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Special Issue

Circular economy in the agri-food sector: A literature review on implementation, interventions, and outcomes

Economia circular no setor agroalimentar: Uma revisão da literatura sobre implementação, intervenções e resultados

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Abstract

Purpose: This study aims to examine circular economy (CE) practices in the agri-food sector, identifying trends, gaps, and interventions to enhance sustainability in food production and consumption, while assessing the environmental, economic, and social impacts of 9Rs framework strategies.

Originality/value: The relevance and originality of this study lie in its unique application of the 9Rs model to diagnose interventions and link them to tangible outcomes in agri-food systems.

Design/methodology/approach: We conducted a systematic literature review, including 70 studies (with 13 analyzed qualitatively), combined with bibliometric mapping using R (Bibliometrix package, v4.2.3) and deductive content analysis in ATLAS.ti (v24) to evaluate 9Rs interventions and their impacts.

Findings: The findings reveal that reduction is the most prevalent 9R strategy, with impacts primarily environmental (42.73%), followed by economic (34.68%) and social (22.59%). Key themes include food loss/waste, supply chain efficiency, food security, and circular bioeconomy, demonstrating the interdisciplinary integration of technology and sustainability.

Contribution/implication: This study contributes to CE and agri-food sustainability literature by empirically validating 9Rs interventions and their outcomes. Methodologically, it advances mixed-methods research through systematic bibliometric and qualitative analysis. Practically, it equips policymakers and industry stakeholders with actionable insights to drive regional circular transitions. Additionally, it calls for greater emphasis on social impacts, often underrepresented in CE strategies.

Keywords: circular economy, sustainability, strategy, 9R framework, agri-food sector

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Resumo

Objetivo: Este estudo tem como objetivo examinar as práticas de economia circular (EC) no setor agroalimentar, identificando tendências, lacunas e intervenções para melhorar a sustentabilidade na produção e no consumo de alimentos, enquanto avalia os impactos ambientais, econômicos e sociais das estratégias do modelo 9Rs.

Originalidade/valor: A relevância e originalidade deste estudo estão na aplicação única do modelo 9Rs para diagnosticar intervenções e vinculá-las a resultados tangíveis nos sistemas agroalimentares.

Design/metodologia/abordagem: Realizamos uma revisão sistemática da literatura, incluindo 70 estudos (com 13 artigos analisados qualitativamente), combinada com mapeamento bibliométrico usando R (pacote Bibliometrix, v4.2.3) e análise de conteúdo dedutiva no ATLAS.ti (v24) para avaliar intervenções 9Rs e seus resultados.

Resultados: Os resultados revelam que a redução é a estratégia 9R mais prevalente, com impactos principalmente ambientais (42,73%), seguidos por econômicos (34,68%) e sociais (22,59%). Os principais temas incluem perda/desperdício de alimentos, eficiência da cadeia de suprimentos, segurança alimentar e bioeconomia circular, demonstrando a integração interdisciplinar entre tecnologia e sustentabilidade.

Contribuições/implicações: Este estudo contribui para a literatura sobre EC e sustentabilidade agroalimentar ao validar empiricamente as intervenções 9Rs e seus resultados. Metodologicamente, avança a pesquisa de métodos mistos por meio de análise bibliométrica sistemática e qualitativa. Na prática, fornece *insights* para formuladores de políticas e *stakeholders* do setor, impulsionando transições regionais para a circularidade. Além disso, destaca a necessidade de maior ênfase nos resultados sociais, frequentemente sub-representados nas estratégias de EC.

Palavras-chave: economia circular, sustentabilidade, estratégia, estrutura/modelo 9R, setor agroalimentar

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INTRODUCTION

"For every expert there is an equal and opposite expert" –
old scientific joke draws on Newton's third law of motion
(Petticrew & Roberts, 2006, p. 4).

The demographic and climate changes are putting stress on the food system. The circular economy (CE) is a topic of great discussion in both research and policy, and its practical application is seen as the answer to many of the contemporary sustainability issues. The agri-food sector has traditionally been a significant source of waste, especially in the industrial stages of raw material transformation and processing (Chiaraluce et al., 2023).

In this sense, understanding the mismatches and potential synergies in the implementation of the CE will help identify new opportunities to optimize circularity in food production systems (Tait et al., 2023). How effectively implement such a transition is, however, still debated (Cagno et al., 2023; Hamam et al., 2021).

Although there is already a trend toward circular economy and sustainability, there is a lack of systematic academic research that rethinks management models based on circularity, especially in the context of agri-food. A methodical, transparent, and repeatable review procedure based on the statistical assessment of science, scientists, or scientific activities could be implemented through bibliometrics (Aria & Cuccurullo, 2017).

Employing a mixed-method approach that combines a quantitative bibliometric review with qualitative content analysis (Bardin, 2011; Petticrew & Roberts, 2006), this study seeks to identify and critically examine CE practices adopted in the global agri-food sector. The empirical investigation is structured around three key research questions (RQ):

RQ1: What is the current state of research on CE in agri-food sector?

RQ2: What theoretical frameworks underpin this field of study?

RQ3: What are the key interventions and measurable outcomes associated with implementing CE principles in the agri-food sector?

To achieve these objectives, we conducted a systematic literature review (SLR) of 70 publications on CE in the agri-food sector, covering research published up to May 30, 2024. The earliest study meeting the criteria dates back to 2020. According to Petticrew and Roberts (2006), a systematic review is of particular value to inform policies and support practice. The authors argue that a systematic review is desirable when developing new

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techniques requires a clear image of previous research, including methodological research. Also, a content analysis was conducted in 13 studies to further enhance the study's scope.

While prior research has mapped CE trends bibliometrically (Chiaraluce et al., 2021) or explored case studies separately (Donner & De Vries, 2023; Klein et al., 2022; Morea et al., 2023), our study's innovation lies in its integrated mixed-methods pipeline: Bibliometrix quantifies research clusters and theoretical frameworks, revealing dominance of the refusing, rethinking, reducing, reusing, repairing, refurbishing, remanufacturing, repurposing, recycling, and recovering (9Rs) model over the traditional reducing, reusing, and recycling (3Rs) (RQ1-RQ2). Content analysis of 13 case studies qualitatively links interventions to contextual factors (e.g., policy → rethink), addressing Tait et al.'s (2023) calls for granular implementation insights (RQ3). Triangulation via a Sankey diagram bridges macro/meso/micro levels, visually demonstrating how context shapes outcomes – a gap in Corral et al. (2022). Our Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) compliant SLR and public codebook enhance reproducibility, advancing Petticrew and Roberts' (2006) standards for systematic reviews.

The findings of this study have both theoretical and practical contributions by offering a bibliometric mapping of the general state and current trends and useful evidence of the interventions and outcomes implemented by several countries worldwide. It supports theoretical insights for the academic community and helps guide circular practices in the agri-food sector. This review is both retrospective and forward-looking. We discuss what has been accomplished so far and the recommended future directions of research on the circular economy in agri-food.

THEORETICAL BACKGROUND

CE is most often described as a combination of 3Rs, although it is barely highlighted that CE requires systemic change (Kirchherr et al., 2017). After analyzing 114 definitions of CE, the authors provided the following synthetic definition:

> (…) an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at

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> the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to support achieving sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers (Kirchherr et al., 2017, p. 229).

In the context of CE implementation, Kirchherr et al. (2017) adapted the model initially proposed by Potting et al. (2017). Many researchers view the various R frameworks as the practical foundation of CE principles. These frameworks extend beyond the traditional 3R activities to include more comprehensive models, such as the reducing, reusing, recycling, and renewing, (4Rs) framework, the reducing, reusing, recycling, renewing, redesigning/rethinking, and remanufacturing (6Rs) framework, and the more detailed 9Rs framework, as illustrated in Figure 1.

Figure 2 offers a complementary perspective by illustrating specific strategies to enhance circularity across various business models. The figure provides concrete examples of interventions and/or strategies, enabling an understanding of how circular practices can be applied. In addition, the widespread use of "outline of a circular economy" (Ellen MacArthur Foundation, 2015) is the primary tool for understanding CE concepts (Figure 2).

The butterfly diagram (Figure 2) shows the continuous circulation of materials within two primary cycles: the technical and biological one. In the technical cycle, products and materials are retained through reuse, repair, remanufacture, and recycling. In the biological cycle, e.g., the agri-food sector, nutrients from biodegradable materials return to earth, supporting natural regeneration.

Regarding the circular economy in agriculture, Velasco-Muñoz et al. (2021) states that it involves a collection of actions aimed at ensuring biodiversity and the regeneration of agroecosystems, as well as the economic, environmental, and social sustainability of agriculture. These practices pursue the efficient and effective use of resources at all stages of the value chain.

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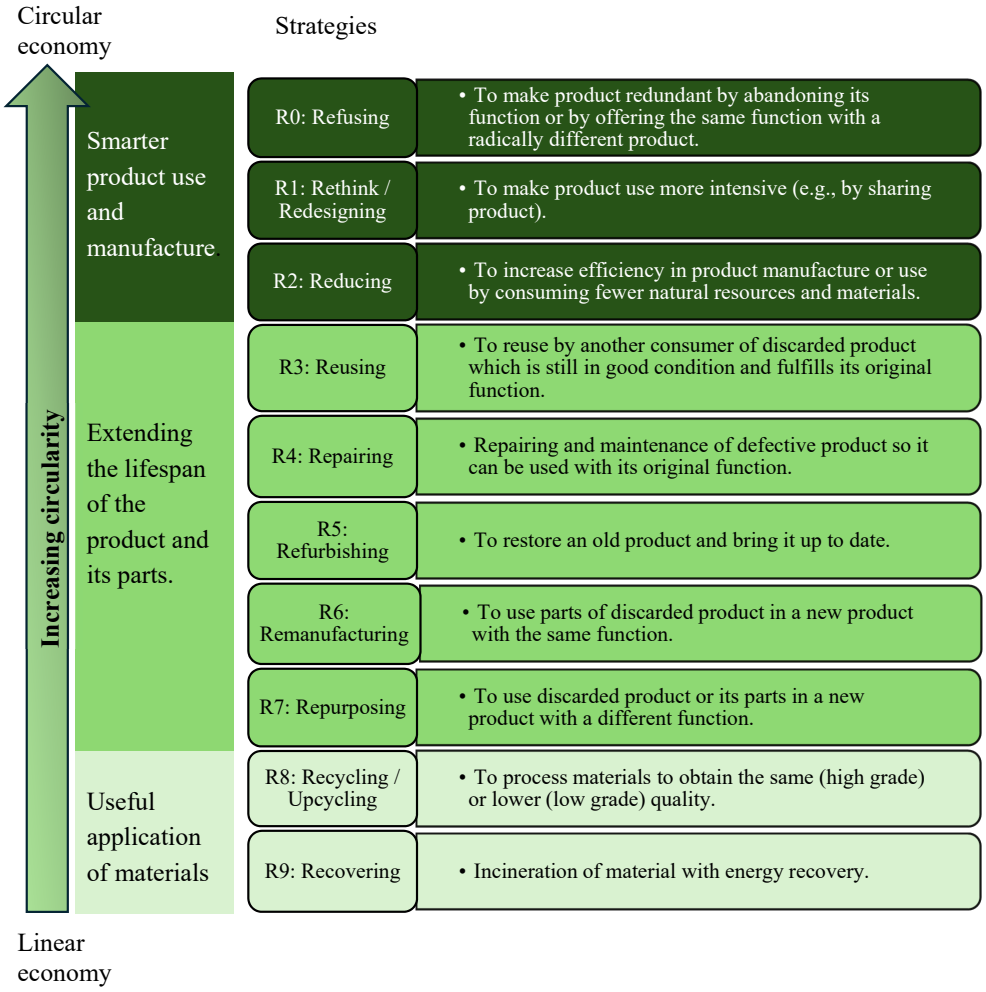
Figure 1

The 9Rs framework: the "how to" of CE



Source: Kirchherr et al. (2017, p. 224) and Potting et al. (2017, p. 5).

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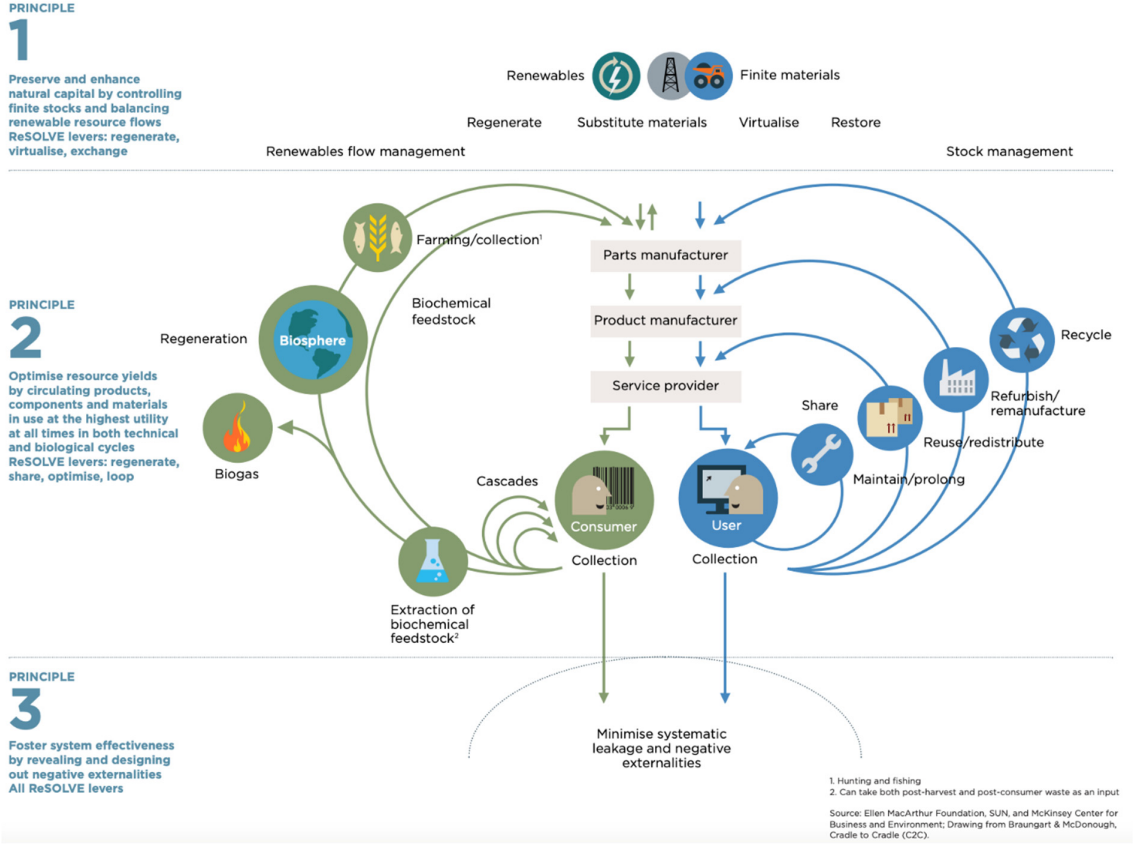
Figure 2

Outline of a circular economy



Source: Ellen MacArthur Foundation (2015, p. 24).

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To support a thorough implementation of the CE model within the agro-industrial sector, it is important to ensure food independence, economic security, and the attainment of sustainable development objectives. Crucial to this effort is the establishment of effective public policies that foster the advancement of innovative, resource-efficient technologies, and the adoption of circular business practices. These initiatives will boost the competitiveness of the domestic agricultural industry, enhance its investment appeal, and protect the environment (Litvak & Litvak, 2023).

Converting unsustainable business models into sustainable ones is the aim of CE. In this regard, performance evaluation seems to be essential for encouraging the adoption of better practices, benchmarking outcomes and successfully communicating them to various stakeholders (Cagno et al., 2023). Businesses may reduce resource consumption and environmental effects, boost customer value, and increase revenue by implementing CE practices (Dziedzic et al., 2022).

MATERIALS AND METHODS

To meet the goal of conducting a bibliometric analysis and identifying the approaches used in research on CE in the agri-food sector, in this section, we will describe the methodological procedures of the systematic review. The systematic review was carried out in accordance with the PRISMA research protocol (Moher et al., 2010; Page et al., 2021), guided by the questions elaborated according to the researchers' prior knowledge on the topic. Thus, a search string was initially built by including terms related to the research subject.

The final search strings developed for both Scopus journal and Web of Science databases, which are presented in Chart 1. The initial search used the combination of terms related to CE, circularity, by-product, and the Boolean operators "AND" and "OR". The best combination of terms was based on previous studies in the field (Chiaraluce et al., 2021; Hamam et al., 2021; Salinas-Velandia et al., 2022; Sánchez-Teba et al., 2021; Yang et al., 2021). Hence, the final search was held on May 30, 2024, with the following search strings: ("circular econom*" OR "circular*" OR "by-product") AND ("agri-business" OR "Agr*" OR "agricultural waste" OR "agri-food") AND ("sustainab*" OR "business model" OR "circular business model") AND ("polic*" OR "practic*").

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Table 1

Search string of the papers in the portfolio (May 30, 2024)

Database	Search string	Results
Scopus	(TITLE-ABS-KEY ("circular econom*" OR "circular*" OR "by-product") **AND** TITLE-ABS-KEY ("agribusiness" OR "Agr*" OR "agricultural waste" OR "agri-food") **AND** TITLE-ABS-KEY ("sustainab*" OR "business model" OR "circular business model") **AND** TITLE-ABS-KEY ("polic*" OR "practic*")) **AND** (LIMIT-TO (DOCTYPE , "ar")) **AND** (LIMIT-TO (PUBSTAGE, "final")) **AND** (LIMIT-TO (LANGUAGE, "English")) **AND** (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")).	542
Web of science	"circular econom*" OR "circular*" OR "by-products" (Topic) **and** "agribusiness" OR "agr*" OR "agricultural waste" OR "agri-food" (Topic) **and** "sustainab*" OR "business model" OR "circular business model*" (Topic) **and** "practic*" OR "polic*" (Topic) **and** Open Access **and** Article (Document Types) **and** English (Languages) **and** All Open Access (Open Access).	525

The inclusion of the keywords "practic*" OR "polic*" greatly limited the number of publications, showing that the combined use of CE in an agri-food context is new and innovative.

According to Petticrew and Roberts (2006, p. 282), protocol "is a detailed plan of the procedures that a reviewer intends to adopt in order to identify, appraise, and synthesize the evidence, and disseminate the findings. Protocols may themselves be peer-reviewed". Figure 3 presents the protocol of this systematic review.

The *first step* was the identification: this is the initial stage when all potential studies are identified through database searches, reference lists, and other sources. Three inclusion criteria were considered in this paper: only academic papers published in indexed journals were included in this review, only papers published in English, and only open-access papers – all papers published until May 30, 2024, in all areas of knowledge. The *second step* is the title, keywords, and abstract screening: in this stage, the titles and abstracts of the identified studies are reviewed to quickly eliminate those that do not meet the inclusion criteria. This step was performed by three researchers independently to reduce bias; and the full-text screening: studies that pass the title and abstract screening are, then, fully reviewed in order to further assess their relevance and adherence to the inclusion criteria. Again, this stage is usually conducted by multiple reviewers to ensure accuracy and consistency. The *third step* is the eligibility: after full-text screening, the studies

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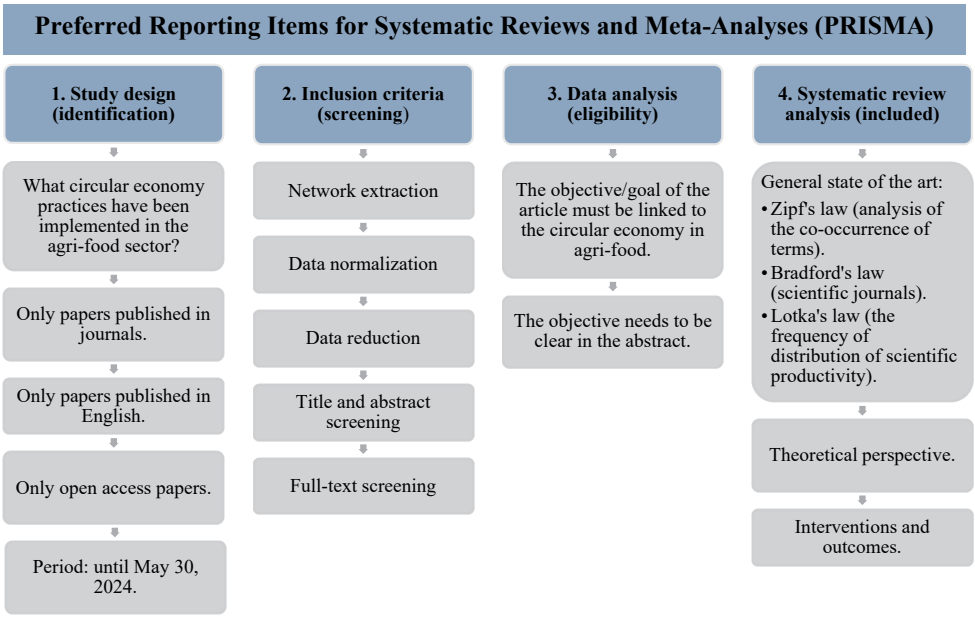
that met all the criteria were considered eligible for inclusion in the systematic review. This step may involve further critical appraisal and assessment of study quality. Finaly, the *last step* of the review was the inclusion: the final set of studies that met all criteria and were deemed suitable for the review were included in the systematic review and meta-analysis. Figure 4 provides an overview of the four steps conducted in this research.

Figure 3

Protocol of the systematic review



The analyses of the selected documents were carried out in the Biblioshiny application, which is part of the Bibliometrix 4.2.3 package (Aria & Cuccurullo, 2017), developed to be used in R programming language. In addition to the research protocol stated in Figures 3 and 4, the systematic review analysis followed four steps: identification, screening, eligibility, and inclusion). The laws governing bibliometric studies used in this review are outlined in Table 2.

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Figure 4

Systematic review protocol based on PRISMA

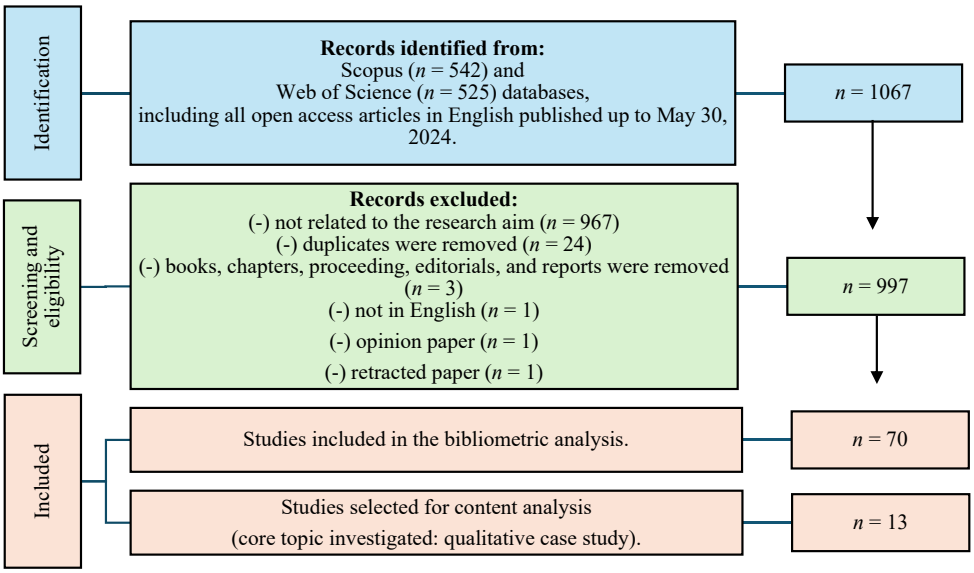

Table 2

Laws governing bibliometric studies

Law	Measure	Criteria	Main goal
Bradford's law	Degree of journal attraction	Journal reputation	To identify the most relevant journals that most effectively cover a specific topic.
Zipf's law	Keyword frequency	Ordered list of topics	To estimate the most recurring topics related to a field of knowledge.
Lotka's law	Author productivity	Size-frequency distribution	To assess the impact of an author's production in a field of knowledge.

Source: Chueke and Amatucci (2015, p. 3).

Bradford's law focuses on the degree of journal attraction and journal reputation, it is used to identify the most relevant journals that effectively cover a specific research topic, highlighting a small set of specialized journals as central sources (Chueke & Amatucci, 2015). Zipf's law is based on the frequency of keywords within academic literature, it estimates the most recurring topics in a given field by analyzing the ordered list of keywords,

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with the law suggesting that a few keywords dominate, while the majority appear less frequently. Lotka's law examines author productivity and size-frequency distribution and helps assess the impact of individual authors by showing that a small number of researchers contribute a significant proportion of the publications in a field. These laws collectively provide a robust framework for understanding the concentration of knowledge and the structure of aca-demic contributions within a specific subject.

To address the research questions, content analysis was employed as methodological approach. Coding was conducted deductively, focusing on themes relevant to the results and discussion sections. The process was performed using Atlas.ti (version 24) software, chosen due to its advanced capabilities in managing and analyzing qualitative data. To ensure consistency and reliability, each paper was coded independently by two authors, and discrepancies were resolved through comparison and consensus. The archive of the content analysis, including coding details and supporting documentation, has been added as Supplementary Material to ensure transparency and reproducibility.

To the best of our knowledge, only Morea at al. (2023) and Corral et al. (2022) assessed the transition to a circularity with the 9R model proposed by Kirchherr et al. (2017) in the agri-food sector, providing further evidence of the applicability of this model. The study advances mixed-methods CE research by integrating bibliometric trends with qualitative case-study analysis to expose gaps between theoretical frameworks (e.g., 9R model) and on-the-ground implementation challenges. Thus, it is necessary to conceptualize both categories – intervention and outcome:

- *Intervention*: Term used to refer to an action intentionally undertaken to bring about some beneficial outcome – for example, a treatment, a program, or a policy (Petticrew & Roberts, 2006, p. 280).
- *Outcome(s)*: The effects of an intervention – for example, the outcomes of an educational intervention could include exam grades and employability in later life (Petticrew & Roberts, 2006, p. 281).

A total of 1,173 interventions (across 10 codes) and outcomes (across three codes) were coded (see Table 3).

Both the Bibliometrix file and the Atlas.ti project have been included as Supplementary Material to ensure transparency and reproducibility of this research. This aligns with the principles of open science, providing full access to the data and tools used in the analysis, fostering collaboration and facilitating further exploration by other researchers.

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Table 3

Category and associated codes: Intervention and outcome

Category	Code	Magnitude	%	Category	Code	Magnitude	%
Intervention	R0 Refuse	7	1.16%	Outcome	economic	198	34.68%
	R1 Rethink	118	19.60%		environmental	244	42.73%
	R2 Reduce	151	25.08%		social	129	22.59%
	R3 Reuse	47	7.81%		Total	571	100.00%
	R4 Repair	14	2.33%				
	R5 Refurbish	34	5.65%				
	R6 Remanuf.	11	1.83%				
	R7 Repurpose	66	10.96%				
	R8 Recycle	82	13.62%				
	R9 Recover	72	11.96%				
	Total	602	100.00%				

RESULTS AND DISCUSSION

The research findings are structured in three parts: general state of art on CE and agri-food; theoretical perspectives on CE and agri-food; and CE in the agri-food: interventions and outcomes.

General state of art on circular economy and agri-food

Here we present and discuss three bibliometric analyses: a) the productivity of authors (Lotka's law), b) the distribution of journals (Bradford's law), and c) the frequency of words (Zipf's law). The portfolio comprises 70 documents (articles) published between 2020 and May 2024, involving 308 authors and 42 sources (journals), and including 4,842 references. On average, each document has received 13.13 citations, and there are 4.64 co-authors per document. To comprehend the impact of CE on the agri-food sector, we compiled insights on knowledge dissemination and research progress from a bibliometric perspective.

Our initial focus was to assess the interest in CE research within the agri-food sector by analyzing the annual number of publications. This analysis addressed the first research question, concerning the global dissemination

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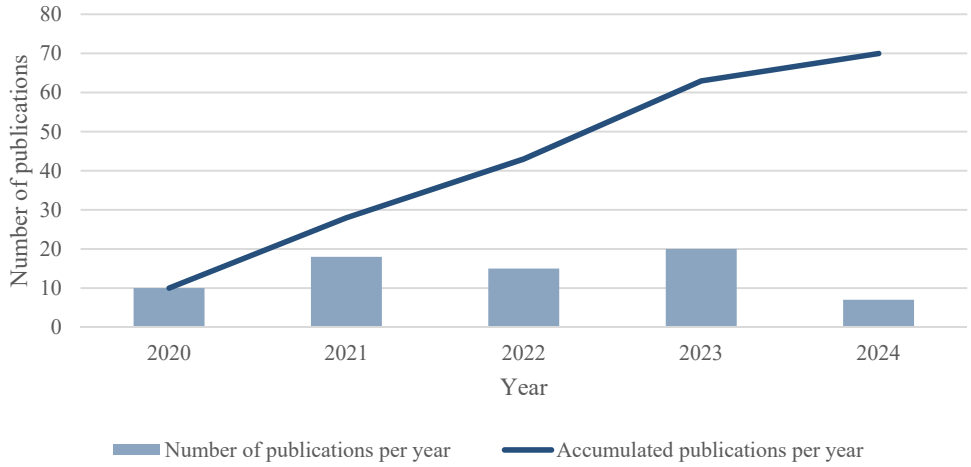
of knowledge. Our findings revealed that research on CE in the agri-food sector has generated 70 publications (refer to Figure 5).

Figure 5

Publications on circular economy and agri-food (2020-2024)



Note. May 2024.

Figure 5 presents the annual and cumulative trends in publications focused on CE within the agri-food sector from 2020 to May 2024. The bar chart illustrates the number of publications per year, while the line graph depicts the cumulative total of publications across this period. From 2020 to 2023, there was an upward trend in the number of annual publications. This growth reflects a rising academic interest in the intersection of CE and agri-food topics. The cumulative line follows this upward trend, indicating a consistent increase in total research outputs each year.

Highlighting the novelty of this research area, to the best of our knowledge, the study conducted by Skar et al. (2020) represents the pioneering effort to investigate CE in relation to the agri-food sector. Notably, the most significant increase in research activity on this topic was observed in 2023. The article provides a roadmap for cities to leverage urban agriculture for sustainability, combining empirical evidence (e.g., Sankey diagrams of resource flows) with actionable frameworks (e.g., institutional logics for policy design). It bridges gaps between research and practice, urging policymakers to prioritize urban agriculture in climate adaptation strategies.

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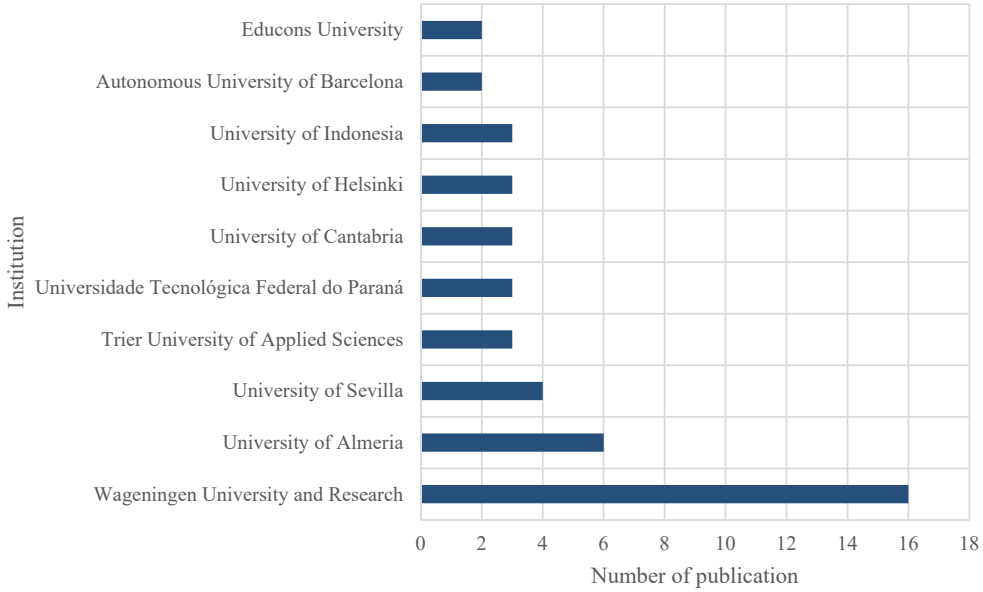
a) The frequency distribution of scientific productivity: Lotka's law

Regarding the most productive institutions on the topic, as shown in Figure 6, Wageningen University and Research (Netherlands) is the leader, with 16 publications, followed by University of Almeria (Spain), University of Sevilla (Spain), Trier University of Applied Sciences (Germany), Universidade Tecnológica Federal do Paraná (Brazil), Universitat d'Alacant (Spain), University of Cantabria (Spain), University of Helsinki (Finland), University of Indonesia (Indonesia), Autonomous University of Barcelona (Spain), and Educons University (Serbia).

Figure 6

Most productive institutions on circular economy and agri-food (2020-2024)



The citation metrics of the selected papers indicate varying degrees of impact within their respective fields (Table 4). Notably, the paper by Hamam et al. (2021), named "Circular economy models in agro-food systems: A eeview", published in the journal *Sustainability*, stands out with a total of 109 citations, averaging 27.25 citations per year and achieving a normalized total citation (TC) of 4.96. This high normalized TC suggests significant influence and relevance in its domain.

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Table 4

Most global cited documents

Paper	Total citations (TC)	TC per year	Normalized TC
Hamam et al. (2021).	109	27.25	4.96
Muscio and Sisto (2020).	63	12.6	1.95
Skar et al. (2020).	62	12.4	1.92
Fortunati et al. (2020).	56	11.2	1.73
Liu et al. (2021).	51	12.75	2.32

The authors (Hamam et al., 2021) conduct a comprehensive review of the academic literature on CE within agri-food systems, aiming to elucidate its primary characteristics and diverse perspectives. This review synthesizes and critically examines existing research in this domain. The findings underscore the imperative for the adoption of cleaner production models and highlight the critical need for heightened stakeholder responsibility and awareness among both producers and consumers. Furthermore, the analysis reveals a pressing need for the development and implementation of appropriate policies and tools to support these initiatives (Hamam et al., 2021).

Analyzing the cluster network, data reveals distinct groupings and influential nodes within the research landscape on CE. Figure 7 shows the clusters network between the publications. Kirchherr et al. (2017) in cluster 2 demonstrates the highest betweenness centrality (298.526) and PageRank (0.109), making it the most influential node in the overall network.

Closeness centrality values indicate the relative accessibility of nodes within their clusters, with cluster 3 nodes generally having higher closeness centrality. These metrics collectively illustrate the structural and influential dynamics within the CE literature, highlighting pivotal works and their interconnections.

Regarding the countries, Figure 8 shows that 27 countries published on the topic during 2020 and May 2024. Italy is the most productive country, with 18 publications, followed by Spain, with 11 publications, the Netherlands (9), United Kingdom (7), United States (7), France (5), Portugal (5), China (4), Finland (4), Brazil (3), and 17 other countries (23 publications).

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Figure 7

Clusters network based on bibliographic coupling analysis (papers)

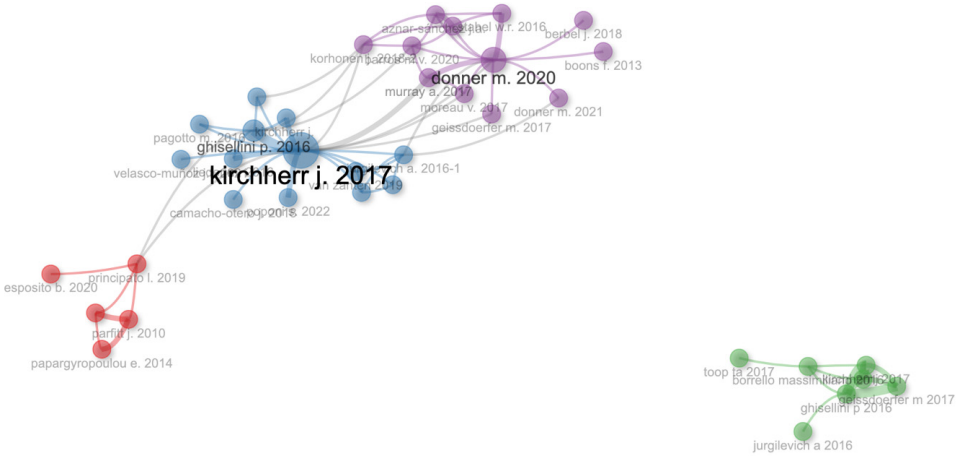
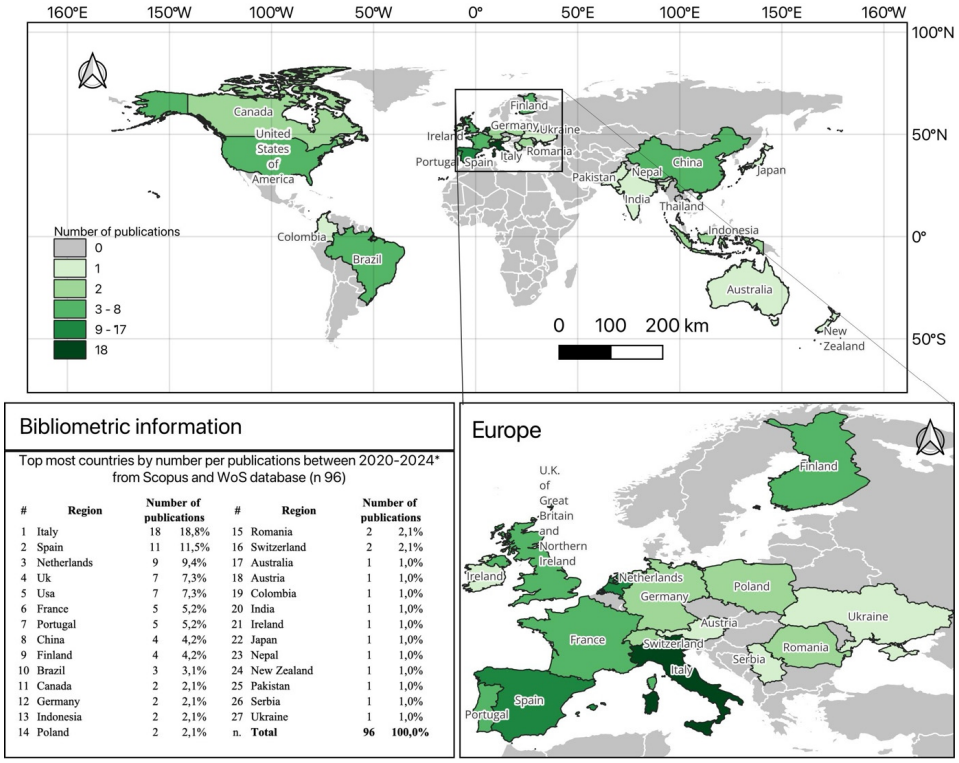


Figure 8

Publications by countries on circular economy on agri-food (2020-2024)



#	Region	Number of publications		#	Region	Number of publications	
1	Italy	18	18,8%	15	Romania	2	2,1%
2	Spain	11	11,5%	16	Switzerland	2	2,1%
3	Netherlands	9	9,4%	17	Australia	1	1,0%
4	Uk	7	7,3%	18	Austria	1	1,0%
5	Usa	7	7,3%	19	Colombia	1	1,0%
6	France	5	5,2%	20	India	1	1,0%
7	Portugal	5	5,2%	21	Ireland	1	1,0%
8	China	4	4,2%	22	Japan	1	1,0%
9	Finland	4	4,2%	23	Nepal	1	1,0%
10	Brazil	3	3,1%	24	New Zealand	1	1,0%
11	Canada	2	2,1%	25	Pakistan	1	1,0%
12	Germany	2	2,1%	26	Serbia	1	1,0%
13	Indonesia	2	2,1%	27	Ukraine	1	1,0%
14	Poland	2	2,1%	n.	**Total**	**96**	**100,0%**

Note. Figure created using QGIS 3.36.3 (Maidenhead, England).

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Country cooperation was assessed by measuring whether a single country or multiple countries appeared in a publication (Figure 9A). Interestingly, single-country publications (SCP) dominate the entire ranking, with only Spain, China, Finland, and Poland working in collaboration with different countries. We noted that Italy ranks first, with the largest number of both SCP and multiple-country publications (MCP). Spain and United Kingdom rank second and third, respectively, in both types of cooperation.

The orange line reveals the citation impact or quality of articles from each country (Figure 9B), while the blue bars indicate the overall research visibility and contribution in terms of citation. Italy is the most-cited country in its publications, with 364 citations. With less than half of the citations, there are the other countries, wherein China and Spain complete the ranking of countries that exceed 100 citations. Norway is the fourth country, with 62 citations, and France is the fifth, with 56. Norway stands out with a notably high average number of citations per article, despite having fewer total citations compared to Italy or China. This suggests that while Norway may have published fewer articles, those articles are highly influential or impactful. Conversely, countries such as Italy have a very high total number of citations but a moderate average citation per article, indicating a larger volume of publications with relatively distributed citations counts.

Figure 9

Geographical dynamics of research in CE in agri-food. (A) represents the cooperation between countries in publications on CE, and (B) shows the most cited countries

Cooperation between countries (A)

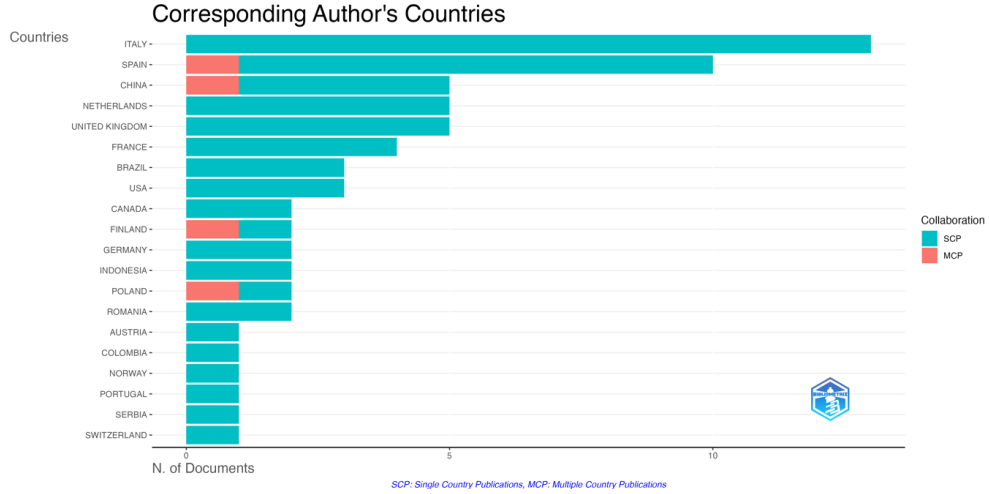

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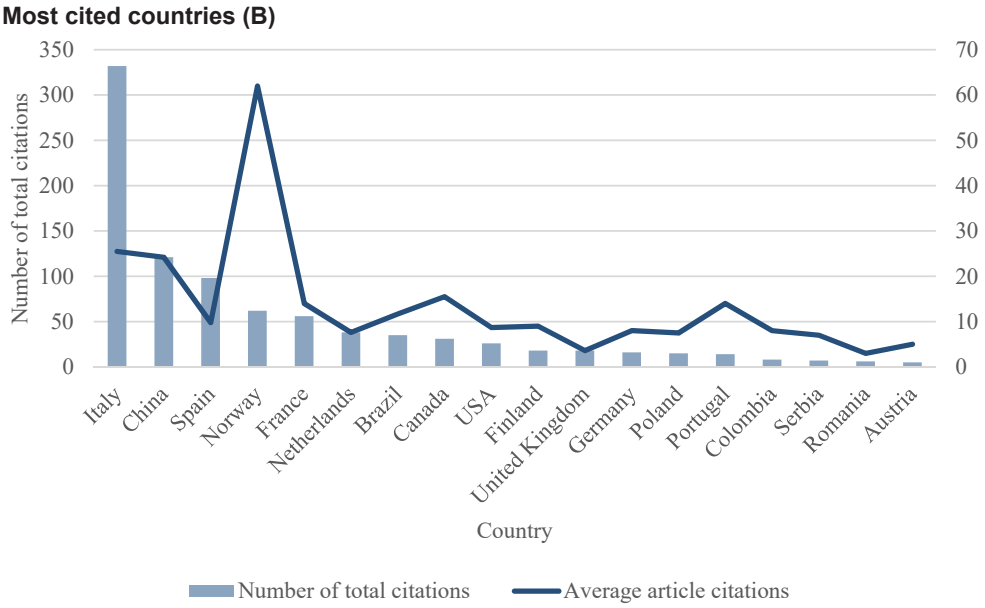
Figure 9 (conclusion)

Geographical dynamics of research in CE in agri-food. (A) represents the cooperation between countries in publications on CE, and (B) shows the most cited countries



b) Analysis of the scientific journals: Bradford's law

The bibliometric analysis shows that publications are distributed in 42 journals. Table 5 lists the top-five journals, with the number of publications (NP), total citations (TC), and impact factor (h-index, g-index, and m-index). This data underscore the prominent roles of these journals in disseminating research on sustainability and related fields, with *Sustainability* (Switzerland) leading in terms of both publication volume and citation impact.

Table 5

Top-five journals per number of publications

Source	NP	TC	h-index	g-index1	m_index2	PY_start
Sustainability (Switzerland)	16	309	8	16	1.6	2020
Frontiers in Sustainable Food Systems	3	43	3	3	0.6	2020
Sustainability	3	40	3	3	0.75	2021

(continues)

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Table 5 (conclusion)

Top-five journals per number of publications

Source	NP	TC	h-index	g-index1	m_index2	PY_start
Sustainable Production and Consumption	3	61	2	3	0.5	2021
Agronomy-Basel	2	40	2	2	0.4	2020

Note. NP, number of publications; TC, total citations, PY, publication year. 1The g-index gives more weight to highly cited articles. 2The m-index displays h-index per year since first publication.

The most productive journal identified is *Sustainability*, which stands out with the highest NP (n = 16) and TC (n = 309) since its inception in 2020, reflecting a strong impact in the field, as indicated by its h-index of 8 and g-index of 16. It is also interesting to note the m-index of 1.6, indicating rapid citation growth. *Frontiers in Sustainable Food Systems* and *Sustainability* each have three publications, with total citations of 43 and 40, respectively, both beginning in 2020 and 2021. These journals have an h-index and g-index of 3, with *Sustainability* showing a slightly higher m-index (0.75) compared to *Frontiers in Sustainable Food Systems* (0.6). *Sustainable Production and Consumption* also has three publications and a moderate TC count of 61, starting in 2021, with a lower m-index of 0.5. Lastly, *Agronomy-Basel* has two publications and 40 citations, with an h-index and g-index of 2, reflecting its contributions starting as of 2020.

c) Analysis of the co-occurrence of terms: Zipf's law

The popular keywords on the topic were identified through a co-occurrence analysis. The analysis started with a total of 292 keywords, as shown in Figure 10. There are eight clusters. CE (the green nodes in Figure 10) is the most central and influential keyword in the network, as indicated by its high betweenness, closeness, and PageRank scores.

Keywords with high betweenness, such as "circular economy" (green) and "agriculture" (blue), act as critical connectors within the network, facilitating the flow of information between different parts (bridging keywords). Keywords in clusters node – "circular agriculture" and "transition" (purple); "agroecology" and "bioenergy" (orange); "food loss and waste" and "food supply chain" (brown); "circularity gap" and "circularity index" (pink); "qualitative research" and "sustainable food systems" (gray) – have identical centrality measures within their clusters, suggesting a high level of interconnectedness and equal significance (equal centrality).

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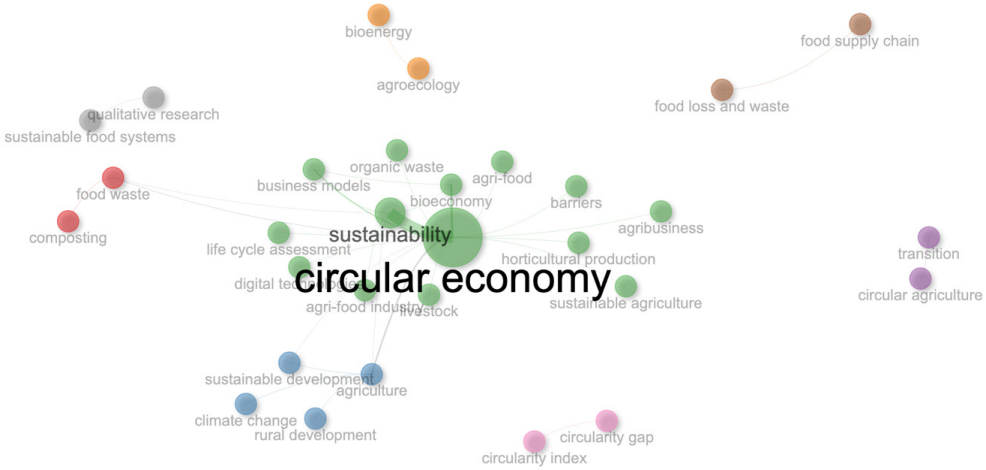
Figure 10

Keywords network based on co-occurrence



That is, the network is highly influenced by the concepts of CE and agriculture, with food waste also playing a significant role. The analysis of centrality measures indicates that some keywords act as crucial connectors and influencers within their clusters, while others share equal importance. This network analysis can help prioritize focus areas for research, policymaking, and implementation strategies in the context of sustainability and CE.

Additionally, we described the most reported countries, keywords, and sources reported in a Sankey diagram (Figure 11). The Sankey diagram illustrates the interconnectedness of global research efforts in sustainability and CE, highlighting key contributing countries, thematic areas, and major academic journals.

As it can be seen, Italy is the main country in research on CE and publications in *Sustainability* (Switzerland). *Sustainability and Circular Economy* are dominant themes across multiple countries, highlighting a global emphasis on addressing environmental and resource-management challenges. Journals such as *Sustainability* (Switzerland) and *Journal of Cleaner Production* are key outlets for disseminating research on these themes, indicating their importance in the academic community. Countries such as the United States and France contribute to a wide range of themes, suggesting a holistic approach to sustainability and environmental research. Countries such as Brazil and Finland focus on specific research areas, indicating specialized expertise and targeted research efforts.

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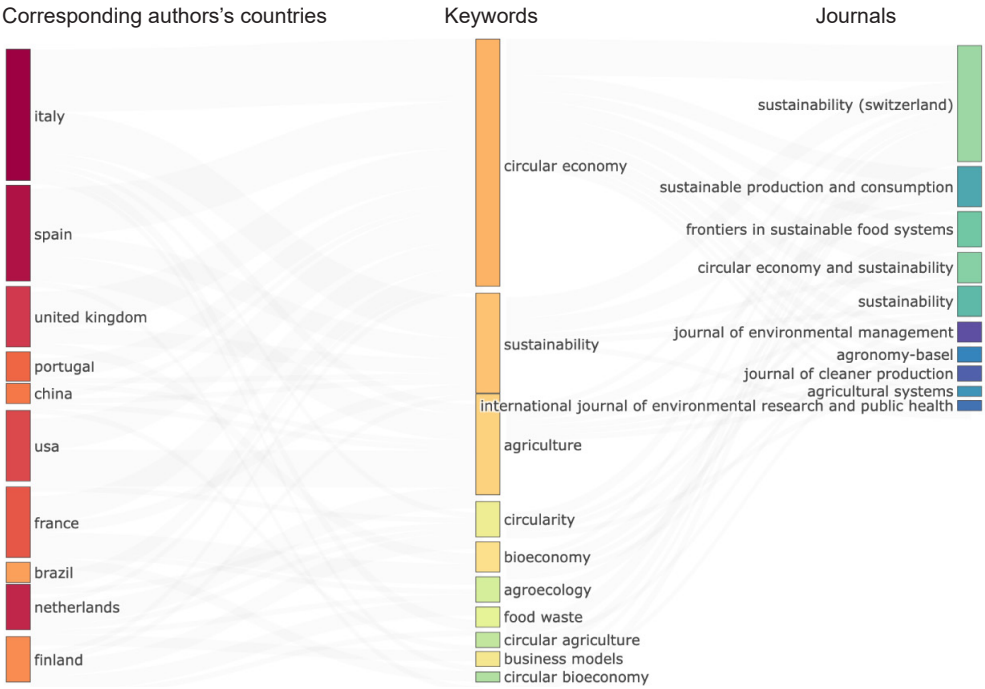
Figure 11

The ten most reported countries, keywords, and sources



The above discussion is used to answer RQ1. That is, we consider the general state of research on CE in agri-food to be multifaceted. The implementation of CE in agri-food is focused not only on technical innovations but also social, economic, environmental, and policy dimensions, aiming for transformation toward sustainability on the agri-food sector. Wageningen University (Netherlands) is the most productive institution, accounting for 16 publications (22.85%). The journal *Sustainability* (Switzerland) has published the highest number of articles, considering the production over the period (2020/2024), and the paper by Hamam et al. (2021) is the most cited.

Theoretical perspectives on circular economy and agri-food

According to Petticrew and Roberts (2006), a comprehensive tabulation of research: covering study procedures, participants, and findings – is a first step in synthesizing the included studies. In this context, Figure 12 illustrates how the portfolio's problem approach, research design, and objectives are interconnected.

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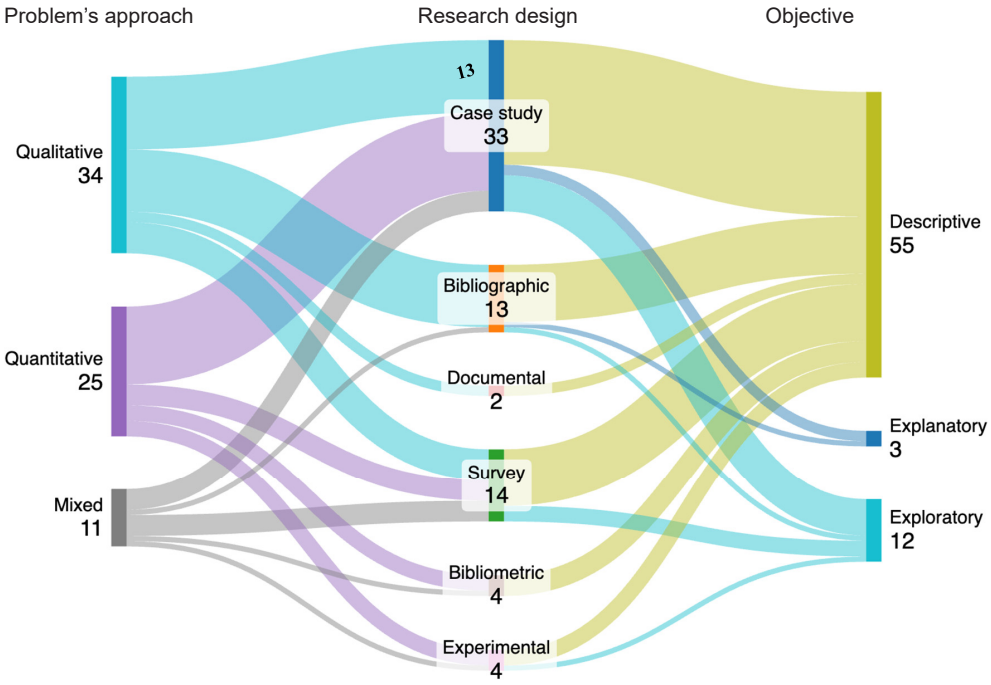
Figure 12

Portfolio problem's approach, research design, and objective (n = 70)



Note. Figure generated with SankeyMATIC.

From Figure 12, it can be observed that the most utilized problem approach method was qualitative (n = 34), with the predominant research design being case study (n = 33) and the primary research objective, descriptive (n = 55). Employing this combination of qualitative case study, 13 articles were selected for content analysis.

Also, it is noteworthy that only four papers employed a bibliometric strategy pertinent to the topics in question. Yang et al. (2021) proposed a solution framework grounded in change management (CM) strategies to address organizational challenges posed by CE, with a particular focus on agribusinesses. Sánchez-Teba et al. (2021) investigated the evolution and interrelationship between the concepts of food waste and supply chain within agricultural companies. Hamam et al. (2021) conducted a comprehensive review of the academic literature on CE within agri-food systems. Finally, Salinas-Velandia et al. (2022) illustrated the transition of horticulture towards a CE.

The thematic map (Figure 13) illustrates the conceptual structure of the literature on CE in the agri-food sector, organized by centrality (relevance)

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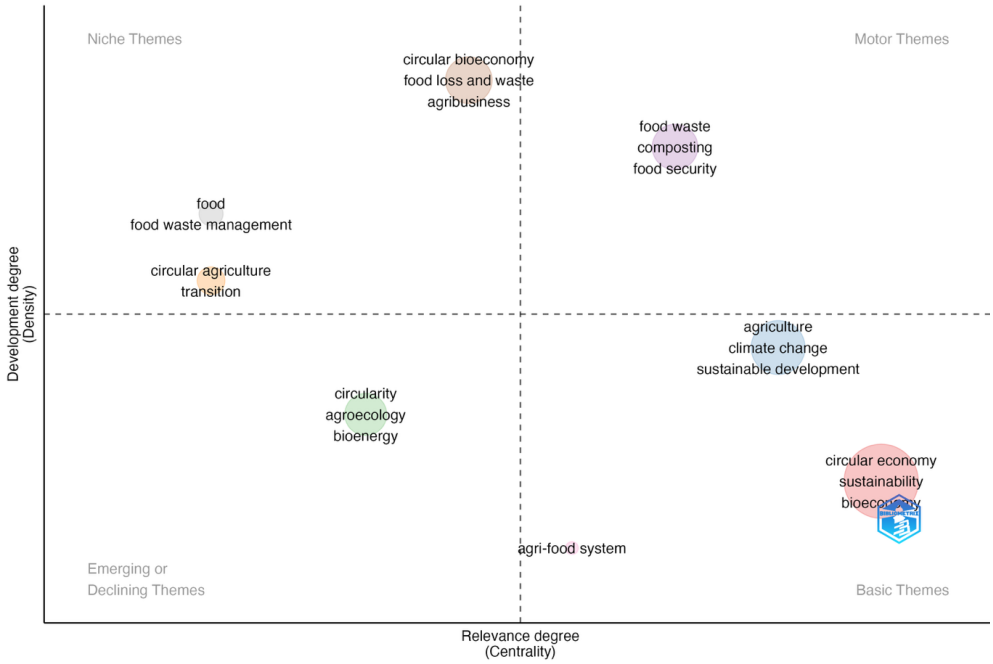
and density (development). Cluster 1 reveals that CE emerges as the most central theme, with high frequency and strong betweenness centrality values for terms like “circular economy” (44 occurrences), “sustainability” (16), and “bioeconomy” (6). These results indicate that cluster 1 forms the backbone of the academic discussion, connecting environmental concerns with systemic transformation. Closely linked, cluster 2 shows that agriculture includes themes such as “agriculture”, “climate change”, and “sustainable development”, showing high centrality but lower density, suggesting its foundational yet evolving role in the field.

Figure 13

Thematic map: Keywords



Note. Generated by Bibliometrix.

Regarding cluster 4, food waste appears in the motor quadrant, with terms such as “food waste”, “composting”, and “food security”, reflecting its maturity and strategic relevance. In custer 6, circular bioeconomy includes “food loss and waste”, “agribusiness”, and “sustainable food systems”, positioned as niche themes with internal consistency but less centrality, signaling specialized subfields. In contrast, cluster 3 – circularity (e.g., “agroecology”, “bioenergy”) – and cluster 5 – circular agriculture (e.g., “transition”) – fall

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into the emerging or declining quadrant, indicating topics under development or with growing academic interest. Cluster 7 – agri-food system – and cluster 8 – food – are less developed and peripheral, suggesting conceptual areas that might require further integration into mainstream discussions.

Our study and observations also enable us to address RQ2: "What theoretical frameworks underpin this field of study?". The theoretical perspectives on CE in agri-food field are drawn from different subjects, including corporate social responsibility (CSR), agroecological symbiosis, governance and stakeholder theory, sustainable consumption and production, food waste management, and strategic management.

Circular economy in the agri-food: Interventions and outcomes

Based on a selection of studies employing a qualitative approach with a case study research design, 13 papers were identified out of the 70 systematic literature reviews (RSL). This last specific objective aims to propose a qualitative exploration of CE interventions and their outcomes, synthesizing the qualitative evidence from case study experiences. In refining the research questions, consideration was given to three key aspects: the level of analysis, the intervention (implementation of CE practices/actions), and the outcomes (the effects of these interventions), as shown in Table 6.

Table 6

The 13 selected papers for content analysis: Qualitative case study

Level of analysis	Paper	Focus	Intervention	Outcomes
Macrolevel (4)	Aznar-Sanchez et al. (2020).	Almería (South-East Spain).	143	66
	Corral et al. (2022).	Municipality of Almócita (Almería, Spain).	35	36
	Iagaru et al. (2023).	Agri-food sector in the Sibiu Depression Microregion, Romania.	53	29
	Hoogstra et al. (2024).	Circular agriculture initiatives in the North of the Netherlands.	24	29
Mesolevel (1)	Huang et al. (2022).	Industrial ecology in Mexico.	11	6

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Table 6 (conclusion)

The 13 selected papers for content analysis: Qualitative case study

Level of analysis	Paper	Focus	Intervention	Outcomes
Microlevel (8)	Morea et al. (2023).	Agribusiness small- or medium-sized enterprises (SMEs) operating in Italy.	53	38
	Fortunati et al. (2020).	Nine companies in the Italian territory.	59	95
	Klein et al. (2022a).	Potato production in Lower Saxony (Northwest Germany).	55	48
	Klein et al. (2022b).	Potato and rapeseed production in Lower Saxony (Northwest Germany).	21	16
	Tait et al. (2023).	Salmon farming in Scotland.	17	15
	Donner and De Vries (2023).	Circular bioeconomy business initiatives in the French agri-food sector.	74	109
	Tumuyu et al. (2024).	Agroindustry company at Sumatera Island, Indonesia.	27	42
	Tumuyu and Marthalia, (2023).	Agrocompany in Indonesia.	30	42

Many papers provided minimal details regarding implementation processes. Among the studies that did include information on these processes, the majority were deemed to lack sufficient detail on study design, rendering the assessment of their quality challenging. Furthermore, it was frequently ambiguous whether the reported insights on implementation were grounded in empirical research.

Although it was possible to code the 13 selected articles according to their level of analysis (micro, meso, and macro), none of them explicitly addressed CE from a regional development perspective. For instance, while it is widely acknowledged that adopting CE practices positively impacts society, the mechanisms through which these benefits materialize remain underexplored. This highlights a significant gap for future research, emphasizing the need for studies that investigate the regional dynamics of CE adoption and their contributions to sustainable development.

Figures 14 and 15 illustrate the relationship between the interventions and the outcomes.

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Figure 14
9R principles (interventions) and outcomes (n = 13)

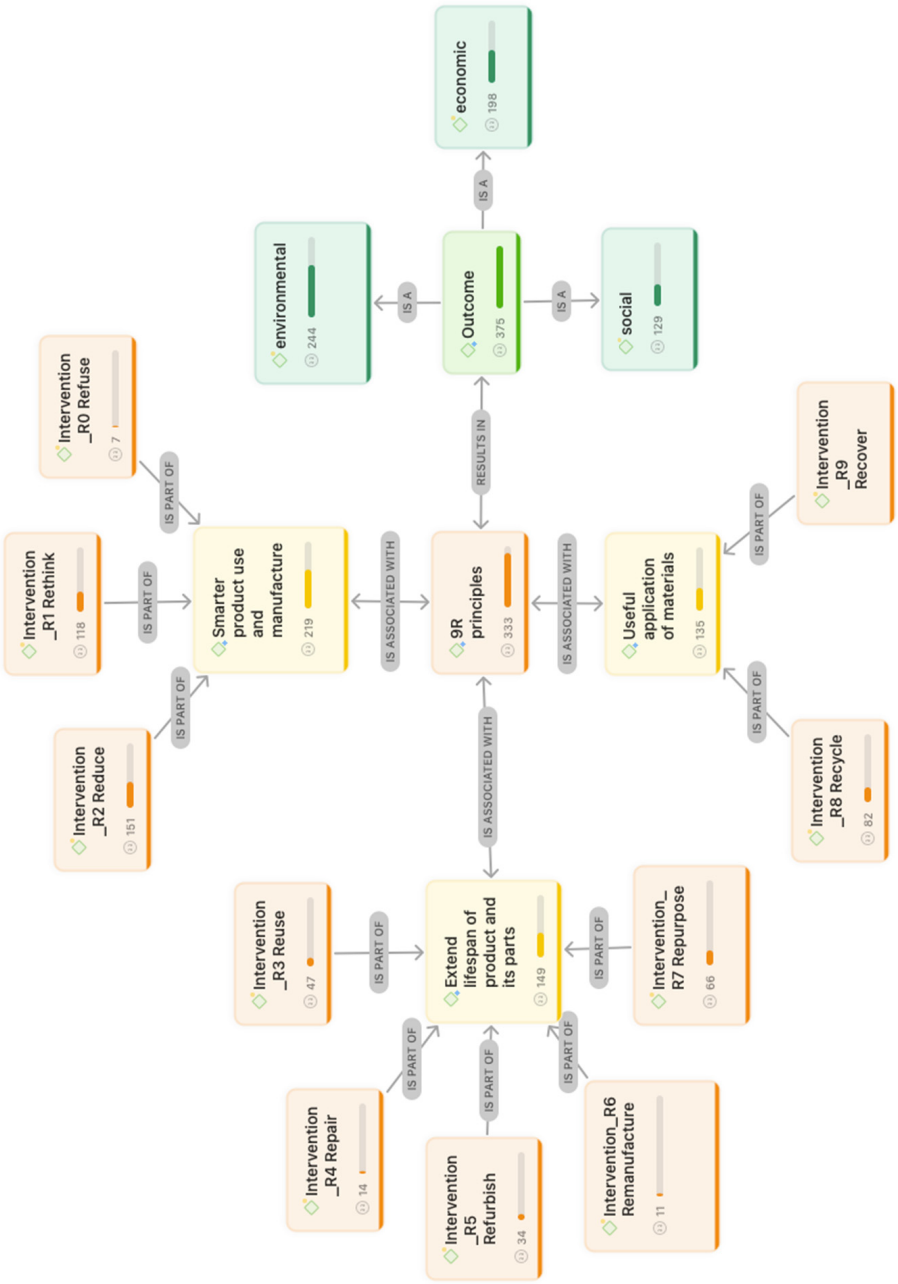

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Figure 15

Co-occurrence: Interventions and outcomes (n = 13)

The Sankey diagram (Figure 15) illustrates the relationships between nine interventions (e.g., rethink, reduce, reuse) and their corresponding outcomes (e.g., economic, environmental, social outcomes), with the thickness of the connecting flows indicating the strength of these relationships. Each intervention (for example, R1 [rethink], R2 [reduce]) has a number indicating how frequently it appears or is discussed in the analyzed studies. The numbers next to outcomes reflect how often each type of outcome (e.g., environmental, economic, social) was identified in connection with the 9R principles: environmental (244 occurrences), economic (198 occurrences), and social (129 occurrences).

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This numerical representation helps highlight areas of focus, gaps, or emphasis in the research on CE interventions and their outcomes. Rethinking is more associated with economic outcomes, as the flow from this intervention predominantly connects to the economic category. Additionally, most interventions in the diagram lead to environmental outcomes (44.64%), suggesting a stronger emphasis on environmental impact compared to economic (40.04%) and social outcomes (15.02%), which are less prominently connected.

Also, our application of the 9R model reveals that rethinking and reducing dominate in contexts with strong policy and cost incentives, respectively. Notably, reusing remains underutilized (15.3%) due to fragmented supply chains – a key gap for future policy. For practitioners, our findings suggest that CSR commitments (e.g., Italian small- and medium-sized enterprises [SMEs]) can amplify repurposing strategies, while regional policies (e.g., Spain's Almería) effectively scale rethinking. This challenges the 3R paradigm (Kirchherr et al., 2017) by showing that advanced Rs (for example, refusing) require systemic innovation.

The results obtained in this research converge in part with Kirchherr et al. (2017). Even though the authors chose to code only the 3R framework, we found that reducing, rethinking, and recycling were the most used intervention strategies in the case studies. These three interventions together sum up more than 58% of the total coded. This suggests that a more comprehensive framework can lead to a more specific result.

Morea et al. (2023) provide empirical evidence demonstrating how CSR can facilitate the adoption of CE practices, particularly within the agri-food industry. Their research enhances our understanding of the synergistic relationship between CSR and CE, showing that CSR initiatives can significantly promote the implementation of CE strategies in this sector. Also, it could be observed that companies operating in the food industry exhibit heightened awareness of sustainability concerns and are progressively pursuing value creation strategies grounded in circularity principles (Fortunati et al., 2020).

To address RQ3 – "What are the key interventions and measurable outcomes associated with implementing CE principles in the agri-food sector?" –, we observed that most of the research focuses on the microlevel, particularly within companies in Italy, Germany, Scotland, France, and Indonesia. The most frequently implemented circular economy practice identified in the qualitative research was the reduction strategy, accounting for 25.08% of interventions. The outcomes of these interventions were primarily environmental (42.73%), followed by economic (34.68%) and social (22.59%) impacts.

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The 13 case studies cover multiple countries (Spain, Italy, Germany, France, Indonesia, etc.), although our aim was not to systematically compare the administrative, cultural, or infrastructural factors influencing CE adoption. Our comparative analysis reveals that CE implementation is highly contextual. In European Union (EU) regions with strong policy frameworks, the rethinking strategy dominates (44% of interventions), whereas in resource-scarce Southeast Asia, the focus shifts to recovering (32%). This divergence suggests that top-down EU policies are less transferable to regions with weak governance. SME-driven circularity models – such as those found in Italy – may offer more adaptable approaches for emerging economies. Future CE strategies must align with local institutional logics – state, market, or community – to avoid "one-size-fits-all" failures.

Building on our mixed methods results, we synthesize how contextual factors at macro, meso, and microlevels shape CE interventions and outcomes. For instance, macro-level policy incentives (e.g., Spain's agro-industrial regulations) drive environmental outcomes via rethinking strategies, while micro-level CSR commitments (e.g., Italian SMEs) favor reducing with social benefits. This integration of Bibliometrix trends and case study evidence addresses the need for contextual rigor highlighted by Kirchherr et al. (2017) and identifies levers for scalable CE adoption.

FINAL REMARKS

This study aimed to identify and analyze circular economy (CE) practices implemented within the agri-food sector globally. By reviewing 70 research papers and analyzing 13 case studies, the study gives a detailed look at the trends, actions, and results related to the 9R framework in different situations.

The findings indicate that the application of CE in agri-food is still at a developmental stage, with significant emphasis placed on reduction strategies and environmental impacts. However, economic and especially social outcomes remain underexplored, pointing to a gap in both empirical evidence and policy focus. RQ1 explored the current state of research on CE practices in the agri-food sector. It was concluded that the research landscape is multifaceted, addressing not only technical innovations but also social, economic, environmental, demographic, and policy aspects, with a clear focus on transforming the sector toward sustainability.

RQ2 investigated the theoretical frameworks that underpin this field of study. It was found that theoretical perspectives on the CE of the agri-food

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sector are derived from various subjects, including CSR, agroecological symbiosis, governance and stakeholder theory, sustainable consumption and production, food waste management, and strategic management.

RQ3 examined what are the key interventions and measurable outcomes associated with implementing CE principles in the agri-food sector. Based on the 13 papers analyzed, the most frequently implemented CE practice identified was the reduction strategy, accounting for 25.08% of interventions. The outcomes of these interventions were primarily environmental (42.73%), followed by economic (34.68%) and social (22.59%) impacts.

Addressing the aim outlined in this study (to identify and analyze CE practices implemented in the agri-food sector around the world), we concluded that aligning people's mindsets with a circularity-oriented culture over time required setting clear goals and targets, developing strategies for effective business innovation, and continually assessing progress through a sustainability lens (environmental, social, and economic perspective).

Theoretically, this study contributes to the literature by integrating bibliometric analysis and case study research to map the dissemination of CE knowledge and practices. It highlights how frameworks such as CSR, stakeholder theory, and agroecological models underpin the evolving landscape of CE strategies in agriculture. Practically, the results emphasize the importance of localized implementation pathways. Interventions such as rethinking or repurposing are more effective when aligned with contextual drivers, such as regional policy instruments or company-level sustainability commitments. This concept is particularly relevant in emerging economies, where top-down frameworks may not always translate into operational impact.

In this sense, Brazil represents a fertile ground for future CE research and policy experimentation. As one of the world's leading agri-food producers, Brazil faces both challenges and opportunities in embedding CE practices in rural, industrial, and urban food systems. Integrating CE into Brazil's national sustainability agenda – through inclusive policies, regional pilot programs, and support for SMEs – can serve as a benchmark for scalable models in Latin America.

However, some limitations must be acknowledged. This study relies exclusively on theoretical methods, making it necessary to validate the findings through case studies and expert interviews to better analyze the results. Additionally, the analysis was based on only two databases, considered only open access journals, and included publications exclusively in English. Given that the manuscript is submitted to a Brazilian journal with a Portuguese-speaking readership, the language scope may limit accessibility and inclusiveness.

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Conflicts of Interest

The authors declare no conflicts of interest.

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ABBREVIATIONS

The following abbreviations are used in this manuscript:

3R	Reducing, reusing, recycling
4R	Reducing, reusing, recycling, renewing
6R	Reducing, reusing, recycling, redesigning/rethinking, remanufacturing
9R	Reducing, reusing, recycling, renewing, redesigning/rethinking, remanufacturing, rejecting, repairing, recovering
Atlas.ti	Qualitative data analysis software (no abbreviation, included for clarity)
CE	Circular economy
CM	Change management
CSR	Corporate social responsibility
g-index	Gives more weight to highly cited articles
h-index	Measures productivity and citation impact of a journal or author
m-index	Citation growth rate of a journal or researcher over time
MCP	Multiple-country publication
NP	Number of publications
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
R	Framework referring to reducing, reusing, recycling, and other related principles (e.g., 3R, 4R, 6R, 9R frameworks)
RQ	Research question
RSL	Research systematic literature
Scopus	Scientific database (no abbreviation, included for clarity)
SCP	Single-country publication
SLR	Systematic literature review
TC	Total citations

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