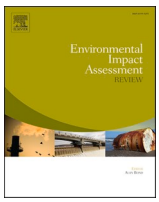
Environmental Impact Assessment Review 100 (2023) 107079

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar



The maturity level of the agri-food sector in the circular economy domain: A systematic literature review

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ARTICLE INFO

Keywords:
Agri-food sector
Circular economy
Industrial symbiosis
Food practices
Systematic literature review
Innovativeness level
Bibliometric analysis
Content analysis

ABSTRACT

The agri-food sector (AFS) is crucial in the transition towards sustainability. The Circular Economy (CE) has gained global attention as a tool to achieve it systemically. Nevertheless, it is necessary to understand the maturity level of circularity in the AFS. For that reason, this study aims to analyse, through a systematic and bibliometric literature review, examples of circularity in the sector at inter- and intra-company levels, considering case studies with a micro or *meso* perspective of analysis. The review was conducted using Scopus and Web of Science databases, identifying 43 peer-reviewed articles published from 2015 to the end of February 2022 and 162 practices. The review explored the maturity level of the agri-food sector in terms of circularity through the innovativeness of its practices. Results show that 51% of the practices have a conventional nature, whereas incremental and radical innovation represent 46% and 3% of the sample. The analysis also investigated, through content analysis, the links with Industrial symbiosis (IS), and sustainability, which remains poorly explored, especially in social terms. Although some limitations are present due to the research criteria, the study allows for deep diving into the characteristics of circularity in the sector by contributing to the definition of a database of circular best practices capable of driving practitioners towards its application and capturing challenges and potential ways of improvement.

1. Introduction

Nowadays, worldwide food production is driven by the linear paradigm of "take-make-use-waste", which enabled the agri-food sector (AFS) to be more resource-intensive but less sustainable. There are several definitions of the AFS. According to the Food and Agriculture Organization of the United Nations (FAO), it is a system that "…covers the journey of food from farm to table including when it is grown, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten and disposed of. It also encompasses non-food products that also constitute livelihoods and all of the people as well as the activities, investments and choices that play a part in getting us these food and agricultural products" (FAO, 2021, page 3).

Currently, Food Losses and Wastes (FLW) characterize one-third of food produced globally (Fassio and Tecco, 2019). Specifically, food loss is any reduction that occurs from harvesting to retail, while food waste is the reduction from retail to consumption phase (FAO, 2019). In addition, the increase in the population level requires the AFS to adequate its productive patterns to feed the additional 2 billion people expected by 2050 (Toop et al., 2017). Food production and consumption directly impact food safety and quality and indirectly impact the environment, affecting overall human health (Gibin et al., 2022).

In this context, Circular Economy (CE) is observed as a possible solution to preserve resources and reduce the negative externalities caused by the production systems, including the agri-food sector, favouring the transition to Sustainable Development (SD) (Esposito et al., 2020). CE is a holistic approach to development, regenerative by design and able to decouple resources exploitation from economic growth (EMAF, 2015). CE principles are not new in the AFS and can be retraced back in the agri-food dynamics. One clear example is the "Farming bricolage" in peasant society, where all edible residues are reinvented in the next meal to eliminate waste (Fassio and Tecco, 2019). To guide the transition to SD in the AFS, it is necessary to understand how the sector implements circularity by exploring intra- and inter-company synergies. The intra-firm dynamics can be captured by analyzing the practices implemented in single organizations (micro perspective), whereas the inter-

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https://doi.org/10.1016/j.eiar.2023.107079
Received 26 November 2022; Received in revised form 18 January 2023; Accepted 22 February 2023
Available online 1 March 2023

firm ones by investigating the relations among different companies, (*meso* perspective). The latter dimension may configure as an example of Industrial Symbiosis (IS), aiming to embrace different entities towards competitive advantage through exchanges of residues, water, and energy (Chertow, 2000). The connection between CE and IS is not new. For example, in Europe, the Action Plan (European Commission, 2015) directly addresses the role of IS in transforming the linear system (Domenech et al., 2019).

Therefore, CE has a strategic role in reaching SD, but the connection is still unclear. Circularity is indeed ruled by eco-efficiency, which is not free from rebound effects and thus CE may not coincide with sustainability. SD implications (economic, environmental, and social dimensions) of circular and symbiotic solutions are still debated and particularly relevant in AFS (Stillitano et al., 2021). A relevant lack suggested by the literature is the non-explicit social commitment of CE. Sustainability pursues society's well-being and the safeguarding of human rights, while CE considers social improvement mainly in terms of employment (Murray et al., 2017). In the AFS, food lies at the core of the human relationship with nature, generating a cultural value which cannot be underestimated (Fassio and Tecco, 2019).

A theoretical overview conducted to highlight the main lacks in the literature on the topic (further details are available in the supplementary materials) shows that the study of CE in the agri-food context is widespread in the literature. Indeed, in the last years, several authors addressed its application, i.e. through studies on CE in the agricultural supply chain, e.g.: i) describing existing practices and possible future scenarios (Esposito et al., 2020), ii) detecting the political and social dimension (Hamam et al., 2021), or iii) highlighting the role of reuse and valorization strategies of waste and by-products (Chiaraluce et al., 2021). Even though circularity is already present in the sector, the challenge to establish an appropriate classification for circular practices in the food system is still open and needs to be filled. Several examples of classification are present in literature (Papargyropoulou et al., 2014; Vandermeersch et al., 2014; Rood et al., 2017); nevertheless, none of them is focused on assessing the maturity of the sector in terms of circularity.

In this context, the present research proposes a systematic literature review (SLR) focused on the *meso* and micro level of circularity practices, considering their earlier stressed context, in the AFS by addressing the research question (RQ): What can we learn from inter- and intra-organization practices and experiences of Circular Economy in the Agri-food sector to assess the circular maturity of the sector? This SLR specifically holistically explore the CE practices of the AFS from an environmental, social, and economic point of view. In particular, the research examines the practice's characteristics, analyzing their goals and innovative or traditional nature to understand if these circularity practices are innovative or traditional, can be connected to IS and if and how they contribute to SD.

After this introductive section, the paper is organized as follows: Section 2 describes the methodology adopted to perform the literature review, exploring in detail the research approach employed for collecting the studies. Section 3 presents the results obtained through the systematic and bibliometric literature review. Section 4, discuss and critically analyse the findings of the literature review. In conclusion, section 5 summarizes the main findings of the analysis and points out future research opportunities.

2. Methods

A bibliometric and systematic analysis of the existing scientific literature was conducted to answer the research question. The bibliometric analysis explores texts, focusing on information regarding authorship, affiliation, collaborations, and keywords while examining the linkages between and among studies (Geissdoerfer et al., 2017). This enables an understanding of how the interest in the topic has evolved in time and space. On the other hand, systematic reviews set clear and explicit research criteria to identify all the evidence in line with the research questions enabling the generation of a picture where bias is minimized and reliable findings are provided (Snyder, 2019). Given the importance of providing a standard peer-accepted methodology, increasing the consistency and robustness as well as the replicability of the analysis, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method is selected as the formal guideline of the present study (Page et al., 2021). The procedure applied for this literature review is summarised below, explaining first the applied search procedure for identifying the literature case studies and then the macro categories of data extracted from each.

2.1. Database search strategy

The search strategy applied is summarised in Fig. 1, showing: i) the keywords and databases employed to identify the sample of articles, ii) the inclusion and exclusion criteria used during the double-screening process, and iii) the final sample of articles and the practices selected for the analysis.

In particular, the research was carried out by searching for keywords capable of qualifying empirical examples of CE (such as “circularity” OR “circular economy”) in the Agri-food sector (“Agri-food”, OR “Food” OR “Agrifood” OR “Agri food” OR “Agriculture”), within the databases Scopus and Web of Science. This choice guarantees that high-level quality articles were included in the analysis, which is a fundamental issue in examining the state of the art of the research topic. In addition, according to Crowe et al. (2011), the term “case study” is added to the search query, allowing an in-depth analysis of the phenomenon observed in its natural context. The research was conducted first on 28 September 2021, second on 31 December 2021, and third on 28 February 2022. All search queries are reported in the supplementary materials (File Excel - Worksheet “Search queries”). This research allowed for identifying 502 articles (Fig. 1) that were reduced by applying the database search filters to select:

- only articles published from 2015 to 28 February 2022 in English. The starting date of 2015 was chosen due to the introduction of the “Closing the Loop: An EU Action plan for the Circular Economy Package” by the European Commission (European Commission, 2020) in December 2015.
- only peer-reviewed articles, excluding items such as reviews, book chapters, conference papers, books, conference reviews, etc. This choice allows for considering only on original high-quality contributions on the topic.
- only research fields in line with the scope of the study were included (excluding fields such as computer science, mathematics, arts and humanities, immunology, psychology, etc.).

After the filter application, the bibliometric data of the remaining 198 articles were exported on Microsoft Excel software to identify and eliminate duplicates (60). Then, a double-screening process was applied to identify only the studies addressing the selected eligibility criteria outlined in Fig. 1.

During the first screening, 87 studies were selected based on title, abstract and keywords, excluding the articles considered out of the scope of the analysis (e.g., papers that i) focus on topics different from CE, such as poverty alleviation, ii) described CE practices not in the agri-food, such as in the industrial solid waste, iii) did not study specific practices, like the analysis of the spatial distribution of biogas production potential, etc.).

The remaining articles were downloaded for the second screening for the full-text evaluation, selecting only articles: i) presenting case studies (e.g., reviews are excluded), ii) describing practices linked or attributable to CE, linked to the agri-food sector, iii) having a micro or *meso* level of analysis. The final sample was then of 43 articles. From the final sample, 162 circular practices were identified. All the practices labelled

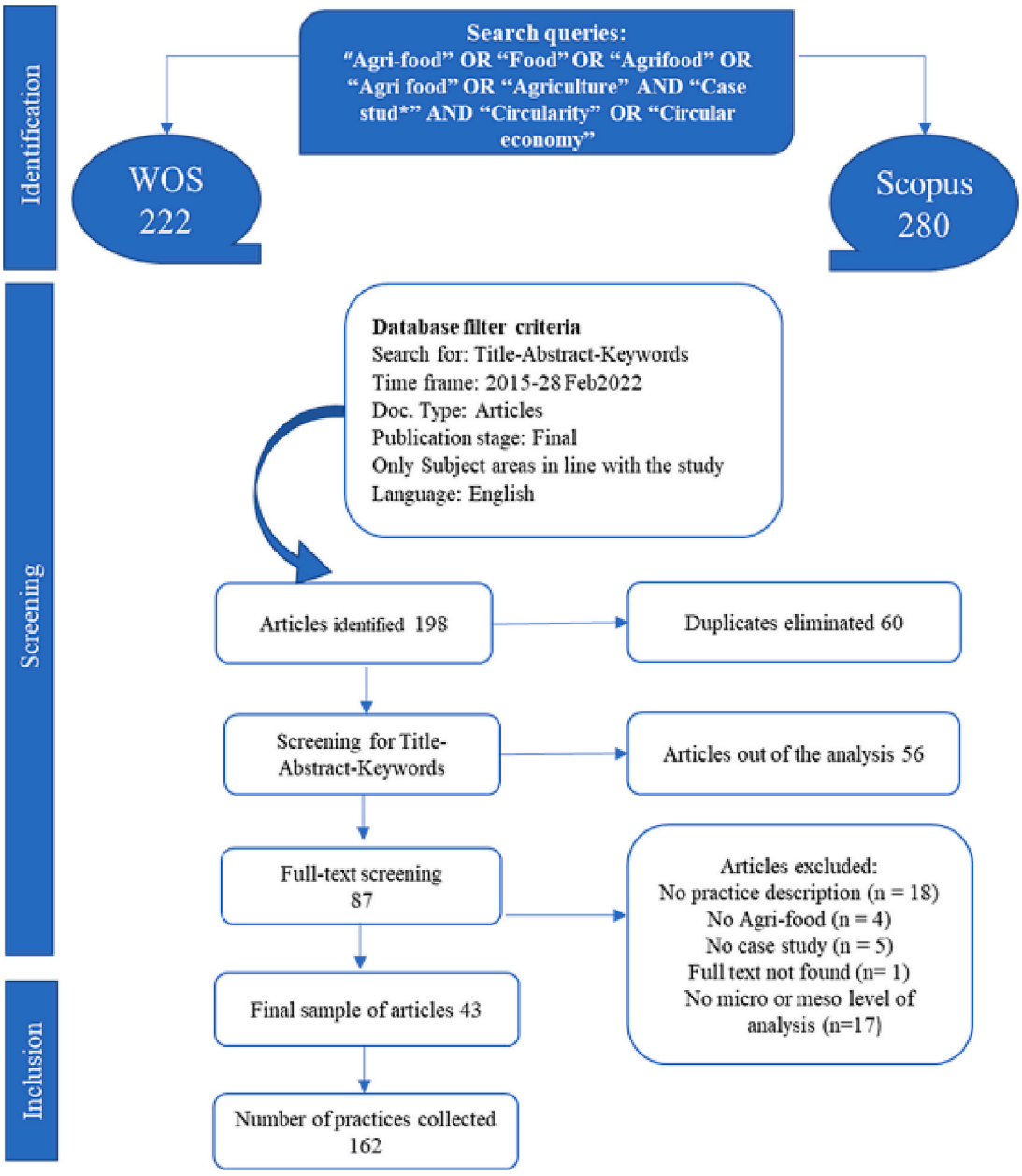

Fig. 1. Flow chart diagram of the database literature search procedure.

as circular or in line with circularity principles are included. Based on this definition, some studies present more than one practice because, for example, in studies focused on the micro level, different scenarios of the same practice have been compared, while in the meso level, more circular practices have been presented in the same organization resource management. All the data collected during the analysis are reported in the supplementary materials.

2.2. Macro categories analysis

The sample analysis was carried out according to 4 macro-categories: 1) Bibliometric information, 2) Context of the studies, 3) Agri-food practices description and classification and 4) Sustainable narratives.

2.2.1. Bibliometric information

This category allows for measuring the level of interest in the topic, contributing to the analysis of circular practice in the sector. It includes bibliometric information regarding the title of the contribution and authors, the year of publication, the journal source, as well as the subject area covered by the journal. All the data regarding the studies extrapolated from Scopus and WOS. Only for the subject area, the definitions proposed by Scopus were adopted to increase the level of uniformity.

2.2.2. Context of the studies

This category considers the number of practices identified and enables to capture of the main characteristics to understand what is possible to learn from such examples of circularity. It includes information regarding the characteristics of the studies in terms of geographical setting, analyzing both country and continent level and supply chain, considered in terms of typology (e.g., agriculture, dairy, livestock, etc.) and stage (namely production, processing, consumption, etc.). In addition, when the case studies respond to multiple typologies of supply chain, the category "various" was adopted.

2.2.3. Agri-food practices description and classification

This category considers the number of practices collected among the

sample of articles and allows for exploring and classifying the practices implemented according to a) innovative or traditional nature and b) level of circularity.

In particular, food practice's categorization organizes the practices per process and goal and is depicted in Table 1. In this case, the coding framework employed for the analysis was developed by adapting existing waste food frameworks. The classification process must consider those issues overlooked by the current waste framework European Commission, 2008. For example, it is focused on prioritizing end-of-life treatments, neglecting more sustainable options like prevention or reuse. In addition, the hierarchy has a general scope, which gives space to personal interpretations by actors and institutions, limiting the capacity to address environmental challenges (Teigiserova et al., 2020). This explains the need to define frameworks able to entail the main characteristics of the food sector, broadening the valorization pathways and, thus, generating positive incomes on an environmental, economic, and social aspect.

Meanwhile, the level of innovativeness classifies practices as conventional, incrementally innovative, or radically innovative and is depicted in Table 2. The transition to circularity requires both incremental and radical changes in a coordinated and integrated way along with the whole food system. The study tries to capture the nature of such innovation, analyzing if the practices detected have a technological or socio-organizational form (Potting et al., 2017). The first describes an innovation focused on technology as a core characteristic, while the latter aims to review the socio-organizational codes and adopt new beliefs and perspectives of action.

2.2.4. Sustainable narratives

Considering the number of studies, this category enables to understand how the studies describe CE and if they are connected to IS and sustainability. The narrative is analyzed following three perspectives: circular economy, industrial symbiosis, and sustainability (see Table 3).

Table 1
Categorization of the food practices per process and goal.

Food practices's categorization			
Process classification	Practice Goal	Description	References
Optimization of the production process	Material in inputs	Optimization in materials use	Papargyropoulou et al., 2014
	Energy in inputs	Optimization in energy use	
	Technologies	Optimization concerning the technologies employed	
Sharing of resources	Tangible	Sharing of tangible resources, e.g., agricultural inputs, energy, food, animal feed, etc.…	Rodrigues et al., 2021
	Intangibles	Sharing of intangible resources, e.g., knowledge, responsibilities, labour, etc.…	
Reprocessing	Nutrients Feed Food Pet food Energy Materials Water	Any operation/ process by which waste food is reprocessed into fuel/ energy/raw materials/value-added products	Garcia-Garcia et al., 2017
Incineration and Landfilling	With biogas recovery	Waste disposal on landfills or incineration	Garcia-Garcia et al., 2017/ Rood et al., 2017
	Without biogas recovery	–	

Table 2
Classification of practices per level and nature of innovativeness.

Innovativeness's level and nature		
Innovativeness level	Description	References
Conventional	Conventional practices are operations and processes well-established in the literature, e.g., agroforestry, inter-cropping, crop rotation, cover cropping, traditional organic composting, and integrated crop-animal farming diversification, soil management, soil conservation, grass strips and living barriers.	Singh and Singh (2017); Altieri and Nicholls (2017)
Incrementally Innovative	All those activities that privilege technological and productivity-oriented innovations to guaranteed resource-efficiency. These kinds of innovations allow the existing products and processes to continue being competitive, but also to be competence enhancing, since they are based on existing knowledge.	HLPE Report (2019); Afuah (2003)
Radically Innovative	All those practices that aim to redesign the food system, entailing a territorial vision, while considering environmental, social, and economic conditions. They generate products that render the existing ones non-competitive, creating also new knowledge, that overcomes the existing one.	HLPE Report (2019); Afuah (2003)
Technological Innovation	Innovative practices for which the technological aspect plays a core role in the transition process.	Potting et al. (2017)
Socio-organizational Innovation	Innovative practices for which the social and organizational aspect play a core role, aiming at long-term change in society's customs and beliefs.	Potting et al. (2017)

The analysis was performed by adopting the content analysis technique. Such qualitative methodology enables the interpretation of text data through a coding process, which discloses research themes and patterns in the text under evaluation (Moldavska and Welo, 2017). In particular, the following considerations were made for:

a. Circular economy. The category investigates firstly if and how the studies define CE, measuring it in terms of "mentioning units"; deep diving into the level of explanation and analysis adopted by the single study. CE is further analyzed through the R framework. The framework summarizes the main circular "actions" (Ghisellini et al., 2016); it was first declined into the 3 Rs form (Reduce, Reuse and Recycle) (Zhu et al., 2019). Nowadays, different forms of the framework exist; the most nuanced includes the 9 Rs (Potting et al., 2017). The present study adopts the 4Rs framework to assess the level of circularity. This configuration was chosen since it was employed in the European waste directive (European Commission, 2008), so it is well-known.

b. Industrial Symbiosis. The present study considers the industrial symbiosis (IS) as part of the CE concept (*meso* level). IS impact on AFS practices has been included since different symbiotic relations have been identified in the sample. The analysis identifies the direct mention of the term industrial symbiosis within the articles considered.

c. Sustainability. To assess the connection between sustainability and circular economy, the sustainability "mentioning unit" is expressed as a direct mention of the term "sustainability" and "sustainable development" in the text. This analysis enables us to understand if sustainability is perceived as linked to circularity or as a stand-alone principle within the sample. The study considers the sustainability pillars adopted by the single articles, considering environmental quality, economic prosperity, social equity, or a combination of more of them.

Table 3
CE's contextualization level and linkages with IS and SD.

Level of contextualization					
Circular Economy		Industrial Symbiosis		Sustainability/Sustainable Development	
Mention	Description	Mention	Description	Mention	Description
Not contextualized	Studies in which the term CE is only mentioned as a keyword, or present in the abstract	Not mentioned	Studies in which the term IS is not directly mentioned in the text	Not mentioned	Studies in which the terms Sustainability or SD are absent in the text
Mentioned	Studies that provide a definition of circularity or directly mention its principles as defined by Kirchherr et al. (2017)	Mentioned	Studies in which the term IS is indirectly mentioned.	Not contextualized	Studies in which Sustainability or SD are not directly mentioned, or only mentioned as keywords, or present in the abstract
Linked to other sustainable streams	Studies that link the circularity to other sustainable thinking streams, excluding of sustainability and IS (treated in detail in the next sections)	Linked to CE	Studies that link IS to CE	Mentioned	Studies that provide a definition of Sustainability or directly mention its principles as defined by WCED (1987)
				Linked to CE	Studies that link Sustainability with circularity

3. Results

In this section, the results of the bibliometric and systematic analysis are discussed. In addition, a critical analysis of the main methodological and technical characteristics of the final sample of articles is provided.

3.1. Bibliometric analysis

The bibliometric analysis is carried out by evaluating a) the yearly distribution of publications, b) the journal source, and c) the research area covered by the journal source. In particular:

a) Considering the yearly distribution, the sample contains 43 studies published between 2015 and the end of February 2022 (Fig. 2). The highest number of publications was registered within 2020–2021, representing 63% of the total sample. Nevertheless, not considering the beginning of 2022, the number of studies has more than doubled during the last years of observation, indicating the growing attention of academia on the topic.

b) Regarding the publishing sources, 25 scientific journals are identified in the sample (Fig. 2). The primary journal source is "Journal of Cleaner Production", which published 10 studies within the period analyzed, showing a constant interest in the topic. The main secondary contributors are "Science of the Total Environment" and "Resource, Conservation and Recycling", both publishing 4 articles. The first has increased the attention in the field only in the last two years, while the latter has shown a steady interest. It is relevant to notice that 19 out of 25 Journals published just one study on CE in

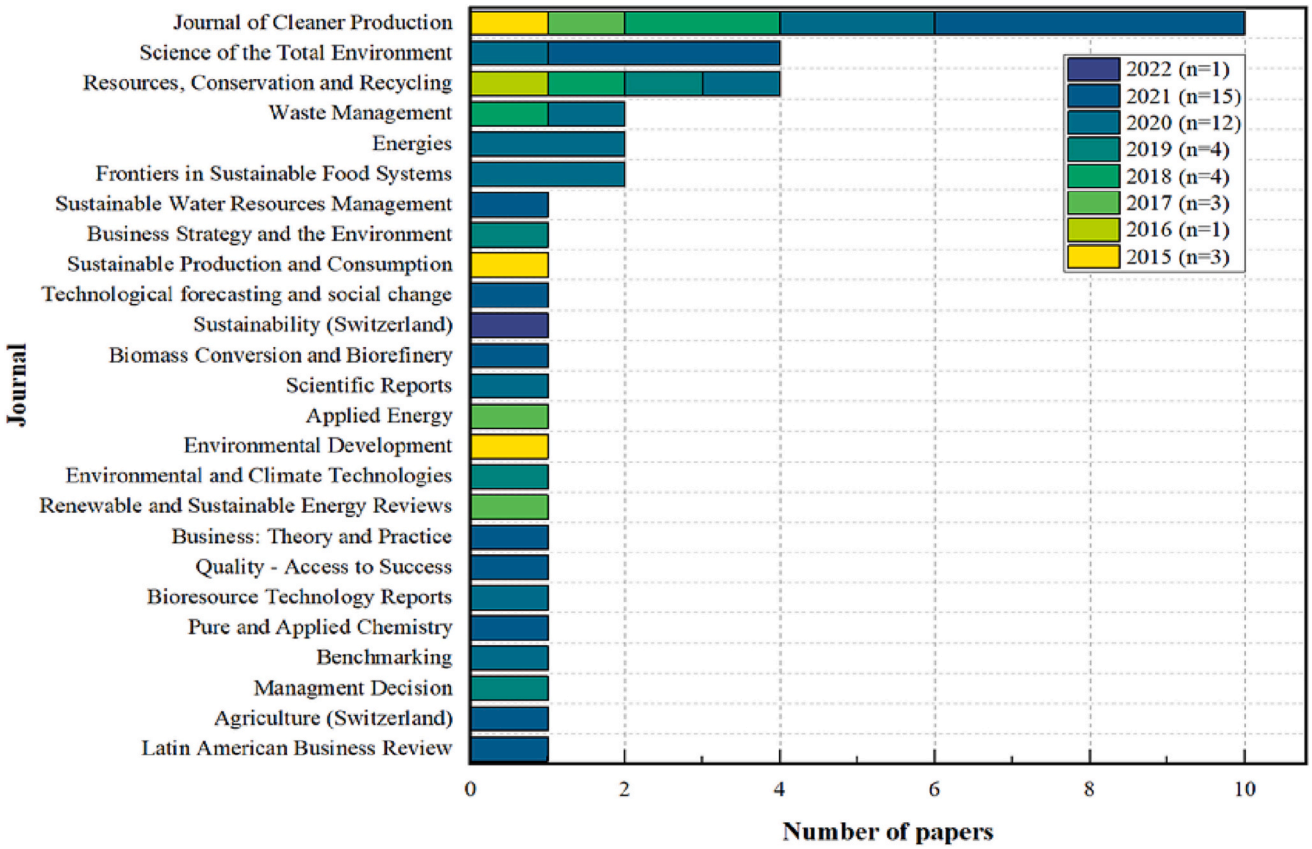

Fig. 2. Number of articles per year and journal.

AFS. These findings are summarised in Fig. 2, analyzing the trend of the topic based on the annual distribution of publications and journal sources.

c) The analysis for the research area per journal confirms the strong environmental vocation of the field, the most recurrent area is "Environmental Science", which represents 25.5% of the total areas identified. It is important to mention that the number of articles does not match the final number of publications in the sample because a study can be connected to more research areas. The second area of interest is "Energy", followed by "Business, Management and Accounting" and then "Engineering" and "Social sciences".

3.2. Context of the studies

This section reports the results linked to the geographical setting as well as the studies' supply chain type and stage. Fig. 3 shows the number of articles per country and continent setting, and the matrix presents the number of practices in terms of supply chain type and stage.

3.2.1. Geographical setting

First it is analyzed the geographical setting, namely where the studies were developed. It is relevant to highlight that some studies are settled in more than one country (Italy-Spain and Brazil-United Kingdom). As summarised by Fig. 3, European studies represent 61% of the sample. Italy's role is prominent contributing to 28% of the total sample. The United Kingdom and Spain are the second-largest contributors among the other European countries, with 4 and 3 publications. Moving to Asia, China maintains a leading role, publishing 4 studies on the topic. Other contributions were identified in Malaysia, Singapore and Turkey. South American publications are dominated by Brazil, which presents 6 studies. North and Central America, as well as Africa show just 1 publication each.

3.2.2. Supply chain type and stage

The analysis of the context also entails the supply chain (SC) type and stage. These findings are summarised in Fig. 3 and quantified for practice. In terms of the typology of the supply chain, agriculture showed the highest number of publications describing 48% of the practices. In detail, Italian agricultural studies present 39% of the practices of the category, while Brazilian ones 25%. The "Various" category is the second most reported, analyzing 26% of the practices. The least explored is fish breeding, characterizing 5% of the practices, all described by Spanish case studies.

Moving to the supply chain stage, the processing phase is the most relevant, representing 30% of the practices, where Italian practices represent 37.5% of the total. This is followed by whole supply chain practices, representing 40% of which 27.5% have a Brazilian setting. The least treated stages are consumption and retail. The consumption stage characterizes the 3% of the circular practices in the sample, which are all settled in Costa Rica. The retail sector is analyzed by 9% of the practices, and 65% of the category has an Italian setting.

3.3. Process classification

This section includes the classification and critical analysis of the practices and processes described by the articles based on the earlier theoretical overview (Section 2.1). As mentioned above, the number of practices does not match the number of articles since the studies may describe more than one "circular" process. The sample includes 162 practices out of 43 articles defined as or linked to CE in the AFS. All characteristics of practices are summarised in Fig. 4.

3.3.1. Process and goal of the practices

Reprocessing processes characterize 66% of the practices. The subcategory Energy reprocessing characterizes 39% of the category. The agriculture supply chain is the most involved in the sample, characterizing 43% of the subcategory. Within reprocessing, the production of nutrients is a relevant goal. It is considered by 25% of the category. Once again, agriculture is the most involved chain, describing 52% of residues and by-products, while more engaged stages are the productive (41%) and end-of-life (22%). Another relevant section is represented by Materials reprocessing. It represents 15% of the. 69% of the practices are linked to the agricultural field, especially in terms of processing (56%). Optimization processes represent 19% of the sample and are analyzed by 10 studies. They mainly focus on optimizing materials used in the inputs (71%). Technological optimization characterizes 22.5% of the category.

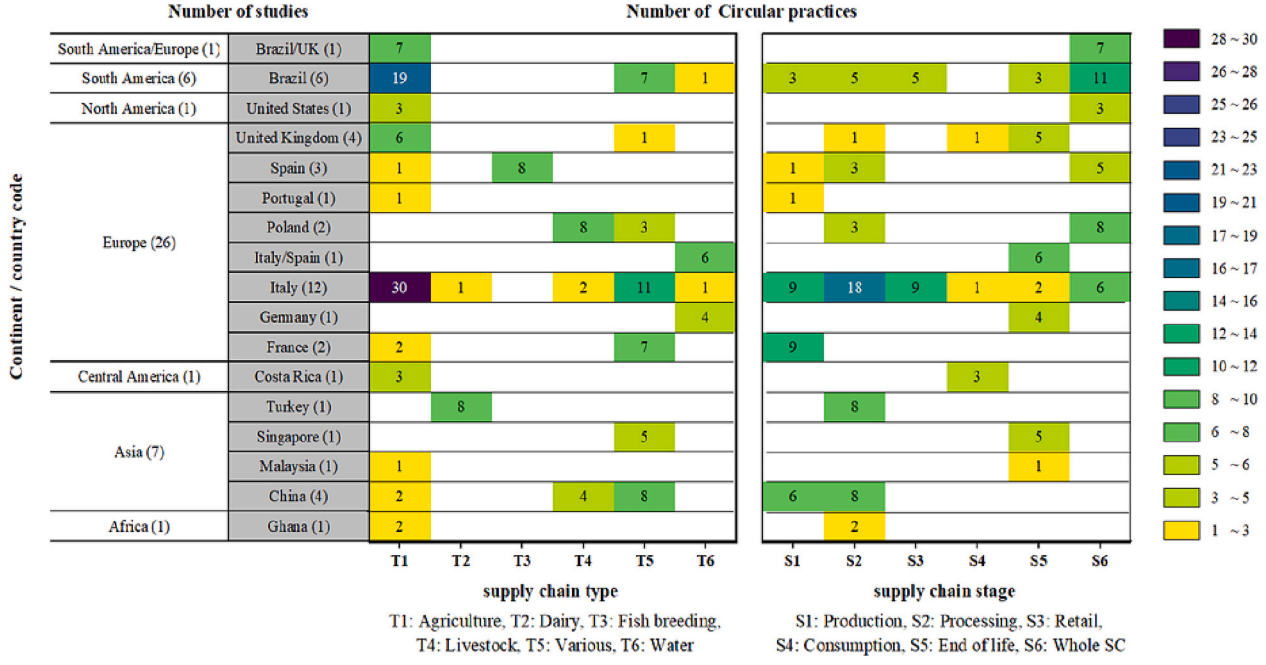

Fig. 3. Relations between the number of studies per geographical setting at the country and continent level (vertical axis) and the number of practices per supply chain type and stage (horizontal axis).

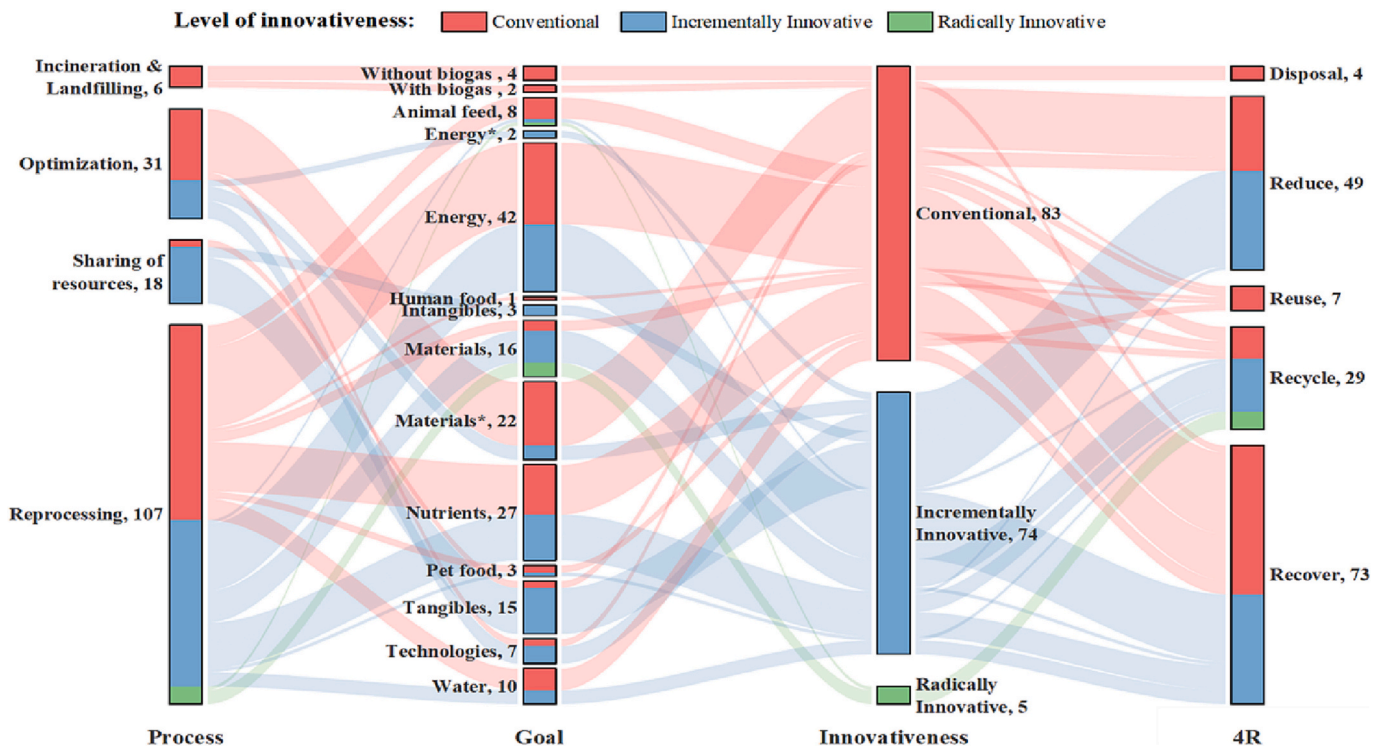

Fig. 4. Relations among process, goal and circularity with the level of innovativeness.

Resource sharing describes 11% of the total sample and is explored by 6 articles. Sharing practices are common at the agricultural level (78% of the category) and usually are considered in studies that analyse the whole supply chain (72%). Finally, incineration and landfilling characterize only 3.5% of the sample and 3 articles. The category considers both biogas recovery and not recovery. The latter represents the most common in the sample, but the least preferable option given the emissions connected.

3.3.2. *Innovativeness of the practices*

Conventional practices cover 51% of the sample. The category involves reprocessing processes (66%) directed to the production of energy (42%) or nutrients (25%). Relevant is the presence of optimization processes in the category, which represent 24% of the conventional practices, almost entirely directed to the valorization of materials (90%). These practices are linked to a wide variety of activities in terms of R framework; 51% of the subsample is related to recovery strategies, 25% to reduce strategies, 11% to recycle strategies and the remaining 8 and 5% to reuse and disposal strategies. In detail, 95% of recovery practices are related to reprocessing options. In comparison, the remaining 5% to incineration and landfilling, 95% of reduce strategies are linked to optimization processes, recycle strategies are full described by reprocessing operations, finally reuse strategies are linked to reprocessing (85%), while disposal options are all directed to incineration and landfilling. On the other side, incrementally innovative practices represent 46% of the sample. The practices entail 63% of reprocessing processes, directed to the production of energy (40%), nutrients (28%) or materials (19%). Sharing practices represent 22% of the subsample and are directed almost entirely to sharing tangible resources (81%); the remaining ones are related to intangible resources. Optimization practices represent another interesting portion of the sample (15%), directly linked to technological and material optimization in 45 and 36% of the cases. Analyzing the nature of innovation, technological innovations characterize 72% of the category, while socio-organizational one represents a still limited 22%. The remaining 6% of practices can be described as a mix of technological and organizational innovation. Regarding 4Rs, incrementally innovative practices are connected to recover strategies for 42%, reduce strategies for 38% and recycle ones for 20%. Specifically, recover and recycle strategies are associated entirely with reprocessing operations, while reduce ones are associated with sharing (57%) and optimization (40%) options. Radical innovation practices characterize 3% of the sample. These practices are entirely reprocessed into materials, and considering the nature of innovation, they pursue only technological innovation. Moreover, radically innovative practices are associated with recycling strategies.

3.4. *Sustainable narratives*

This section includes the results of the content analysis performed on CE, IS and sustainability following the measuring units chosen, summarised in Fig. 5 per number of studies and Fig. 6 per number of practices. This enables the articles 'classification according to their level of understanding of the sustainable narratives mentioned (Section 2.1), capturing how they are described and embodied and the possible links between them.

3.4.1. *Circular economy*

As evidenced by Fig. 5, most sample studies contextualize CE (51%) by adopting a definition or recalling its core principles. Different definitions of CE have been encountered in the sample, like the one provided by Kirchherr et al. (2017) or the one provided by Korhonen et al. (2018). These studies were settled mainly in the agricultural field; significant also is the number of studies dealing with fish breeding. 75 circular practices were connected to contextualizing papers, 43% of them follow recovery strategies, 27% reduce, and 17% recycle operations. The remaining 8% and 4% were linked to reuse and disposal options. Nevertheless, 37.5% of the studies did not characterize the concept, e.g., limiting to mention of it among the keywords or the abstract. These studies were settled in different supply chains, where the agricultural one is the most relevant. 55 practices were associated with these studies, of which 53% are classified as recovery strategies and 29% to reduce ones. The remaining studies (11.5%) combine circularity with other

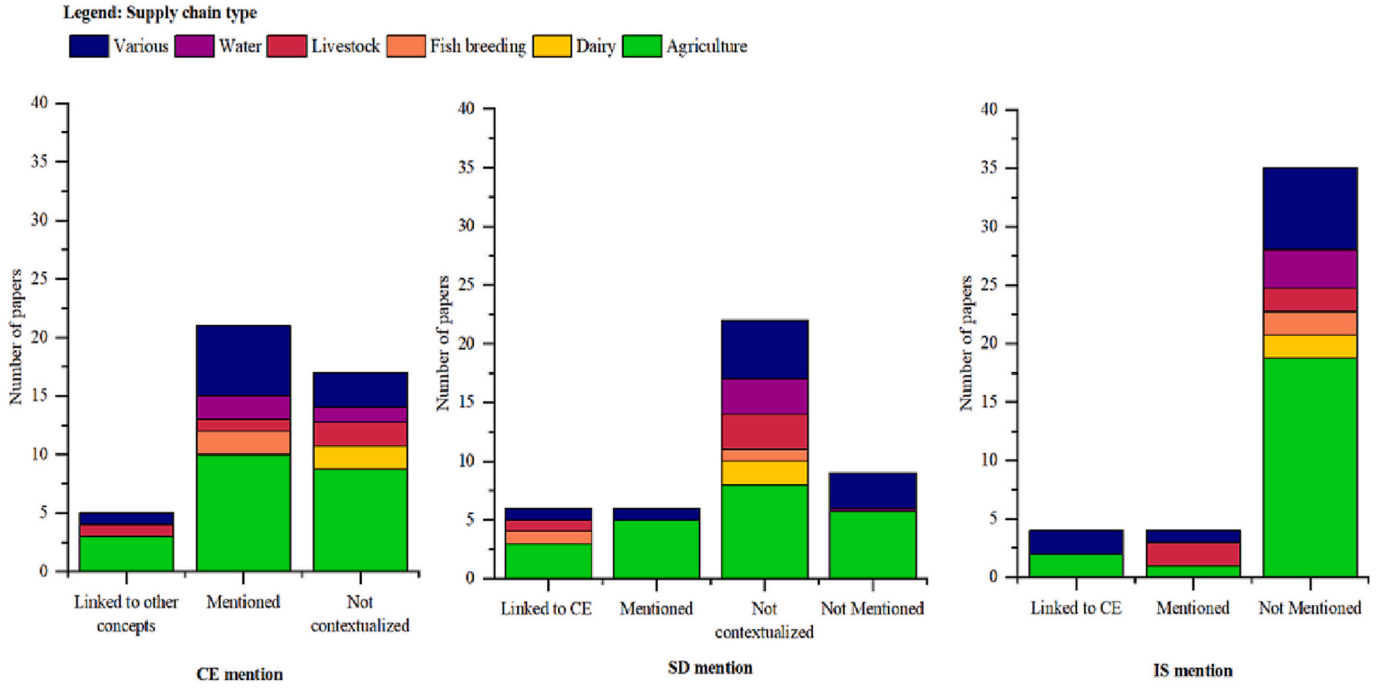

Fig. 5. Level of conceptualization of Circular economy (CE), Sustainable development (SD) and Industrial symbiosis (IS) per number of papers and supply chain type.

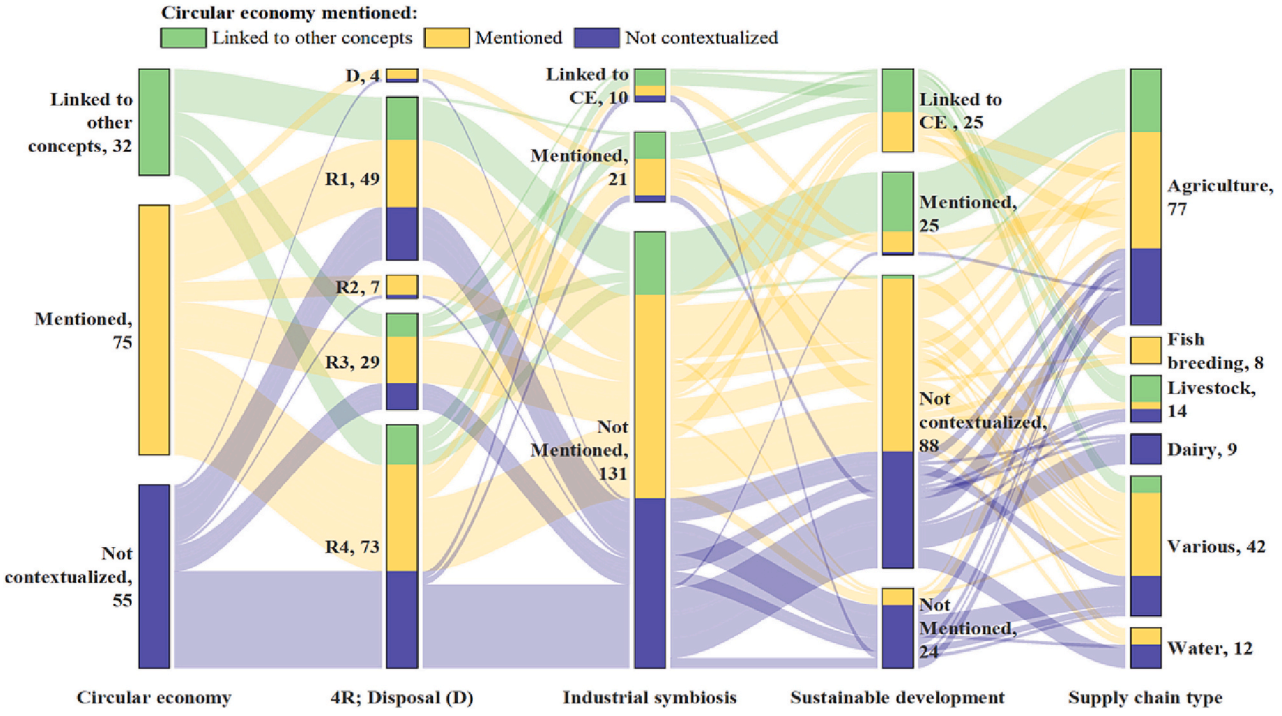

Fig. 6. Content analysis: Level of conceptualization of CE, IS, SD per number of practices per supply chain type and R framework.

sustainable narratives, emphasizing the similarities and connections. Ultimately, the link with the circular bioeconomy was evaluated by 2 articles. The link with the sharing economy is analyzed only by 1 study. In the end, the link with industrial ecology was addressed by 1 contribution. Such studies were settled only in the agricultural and livestock supply chain and in the residual category. They were associated with 32 practices, of which 40% are related to reducing strategies, while 37.5% are to recovery ones.

3.4.2. Industrial symbiosis

The analysis revealed that 9% of the articles directly mentioned the term “industrial symbiosis”. In detail, 21 practices were identified,62% of them were classified as recover, 19% as recycling and the remaining 14% and 5% are disposal and reducing operations. These studies were associated with the agricultural, livestock and various supply chain. Another 9% linked IS to CE. In this case,10 practices were identified, 90% were recovered, and the remaining 10% were recycling strategies. Such studies were settled in the agricultural supply chain and various

categories. The remaining 82% of the studies did not include IS. In conclusion, 131 practices were identified among the studies that do not mention IS. In this case, 39% were recovering strategies, 37% were reducing, 18% were recycling, 5% were reusing and 1% were disposal ones. Here the agricultural supply chain prevailed as the setting of the studies.

3.4.3. Sustainable development

The analysis based on SD's link indicates that most articles of the sample mention the concept of sustainability without contextualizing it (51%), namely, without mentioning its principles or giving a definition of it. In this case, 88 practices were detected; 50% is connected to recovery options, 25% to reducing ones, 14% to recycling ones, and the remaining 7% and 5% to reusing and disposing. These studies showed applications in every supply chain type categorized. Besides that, another 21% of the sample did not mention the concept at all. These studies were associated with 24 practices. 46% of such practices were reducing operations, 33% recovering and 21% recycling ones. Here, the study setting was divided into the agricultural supply chain and the various category. The remaining studies linked sustainability to CE (14%) or mentioned the concept, contextualizing it (14%). 25 practices were identified for studies that link SD to CE; in this case, 48% is made of recover strategies, 32% by recycling operations and the remaining 16% and 4% by reduce and reuse operations. These studies were mainly settled in the agricultural supply chain. Whether studies that mention SD were associated with 25 practices, 48% pursue reduce strategies, 36% recover and the remaining 16% recycle. These studies were settled almost entirely in the agricultural supply chain.

In terms of pillars, there is a clear dominance of the environmental one. Considering those studies that mentioned or linked SD to CE, this dimension is present in all 12 studies alone (75%) or combined with other perspectives (25%). Indeed, the environmental pillar is combined with the economic dimension in 17% of studies. The less explored remains the social pillar, directly mentioned only by 1 study, which mentions all three pillars (Kowalski and Makara, 2021).

4. Discussion

The analysis showed a growing number of peer-reviewed articles on the topic. Such increase is easily explained by the numerous international measures implemented to foster circularity, such as the European Green Deal (European Commission, 2020), and, specifically, the Farm to Fork strategy (European Commission, 2020). The analysis emphasized the high level of fragmentation in the field, already been pointed out by Masi et al. (2017) and Esposito et al. (2020). Interestingly, this has gained the attention of journals with wide areas of research interest. The main area of research is linked to the environmental dimension, but there is a consistent presence of the economic dimensions, as well as areas, although limited, linked to the social sciences. This signals the progressive multidisciplinary nature of CE in the AFS. Thus, the bibliometric analysis has highlighted academia's increasing interest in applying CE to the AFS.

On the same line, the context analysis showed that the interest in the topic has spread geographically. The leading role of Europe confirms the relevance of the European Action plan (European Commission, 2015) in boosting attention on this topic. The key role of Italy could be explained by the numerous policy interventions adopted for circularity, e.g., law 211, adopted in 2015, which aims to contain excessive natural resource use (Ghisellini and Ulgiati, 2020). Nevertheless, new actors emerged from the analysis. Relevant is the role of Brazil in South America. The country has indeed introduced several initiatives for the sustainability of the AFS; for example, the Low-Carbon Agriculture Plan, launched in 2010, provides financial support to farmers who want to introduce sustainable agriculture techniques (Neate, 2013). Moreover, the interest of Asian countries remains; China, was the first to introduce CE at a policy level, but new Asian actors, namely Malaysia, Singapore, and Turkey, showed interest in the topic.

Moving to the supply chain, the agriculture sector is the most involved in CE's initiatives. Circularity is not new in the sector. For a long time, agriculture has been closing the loop of resources, e.g., using animal waste as organic crop fertilizer (Barros et al., 2020). On the contrary, a lack of contribution is reported on the consumption and retail stage. The lack of the first could be explained by the research query of the study, which is focused on the organizational level and does not directly address consumers. The latter's lack is in line with previous literature (Esposito et al., 2020). Nevertheless, interesting insights come out of the analysis. The retail stage could ensure the quality and safety of perishable food products, also reducing the environmental impact of transportation (Kazancoglu et al., 2021). As highlighted by the sample, management operations and store suppliers are critical to reducing waste. In this sense, technological innovations could be adopted to guide store suppliers according to sales forecasts and perishability information. For example, cameras and odour sensors could be employed in supermarkets to collect information and used to predict the deterioration of food products (De Souza et al., 2021). Thus, more studies are needed in retailing stage for the AFS and technology could play a key role in their implementation.

Despite the increased interest in the topic, the lack of a common classification for food streams limits the possibility to develop regulatory measures to exploit food circularity potential (Teigiserova et al., 2020). Classifying processes and practices of the sector is crucial to understanding which strategies could promote the reuse or transformation of food in a sustainable sense. In this case, the classification process and analysis enabled the assessment of sector's maturity in terms of circularity, given the high presence of conventional practices. In detail, a table containing the description of the whole set of CE practices is available in the supplementary material. Circularity is a stable presence in the sector, but its level is still low according to the Rs framework; indeed, conventional practices mainly adopt recovery strategies, especially to produce energy. Nevertheless, a significant portion of such practices employs reduction strategies. According to CE principles, reducing, reusing, or recycling operations should be preferred to recovery ones, to retain the highest value of resources as long as possible (Korhonen et al., 2018). Thus, reducing strategies should be promoted in the sector. An example is the use of manure or crop residues to obtain organic fertilizer, avoiding damage to the soil and the underwater (Kowalski and Makara, 2021; Fernandez-Mena et al., 2020; Novara et al., 2022). Other examples are the use of dripping irrigation and nozzle spray to reduce irrigation water (Novara et al., 2022; de Vasconcelos et al., 2021). Relevant is also food donation; nevertheless, the portion of food redistributed is still limited due to a lack of data regarding food quantity and quality (Amicarelli et al., 2021).

Incrementally innovative practices play another relevant role in the sector's maturity and circularity. Recovery processes are still the most common but reuse operations are considerable. Recovery strategies are dominated by reprocessing processes, directed to energy nutrient and material purposes. While reuse strategies are pursued by optimization and sharing processes. Sharing options have a high potential, especially in rural contexts. It promotes efficient use of resources and interactions between individuals, empowering communities (Rodrigues et al., 2021). Common examples are the exchange of agricultural inputs (Maass and Grundmann, 2016; Fernandez-Mena et al., 2020) or food donation (Rodrigues et al., 2021; de Vasconcelos et al., 2021). In this context, the presence of both technological and socio-organizational innovation is needed. So far, solely the technological dimension has been pursued, leaving small room for socio-organizational change (Potting et al., 2017). The same tendency was encountered in the AFS, where socio-organizational innovations are mainly represented by sharing practices. Nevertheless, the AFS plays a cultural and not solely a nutritional role; thus, it is relevant to support technical change with socio-organization to allow circularity to take root in society.

Lastly, a limited number of practices were classified as radically

innovative. According to the literature indeed, innovation in CE involves improvements to existing processes (Homrich et al., 2018). Here, the technological dimension of innovation was favoured, excluding the socio-organizational one. Moreover, all the practices of the subsample are connected to recycling strategies to obtain renewed materials, showing a medium level of circularity. A representative example is given by the first citrus fabric in the world that obtains acetate and silk from citrus waste (Boccia et al., 2021).

Thus, the presence of many conventional practices indicates that CE is already part of the AFS. As the analysis pointed out, rediscovering conventional practices is urgent to improve the integrity and resilience of the geosystems. It is urgent, though, to match such knowledge with incrementally innovative techniques, which showed already a good level of circularity. Enriching conventional practices with technological and socio-organizational innovations following the R framework will allow the sector to exploit the full circularity (Potting et al., 2017).

To promote circularity in the sector is crucial to assess its level of awareness regarding CE. For this reason, content analysis was adopted. It allowed to track the level of conceptualization of CE and the link with other narratives. The analysis evidenced a good level of contextualization, considering that the review analyzed empirical case studies, where the theoretical part is usually limited. Moreover, a small but significant portion of the articles explored the relations between CE and other sustainable constructs (i.e., bioeconomy, industrial ecology, sharing economy), emphasizing the evolutionary nature of CE. Contextualizing and non-contextualizing studies favour recovery strategies, while those studies that stress the evolutionary conception of CE entail more reducing strategies, which entail a higher level of circularity. Nevertheless, the study considers only peer-reviewed contributions; thus, this result is limited to the academic field. Overall, CE is presented as an evolving social construct built upon sedimented layers of different constructs, all contributing to the sustainability agenda (Zucchella and Previtali, 2019). In this sense, some studies have linked CE to IS. Despite a limited number of studies did so, it is still an interesting result, given that IS was not present in the research keywords. Such articles embody a wider perspective, defining case studies involving more than one process. The studies that mention IS emphasize the systemic perspective of CE, namely the capacity to give results on different levels of SD. However, the lack of an environmental organizational perspective limits the possibility of exploiting the synergies of IS in a circular sense. According to some authors (Zucchella and Previtali, 2019) the presence of an "intermediary" is crucial to create a network of stakeholders and, operating from the inside, guiding them towards sustainable business models. Thus, an organizational perspective would improve the presence of IS in the sector.

Finally, the link with SD is mentioned but rarely contextualized. It is perceived in the sample as a long-term goal of circularity, but too wide and vague in the short term, even though a well-known definition of SD exists (Baratsas et al., 2021). One possible explanation for the low contextualization could be the empirical nature of the studies analyzed. Moreover, most of the studies address solely the environmental pillar of SD. Only a few studies combine the environmental pillar with the economic one and no one analyses in detail the social perspective. Examples of practices with positive social implications are donating surplus food to charity (Principato et al., 2019), or promoting occupation (Kowalski and Makara, 2021). The study highlighted the underestimation of the social pillar, already pointed out by the literature (Murray et al., 2017; Ghisellini et al., 2016). Such lack in the sample seems not linked to the methodology adopted by the studies, the only article which directly address the pillar used a quali-quantitative approach, while those who present socially relevant practices show a qualitative or a quantitative nature with no significant trend. On the contrary, the AFS should involve social communities in the transition by promoting bottom-up initiatives that raise awareness over sustainability discourse and stimulate their engagement in circular actions.

5. Conclusions

The present study aimed to provide a systematic and bibliometric analysis of the CE practices in the AFS at the micro and *meso* level. It investigated the context of such practices and prosed a classification to analyse the sector's maturity and circularity. In addition, the awareness of the sector regarding CE and its relations with IS and SD was assessed. The analysis identified 43 scientific articles allowing the collection of 162 practices.

Research interest in CE's is growing and spreading. The sector's maturity has been assessed due to the large presence of conventional practices but with a low level of circularity. On the contrary, incrementally innovative practices show higher levels of circularity. Therefore, it is crucial to couple conventional knowledge with innovative techniques both in technological and socio-organizational terms. The sector already proved its awareness regarding CE. On the contrary, the links with IS are not fully exploited, while SD is considered the long-term objective of CE but is still a vague concept. Especially its social side is underestimated in the sector. This research enables to capture the characteristics of circularity in the AFS and reporting examples of best practices. This allows us to guide practitioners interested in applying CE in the sector and academics to identify possible improvements.

However, some limitations are present; for example, regarding the research methods adopted, which may have excluded some potentially relevant studies. Moreover, the relevant presence of conventional practices was considered a proxy of the sector's maturity; nevertheless, it may also be due to its minor structural elasticity to innovation and this aspect could inspire future research. Thus, future research is planned to guide companies of the AFS towards circularity, understanding how they assess circularity and sustainability by providing a selected case study analysis. Further future investigation should also integrate the macro scale into the analysis, exploring the circular practices implemented at city, region or country scales in the sector.

Finally, it is hoped that the present SLR can advise future research, contributing to the diffusion of CE practices in the AFS. Relevant lacks have been identified in this study, namely the limited role played by incremental innovativeness and the lack of social perspective. To promote social sensibility, the sector should boost community engagement through sensibilization campaigns or incentives to stimulate circular and sustainable actions. This would guide, on the one hand, communities towards awareness and smart initiatives and, on the other, the policymakers in designing their policy interventions on communities' ideas and needs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eiar.2023.107079.

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