, the citation analysis may be subject to biases, such as publication and prestige bias, which influence the ranking and interpretation of key groups and contributors.

Moreover, it is important to consider that the concept of the SC originates from the business sector and is primarily used in that context (Ketchen & Hult, 2007). This implies lower academic interest in publishing research on this topic compared to other more theoretical areas. As a result, the available scientific literature may be limited in certain aspects, potentially influencing the depth of the analysis conducted.

Another limitation to consider is citation bias (Flammer, 2021). By focusing on highly cited studies, there is a risk of overvaluing well-established works at the expense of emerging research that has not yet had sufficient time to accumulate a significant number of citations. This could affect the identification of recent trends or disruptive innovations in agri-food SCM.

Despite these limitations, the study makes a significant contribution and presents a methodological framework that can be replicated and adapted for future research, promoting the comprehensibility and reproducibility of findings in this important area.

6.5. Practical implications

This study provides a valuable contribution to research in the agricultural CE by offering a rigorous and replicable methodology for future research and identifies priority areas for study (waste conversion, integrated circular production systems, and specific applications) in agricultural sub-sectors. For example, Longo *et al.* (2024) propose that, in olive oil production, the abundant agricultural olive residue generated can be upcycled for lactic acid production, which has wide industrial applications in the food, pharmaceutical, and cosmetic industries. Another group has suggested implementing reverse logistics practices for indigenous chickens through the recycling and reuse of poultry litter generated as a natural and enriching fertilizer in crops like bananas, enhancing soil fertility (Abbasi *et al.*, 2024)

Furthermore, this manuscript reveals strategic information for policy and business decision-making (highlighting leading countries and journals, as well as key contributions), analyzes barriers to the adoption of the CE, offers a multidimensional perspective of the field (including collaboration analysis), and emphasizes the importance of the CE for sustainability.

Its practical approach and solid methodology make it an essential tool for the scientific community and the formulation of public policies.

6.6. Theoretical Contributions

The methodological innovation of this study lies in the integration of two complementary methodological approaches: the ToS and PRISMA methodology. This combination enables the identification of emerging studies in our area of interest and provides a structured framework for detecting research gaps and future trends. Additionally, the article highlights the need to develop more precise evaluation tools and foster interdisciplinary collaboration, both of which are fundamental elements for advancing knowledge in the sustainable management of SC within the CE paradigm.

Additionally, this methodological combination ensures that, while other literature reviews are often fragmented or focus on individual papers, the methodology used in this study is rigorous and replicable. This research contributes to the literature by identifying priority areas within agricultural CE and SC. It provides a structured theoretical foundation for future studies and guides the development of more effective strategies for implementing CE principles in agriculture.

The context-specific nature of some research may limit the generalizability of the findings to other products, regions, or farming practices. Nevertheless, CE in ASC is a challenging research topic that is attracting the attention of academics. In this sense, qualitative and quantitative data sources and complementary modeling techniques can provide a more comprehensive perspective for CE in ASC analysis, and thus provide more and better contributions for the implementation of circularity practices in the ASC.

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