Towards Circular Economy in the Agri-Food Sector. A Systematic Literature Review

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Abstract: Over the last decade, the unsustainability of the current economic model, based on the so-called take-make-dispose paradigm, has emerged. In particular, the agro-food sector (AFS) has been severely affected by such problems as resource scarcity and food loss and waste generation along the supply chain. In addition, climate change and biodiversity loss have helped to define an imperative paradigm shift towards a circular economy. Recently, with the publication of Sustainable Development Goals (SDGs), the scientific research examining the adoption of circular economy (CE) models and tools has increased. In this context, the importance of shifting towards a circular economy has become urgent. In this paper, a systematic literature review (SLR) was performed to investigate the state-of-the-art research related to the adoption of circular economy models and tools along the agro-food supply chain. Furthermore, this review highlights that, due to the complexity of the agri-food supply chain, it is almost utopian to define a unique circular economy model for the whole sector. In addition, it emerges that future researches should be concentrated on the integration of different stages of the supply chain with circular economy models and tools in order to create a closed-loop agri-food system.

Keywords: sustainability; circular economy; LCA; agro-food supply chain; food waste

1. Introduction

In recent decades, the current economic model based on the take-make-dispose paradigm [1] has been widely criticized for its unsustainability. Due to the over-exploitation of resources [2] and degradation of the environment [3], this model is seen as exerting negative effects on the equilibrium of the ecosystem.

In particular, the agro-food sector (AFS) has been severely affected by problems such as resource scarcity, food loss and waste generation along the world's supply chain, which, in 2019, totalled approximately 1.3 billion tons annually with a cost of more than 1000 billion dollars per year [4]. The mismanagement of resources and processes represents only one of the causes of such problems [5]. Moreover, consumers' unsustainable consumption patterns have contributed significantly to these problems [6].

Over the past few years, the agro-food system has been paying close attention to cross-cutting issues such as food safety, production traceability, product quality, respect for the environment and human resources. Thus, the production systems have begun to move towards sustainable approaches [7]. The growing attention paid by policy makers, non-governmental organizations and scholars has prompted agri-food companies to incorporate sustainability into their corporate strategies.

In this context, objectives such as the reduction of waste and loss, conservation of natural capital, biodiversity and eco-systemic services, reduction of land use and improvement of soil quality are fundamental for the realization of the so-called "decoupling". The latter is aimed at dissociating

environmental degradation from economic development, thus considering the protection of natural resources and the protection of human health as essential aspects of economic development itself.

It is clear that, in order to achieve these objectives, the sector must be able to involve, in addition to primary producers (often the weakest link in the supply chain, as shown by the value chain), numerous categories of stakeholders, such as customers and consumers, investors, public decision makers, the process and transformation industry and distributors [6,7].

Accordingly, a need to radically redesign the traditional linear economic path of production and consumption emerges [8]. In this scenario, the circular economy (CE) is emerging as a possible strategy which is able to overcome these critical issues.

Hence, adopting CE models and tools in the AFS is imperative for overcoming the problems of food waste and food loss and to reach sustainable development goals. In this perspective, the Life Cycle Assessment (LCA) methodology represents the most used tool in order to assess "potential environmental impacts associated with all the stages of a product, process or service" [9].

Considering the increasing attention paid by academics and practitioners to the topic [10], there is a need to investigate how the research is analysing the CE applied to the AFS for loss and waste management in a closed-loop perspective.

Furthermore, considering the lack of systematization of the knowledge about this issue, this study reviews the literature to offer an overview of the state-of-the-art research and to provide guidelines for future studies on this topic.

Two research questions have guided this paper. The first question attempts to provide a descriptive framework of the existing literature on the CE applied to the agri-food supply chain, highlighting the main trends in this research field. The second question aims to facilitate future research streams in a changing socio-economic context. To answer those questions, a systematic literature review (SLR) has been performed by analysing 87 articles following the literature review methodology developed by Denyer and Tranfield [11].

This paper provides a critical review of the existing literature published on the Scopus and Science Direct and Web of Science databases to answer the following research questions (RQ):

RQ1: How does the research analyse the CE as applied to the AFS?
RQ2: What are the possible scenarios and lines of future research?

The paper is structured in four sections. The first section after the introduction defines the literature review methodology that is adopted. In the second section, the results are presented through a descriptive analysis. The third section provides a thematic overview of the analysed articles, highlighting the main categories and trends in literature, while the fourth section aims to identify and outline future research directions.

2. Materials and Methods

Following the previous studies dealing with the SLR methodology [3,11–13], this paper has been developed through the five-step process (Figure 1) theorized by Denyer and Tranfield. Different from a narrative literature review characterized by a subjective and narrative approach to interpreting previous contributions [14], an SLR needs to follow a rigorous methodology to avoid the weaknesses of a narrative style and to provide a valid and structured contribution.
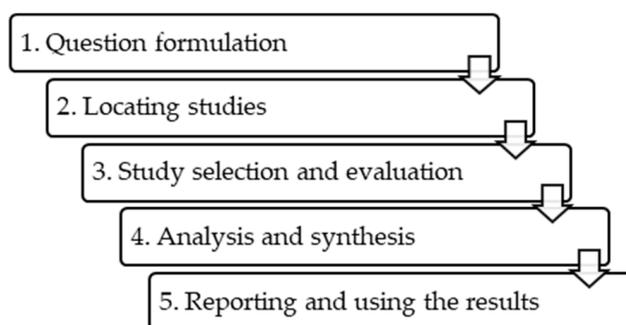
Figure 1. Systematic Literature Methodology. Adapted from Masi et al., 2017 [12] and Denyer and Tranfield, 2009 [11].

2.1. Locating Studies

In accordance with previous studies dealing with SLR, to answer the research questions highlighted in the first step, two databases were selected, as follows: "Web of Science" and "Scopus". In order to strengthen the search process, "Science Direct" database was also used. The keywords were chosen in accordance with the CE definition provided by Sauvè et al., according to which CE refers to "production and consumption of goods through a material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste in each step of the life cycle of the product" [15]. Given the similarity with the LCA for the identification of CE models, the research was based on the following keywords: "Circular Economy", "Agro-food sector", "Life Cycle Assessment" and "Food waste". The search strings aim at retrieving contributions in which the AFS is analysed in combination with one of the other issues. Table 1 provides the different query structures for each database. The research was performed on 10 April 2020 with no time restriction. However, books, book chapters, theses, conference papers, editorials, reports and other types of contributions were rejected, and only scientific articles written in English were included. The rationale for this is the need to provide a high-quality research. After the first screening, the resulting number of papers was 596 (Scopus), 191 (Science Direct) and 28 (Web of Science), for a total of 815 articles.

Table 1. Search strings used in SCOPUS, SCIENCE DIRECT and WEB OF SCIENCE database.

Database	Search String	Application
SCOPUS	ALL ("Agro-food sector" AND ("Circular Economy" OR "Life Cycle Assessment" OR "Food waste"))	The search fields were Title, Abstract and Keywords. The database retrieved 596 articles.
WEB OF SCIENCE	(Agro-food AND ("Circular Economy" OR "Life Cycle Assessment" OR "Food waste"))	The search was made in all field. The database retrieved 28 articles.
SCIENCE DIRECT	("Agro-food sector" AND ("Circular economy" OR "Life cycle assessment" OR "Food waste"))	The search fields were Title, Abstract and Keywords. The database retrieved 191 articles.

Table adapted from Masi et al., 2017 [12].

2.2. Study Selection and Evaluation

Starting from the 815 articles retrieved from the first screening in the Scopus, Science Direct and Web of Science databases, a rigorous selection process was followed, which was structured in five steps. The research field had no restrictions. However, the analysis was mainly focused on contributions concerning social science. After removing 120 duplicates, the title and abstract of each paper were inspected to eliminate contributions unsuitable for the analysis. Subsequently, a full text screening was performed to exclude papers not committed to the research goals previously highlighted. With the aim

of conducting the analysis with methodological rigor and to assess the relevance of the contributions, a number of inclusion and exclusion criteria were formulated [16]. The developed inclusion criteria are as follows:

- Conceptual studies based on CE applied to AFS;
- Conceptual and empirical studies that explore the use of life cycle assessment in AFS or provide a Life Cycle Assessment (LCA), Social Life Cycle Assessment (S-LCA) or Life Cycle Costing (LCC) analysis on a food product aimed at studying the development of the CE in the AFS;
- Conceptual and empirical studies that analyse problems of food waste and food loss during the whole agro-food supply chain.

The exclusion criteria used to reject contributions that are inconsistent with research questions are as follows:

- Empirical studies on the CE concerning chemistry, biology and biotechnology focusing more on the nutritional and organoleptic characteristics of food and not aimed at the research objectives;
- Conceptual and empirical studies that exclusively analyse the environmental impact of a food production system.

From this analytical process, 87 relevant articles were identified, which composed the final sample of reviewed articles, as described in Table 2.

Table 2. Database development with resulting number of articles.

Sample	Number of Articles
1. Articles from search strings in database (WoS 375 + SC 596 + SD191)	815
2. Duplicated articles removed	−120
3. Contributions concerning other fields (title and abstract screening)	−230
4. Contributions not committed to the purpose of the paper (full text screening)	−230
Final sample	*87*

Table adapted from the methodology used by Manes Rossi et al., 2020 [17].

2.3. Analysis and Synthesis

All the contributions selected were analysed from a descriptive and thematic perspective. The coding process was performed before going through the papers. The descriptive analysis was based on the categorization of the papers per journal and per year. The analytical framework adopted in this SLR is based on frameworks previously developed by Manes Rossi et al. [17] and Bisogno et al. [13]. However, some adjustments have been made to obtain a framework coherent with the peculiarities of this review.

The framework consists of five categories, namely:

A.   Country of Research,
B.   Research Methods,
C.   Scientific Field,
D.   Focus on Tools Implemented,
E.   Focus on Type of SC and
F.   SC Stage.

The A "Country of research" category includes the following six sub-categories: A1 Europe/UK, A2 North America, A3 South America, A4 Oceania, A5 Asia and A6 Africa. The B "Research Methods" category, inspired by Bisogno et al. [13] and Manes Rossi et al. [17], consists of the following four sub-sections: B1 Case/Field Study/Interviews, B2 Survey/Questionnaire/Other empirical, B3 Commentary/Normative/Policy and B4 Literature review. Considering the fragmentation of the CE

studies across various disciplines [18], the category C "Scientific field" has also been included in the analytical framework adopted to assess the different approaches used by scholars. As this systematic literature review is based on the circular economy applied to the AFS, it seemed appropriate to introduce the category D "Focus on tools implemented" to highlight the most widely adopted CE instrument in the AFS. This category identifies the following tools: D1 Life Cycle Assessment (LCA); D2 Social Life Cycle Assessment (S-LCA); D3 Environmental Life Cycle Assessment (E-LCA); D4 Water Footprint Assessment (WFA) and D5 Combined tools (including papers that provide contributions through the combined use of LCA with other tools, i.e., life cycle costing, life cycle carbon footprint, food-waste-energy nexus, life cycle energy assessment, Strengths, Weaknesses, Opportunities, and Threats (SWOT) and Threats, Opportunities, Weaknesses and Strengths (TOWS)analysis, life cycle inventory and externality assessment (ExA)); D6 Others (including technological tools used to convert food waste, by-products and co-products into resources able to be reintegrated in a new production process, i.e., rainwater harvesting tools, pelletization, the Cornell Net Carbohydrate and Protein System, hot air drying or freeze-drying, solvent-based extraction and pressurized liquid extraction) and D7 None (to which belong scientific contributions that do not provide an on-field analysis and therefore do not analyse the CE through the implementation of an enabling tool). In addition, as a review focused on agro-food SCs from a sustainable management perspective, the categories E "Focus on type of SC" and F "SC Stage" have been proposed to analyse the value cogeneration dynamics in a circular intra-chain and inter-chain approach.

All the results obtained following the analytical process previously described have been reported both descriptively and thematically, providing a comprehensive depiction of the state-of-the-art research regarding the CE in the AFS and subsequently identifying possible development perspectives.

3. Descriptive Analysis

To analyse the development of the research in the CE field applied to the agro-food sector and to understand the trends in the scientific field, the 87 articles identified are presented, including the publication years, journals, citations, citations per year and analytical framework adopted.

Figure 2 shows the distribution of the articles from 2006 to 2020. It seems necessary to highlight that the search process has been conducted without a time restriction. The first contributing work selected was published in 2006, as until 2006, the AFS was mainly explored through the use of previously evolved concepts, such as the closed-loop system [19], industrial ecosystem [20], industrial ecology [21], industrial metabolism [22], industrial symbiosis [23] and cradle-to-cradle design [18,24,25]. These concepts subsequently led to the development of CE, which has particularly affected scientific research since 2015. Indeed, from 2015 to 2020, a growing trend emerges. Indeed, 2015 represents a turning point for scientific research due to the publication by the United Nations of the Sustainable Development Goals Agenda 2030, which has motivated a growing number of scholars to investigate possible guidelines to achieve them in different sectors. Furthermore, the literature production significantly increased in 2018. In fact, the scientific production has also been stimulated by the European Regulation 353 (on the establishment of a framework to facilitate sustainable investments), which has indicated the need to support "the transformation of Europe's economy into a greener, more resilient and circular system" [26].
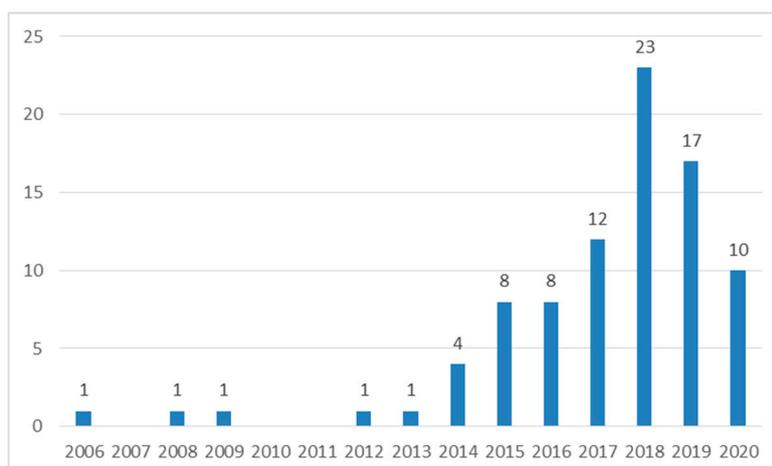
Figure 2. Number of articles per year. Table developed in accordance with the methodology used by Merli et al., 2018 [3].

The articles were published in scientific journals, as described in Table 3. The journals from which fewer than two articles were selected have been aggregated in "Others". The journal including the highest number of articles is *Sustainability* (SUST) followed by *Journal of Cleaner Production* (JCP). The range of topics covered by these journals allows the publishing of different scientific contributions from various scientific fields. This finding confirms a relevant fragmentation in the scientific literature, as already highlighted by Masi et al. [12], who also refer to the AFS. Finally, according to the analysis, the majority of journals published fewer than four articles.

Table 3. Number of articles per journal.

Code	Journal Name	No.
SUST	Sustainability	37
JCP	Journal of Cleaner Production	10
RCR	Resources, Conservation and Recycling	2
WT	Water	2
AGR	Agriculture	2
ENG	Energies	4
STE	Science of the Total Environment	3
NUT	Nutrients	2
FDS	Foods	3
RSC	Resources	2
OTH	Others	20
	Total	87

Table developed in accordance with the methodology used by Manes Rossi et al., 2020 [17].

The predominance of *Sustainability* over the other journals is evident from Figure 3, which represents the share of publications per year, identifying *Sustainability* compared to *Journal of Cleaner Production* and to all the other journals aggregated. In accordance with Merli et al. [3], the analysis shows that most of the journal have as main topics environmental issues. Thus, it suggests that scholars have mainly studied the CE as an approach to manage environmental aspects of the traditional "take-make-dispose" based production systems.
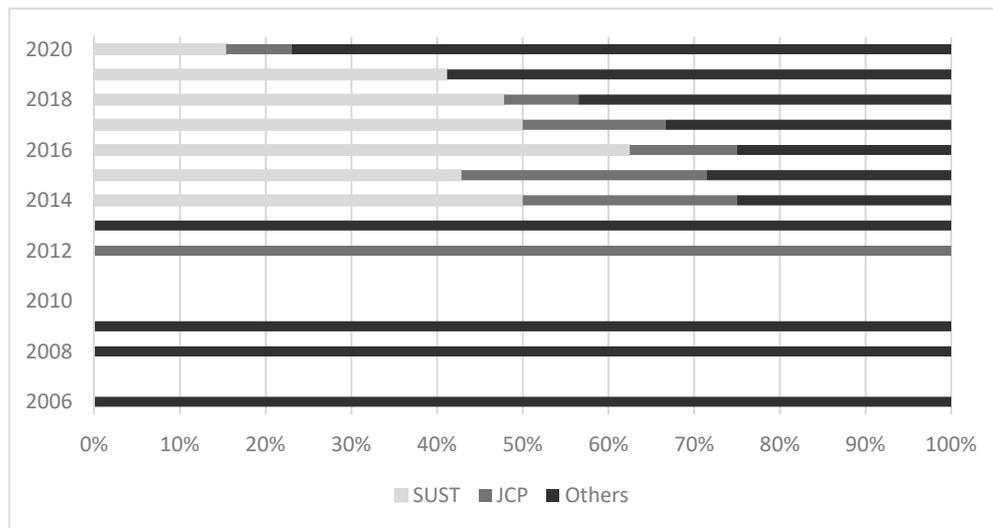
Figure 3. Share of publications per year. Table developed in accordance with the methodology used by Merli et al., 2018 [3].

4. Research on the Circular Economy Applied to the Agro-Food Sector: The State-of-the-Art Research

Table 4 shows the results derived from the coding activity of the 87 articles according to the analytical framework previously described.

Table 4. Analytical framework of Circular Economy applied in the agro-food sector (AFS).

A.	Country of Research	No.	%	B.	Research Methods	No.	%
A1	Europe/UK	27	80.00	B1	Case/Field study/Interviews	66	76.00
A2	North America	5	6.00	B2	Survey/Questionnaire/Other empirical	3	3.00
A3	South America	4	5.00	B3	Commentary/Normative/Policy	11	13.00
A4	Oceania	1	1.00	B4	Literature review	7	8.00
A5	Asia	5	6.00		Total	87	100
A6	Africa	2	2.00				
	Total	87	100				

C.	Scientific Field	No.	%	D.	Focus on Tools Implemented	No.	%
C1	Agricultural science	19	21.84	D1	LCA	33	37.93
C2	Biology/Chemistry	7	8.04	D2	S-LCA	3	3.45
C3	Environmental science	22	25.29	D3	E-LCA	2	2.30
C4	Economy/Management	34	39.08	D4	WFA	3	3.45
	Mixed fields	5	5.75	D5	Combined tools	14	16.10
	Total	87	100	D6	Others	15	17.24
				D7	None	17	19.54
					Total	87	100

E.	Focus on Type of SC	No.	%	F.	SC Stage	No.	%
E1	Agriculture	45	51.72	F1	Production	14	16.10
E2	Dairy	3	3.45	F2	Processing	25	28.73
E3	Livestock farming	11	12.65		Retail	1	1.15
E4	Fish breeding	5	5.75	F3	Consumption	4	4.60
E5	Various	23	26.43	F4	The whole SC	43	49.42
E6	Total	87	100	F5	Total	87	100

Table developed in accordance with the methodology used by Manes Rossi et al., 2020 [15] and Bisogno et al., 2018 [13].

4.1. Country of Research

The first category concerns the "Country of Research". It was determined based on the country where the research took place. For articles where this data is not available, the country of research is based on the authors' affiliation. It is clear that the greatest number of the articles are located in Europe and the UK, with an overall percentage of 80.45%, totalling 70 articles. This trend can be explained by the emphasis that the European Union has placed on the development and adoption of CE models in all sectors and the sustainable performance of food products and processes by a plethora of measures adopted (e.g., [27]). In particular, with the communication "Towards a circular economy: A zero waste program for Europe" [28] and the communication "Closing the loop—An EU action plan for the circular economy" [29], a great deal of attention has been paid to CE issues in European countries. In addition, the catalysing actions promoted by The Ellen McArthur Foundation (e.g., "The Circular Economy 100 (CE100) Network", "Cities and CE for Food "and "Make Fashion Circular") have stimulated European scholars in investigating the CE as "an industrial system that is restorative or regenerative by intention and design" [30]. Among European countries, Italy has provided a wider number of contributions, i.e., covering 36.78% of the analysed papers. This is justified by Italy's strategic positioning on the CE and due to the increasing regulatory focus (e.g., law 221, 28 December 2015; the document named "Towards a model of Circular economy for Italy" and other legislative decrees) on these aspects [31]. Although Asian countries, in particular China, are pioneers of the CE as a new model of sustainable development [8], only a limited contribution is detected from this country of research (5 articles, i.e., 6.00%). In particular, it seems that the recent regulatory policies (e.g., guidelines for eco-industrial parks, 11th and 12th five-year plans for National Economic and Social Development, "Circular Economy Promotion Law" [32]) about the adoption of the CE involving Asian countries did not stimulate significant research on this topic. However, among Asian states, China has paid particular attention to CE issues from a regulatory point of view. In fact, Yuan et al. [33] have shown that it has been one of the foundation strategies of the country in the 21st century. North America (5 articles, i.e., 6.00%), South America (4 articles, i.e., 5.00%), Africa (2 articles, i.e., 2.00%) and Oceania (1 article, i.e., 1.00%) have contributed fewer works than the other regions, as is shown in Figure 4.
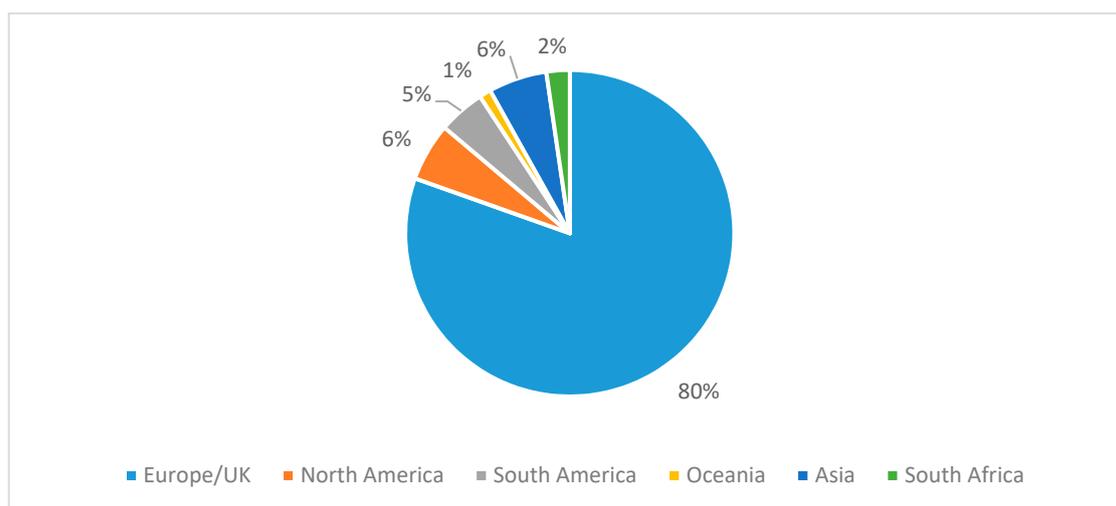

Figure 4. Distribution of literature published in the sample by country.

4.2. Research Methods

Concerning the category "Research Methods", Figure 5 shows the percentage of papers belonging to each sub-category with the aim of investigating the research methodologies adopted by scholars to evaluate the research trend in the journey from a linear economy approach to a CE one from a chain

perspective [34]. In this context, it is a priority for researchers to determine the most suitable route for the creation of sustainable and efficient agro-food systems [35]. Not surprisingly, case/field studies and interviews have been widely adopted to conduct an analysis of the individual SCs of the AFS (66 articles, i.e., 76.00%). In fact, most scientific contributions concerning CE are focused on the use of environmental, social and economic impact assessment tools (e.g., [36–40]). Instead, only three articles belong to "Survey/Questionnaire/Other empirical" (i.e., [41–43]). Critically assessing these data, an increased trend towards empirical research rather than conceptual research is demonstrated. The theoretical categories, which are discussions not supported by empirical evidence, include 18 papers from which 7 articles (i.e., 8.00%) are literature reviews, while 11 papers (i.e., 13.00%) are structured as commentary or normative/policy contributions. However, based on the assumption that CE has emerged from policy legislation rather than academics [44], theoretical articles can make a valuable contribution to critically analysing the paradigm transition required at the European and international levels. Thus, these contributions could enrich the academic debate and establish a foundation for future research.
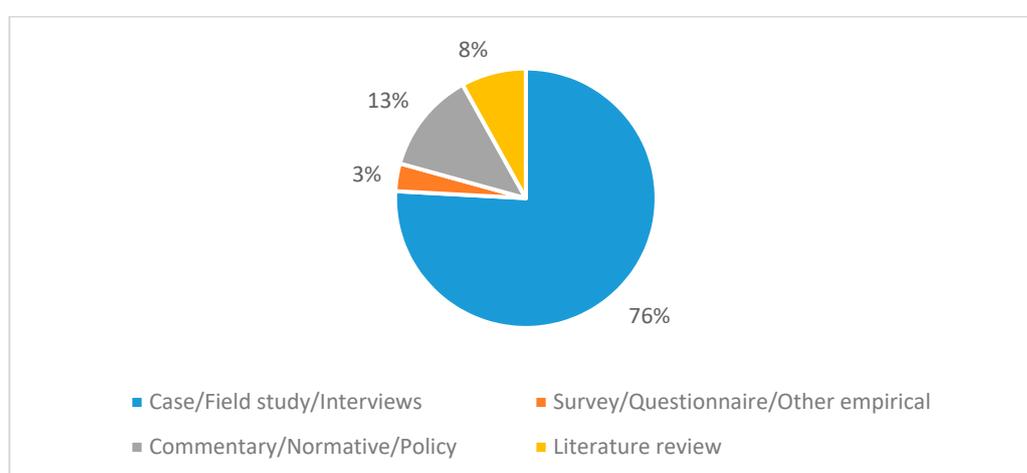

Figure 5. Research Methods.

4.3. Scientific Field

Analysing the international scientific literature, several approaches to CE emerge. These approaches are observed mainly due to the varied perspectives of analysis perspectives adopted by scholars of different disciplines [18]. However, each approach can be perfectly integrated with the others because of the need to address environmental challenges [15]. In this context, this goal can be achieved through important inter-disciplinary efforts [45]. For this reason, it has been decided to assess the scientific field of each paper (Figure 6). Among the 87 articles selected, 22 papers (i.e., 25.29%) analyse CE through an environmental sciences point of view. The articles coded as "mixed field" (5 articles, i.e., 5.75%) investigate the CE in the AFS through two or more scientific disciplines that work together to reveal and address the different issues of the same topic [15]. Nevertheless, it is important to stress that the environmental sciences concerning the CE could be considered a transversal analysis approach to all disciplines. Only a small number of articles (7 articles, i.e., 8.04%) belong to the category "Biology/Chemistry"; this result is entirely in line with one of the exclusion criteria defined in the selection process followed in this SLR. The majority of the articles (34 articles, i.e., 39.08%) discuss the adoption of CE from a managerial point of view, providing an environmental focus [3]. Considerable attention has also been dedicated to this topic by agricultural science, which provides 19 scientific articles (i.e., 25.29%).
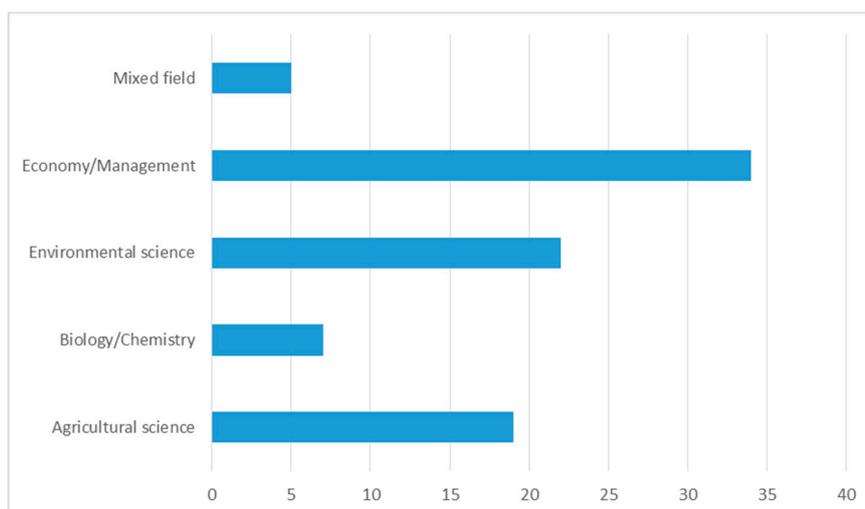
Figure 6. Scientific Field.

4.4. Focus on Tools Implemented

In relation to the fourth category "Focus on tools implemented", Figure 7 illustrates the distribution of 87 articles per tool.
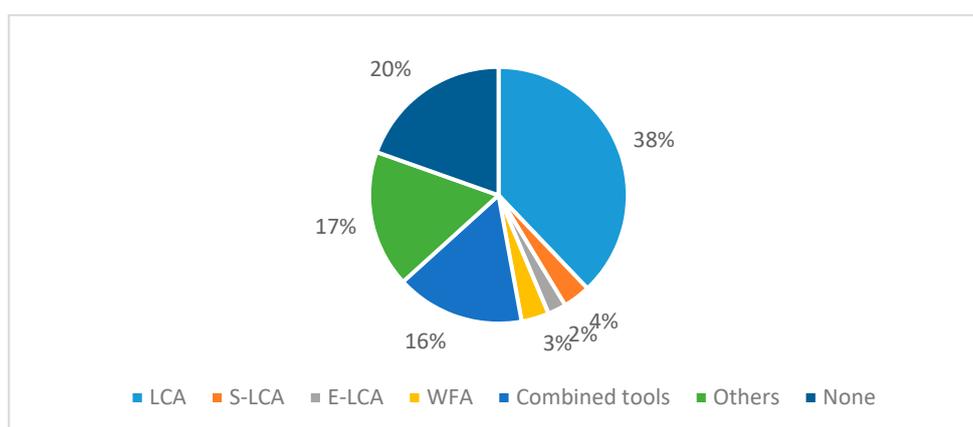

Figure 7. Tools implemented.

Life Cycle Assessment (LCA) is the most used tool (33 articles, i.e., 37.93%) and is based on an iterative process proposed by the international standard UNI EN ISO 14040:2006 (Principles and framework) and by UNI EN ISO 14044:2006 (Requirements and guidelines); it is composed of by four steps, i.e., goal and scope definition, inventory analysis, impact assessment and interpretation [46]. LCA is a versatile tool that can be used both (1) to assess environmental impacts to improve production or optimize resource management (e.g., water, energy, gas, etc.), (e.g., [47]) and (2) to support policy interventions by identifying drivers for reducing the environmental burden of agriculture and food systems [48,49]. This trend is justified by the common agreement that LCA is the tool that allows for better evaluation of the balance between efforts and benefits in implementing CE solutions at the micro level [50].

Nevertheless, LCA is only one of the assessment tools available. In fact, other instruments are taken into account in this analysis, i.e., S-LCA (3 articles, i.e., 3.45%), E-LCA (2 articles, i.e., 2.30%) and WFA (3 articles, i.e., 3.45%), although they are less often adopted. The articles in which LCA has been used in combination with other tools (i.e., Life Cycle Costing (LCC), Food Waste Energy Nexus, Life Cycle Environmental Assessment, SWOT, TOWS, Life Cycle Inventory and Externality

Assessment (ExA)) have been grouped under the category "Combined tools" (14 articles, i.e., 16.10%). The low number of contributions in which more circular economy tools are used in an integrated way highlights a gap in the literature. This suggests the need to investigate the strengths and weaknesses resulting from a combined approach to assessing impacts in a triple-bottom-line approach.

With the aim of providing a complete analysis of the sample, technological tools used to convert food waste, by-products and co-products into resources able to be reintegrated in a new production process were also considered (i.e., rainwater harvesting tools [51], pelletization [52], Cornell Net Carbohydrate and Protein System [53], hot air drying or freeze-drying [54], solvent-based extraction and pressurized liquid extraction [55]); these represented 17.24% of the total items (i.e., 15 articles). In such cases, these technologies are used in a micro and meso perspective. However, these studies "are often hampered by data discrepancies" [56]. This entails that, in order to optimize CE practices in a macro perspective, digital technologies tools (i.e., data-driven analysis and mathematical and computer optimization models) could also be integrated [57].

Last, it is worth noting that 17 articles (i.e., 19.54% of the sample) have not taken into account impact assessment tools, thereby providing only a theoretical contribution on the topics covered by the SLR. Instead, a large portion of the sampled articles (17 articles, i.e., 19.54%) did not use any CE tool to assess the social, economic and environmental impacts of a product but analysed the agro-food SC from a theoretical point of view. The analysis shows that, on one hand, although the adoption of combined instruments is not widespread, it can help to provide a wider assessment of the sector in a triple-bottom line approach. On the other hand, it shows a growing interest of research towards the assessment of the technological tools provided for food waste and loss treatments.

4.5. Focus on the Type of the Agro-Food Supply Chain

The analysis of the categories "Type of SC" and "Stage of SC" aims to highlight the agro-food SC that has been most explored by scholars and to point out the literature gap to provide useful insights for future research.

As Figure 8 shows, the sub-category "Agriculture" is the most analysed among the 87 reviewed articles, comprising 51.72% of the sample (i.e., 454 articles). This finding is observed because the agriculture SC is composed of a wide diversity of products [58]; thus, each SC configuration is differentiated according to the specific characteristics of the food. The most investigated items of this sub-category are wine (e.g., [38,50,59,60]) and olive oil (e.g., [47,61]). In the "Dairy" category, three articles (i.e., 3.45%) were detected (e.g., [62]). Concerning livestock farming, 11 scientific contributions were collected (i.e., 12.65%), focused on poultry [63,64], swine [65] and beef [66] sectors. In contrast, the "Fish breeding" category provided only a few contributions (5 articles, i.e., 5.75%). It is also worth noting that 23 articles (i.e., 26.43% of the sample) dealing with various SCs have combined agriculture with dairy, livestock farming or fish breeding to assess the entire AFS [27,67,68]. Among these, three articles analysed local food SCs [69,70]. In addition, part of the reviewed articles investigated the problem of food loss and waste [40,41,49,52,68,71] to assess the related environmental impacts. Among these, Mouron et al. [72] investigated how food loss management could reduce environmental impacts. Following this approach, as stated above, some scholars analysed different technologies for food waste treatment to use residues from animal feed [41,52,63] and biofertilizers [37,53,55,73] or to turn them into energy [74,75]. Last, only one article is focused on food redistribution [42].
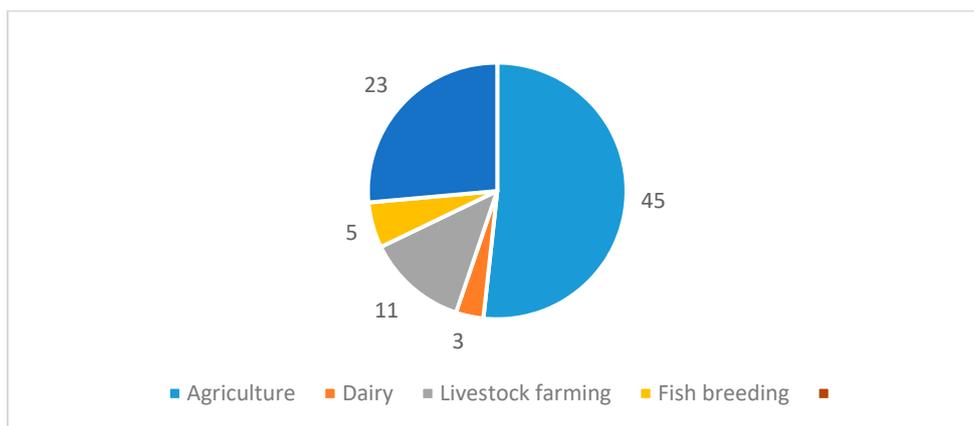
Figure 8. Type of Supply Chain.

4.6. Focus on the Stage of the Agro-Food Supply Chain

Although the dominant perspective considers that the ASC should be analysed in a "farm-to-fork" approach to assess the adaption of CE models and tools, some authors have focused their research on a specific stage of the SC. Adapting the classification previously developed by Yakovleva et al. [76], the analysis has been carried out in the following phases: production, processing, retail and consumption (Figure 9). Contributions that have analysed all the stages of the agro-food SC have been grouped in the category "The whole SC". Most of the selected articles have investigated the entire SC, with 43 contributions (i.e., 49.42%). Less attention is given to consumption (4 articles, i.e., 4.60%) analysed from the perspective of waste generation. The lack of scientific production related to this stage is in contrast with the high impact that the household sector has in the production of food residue. In addition, the literature shows that the lowest food waste production, from a life cycle perspective, is connected to the retail stage (1 article, i.e., 1.15%). This shows the need to define strategies and best practices for the collection and transport of food waste, thereby creating new business opportunities [40]. The cultivation and breeding stages are grouped in the sub-category "production", which provides 14 articles (i.e., 16.10%), while the processing of raw materials has been investigated by a greater number of scholars, covering 28.73% of the sample. This could be justified by the fact that, only recently, the attention of organizations such as Food and Agriculture Organization (FAO) and the Ellen McArthur Foundation has shifted from optimising production processes to responsible consumption.
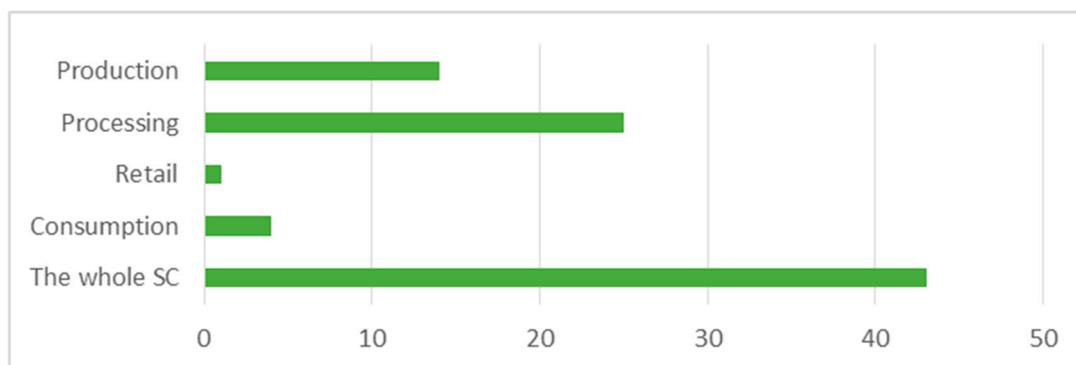

Figure 9. Stage of the Supply Chain. Adapted from Yakovleva et al. (2004).

4.7. Comparative Analysis between the Environmental Assessment Tools Implemented and Type of Supply Chain

To provide a comprehensive framework of the scientific literature concerning the CE applied to the ASC, a joint analysis has been carried out to assess each SC stage, the type of tool implemented,

the perspective of the analysis adopted and the geographical reference. In addition, in keeping with several scholars [32,47,77], the industrial symbiosis dimension on three levels has been analysed: the macro level (international), the meso level (state, province and city) and the micro level (organization). Among the articles analysed in the sample of the present SLR, the contributions that provide an analysis perspective of CE tools applied to a specific product were selected. This perspective of varied analysis aims at highlighting the different assessment tools used for agricultural products and for dairy, livestock farming and fish breeding products, as summarized in Table 5.

Table 5. Comparative analysis between environmental assessment tools and type of supply chain.

Authors	Geographical Location	Supply Chain	Product	Tool	Industrial Symbiosis Dimension
Martínez-Blanco et al. (2009)	Barcelona	Agriculture	Tomato	LCA	Meso
Arnal et al. (2018)	Italy	Agriculture	Tomato	LCA	Meso
Mouron et al. (2016)	Swiss	Agriculture	Potato	LCA	Meso
Salomone and Ioppolo (2012)	Sicily	Agriculture	Olive oil	LCA	Micro
Stillitano et al. (2019)	Sardinia	Agriculture	Olive oil	LCA, LCC	Meso
Tsarouhas et al. (2015)	Greece	Agriculture	Olive oil	LCA	Meso
Arzoumanidis et al. (2014)	Italy	Agriculture	Wine	Simplified LCA	Meso
Bonamente et al. (2015)	Italy	Agriculture	Wine	WFA	Micro
Martucci et al. (2019)	Italy	Agriculture	Wine	S-LCA, VIVA	Meso
Aivazidou and Tsolakis (2020)	Italy	Agriculture	Wine	WFA	Meso
Falcone et al. (2016)	Calabria	Agriculture	Wine	LCA, LCC, MA	Meso
Balafoutis et al. (2017)	Greece	Agriculture	Wine	LCA	Micro
Pires Gaspar et al. (2018)	Beira	Agriculture	Peach	E-LCA	Meso
Antonelli and Ruini (2015)	Italy	Agriculture	Pasta	WFA	Micro
Wang et al. (2015)	Jilin (China)	Agriculture	Maize	CFA, LCA	Meso
Neira (2016)	Ecuador	Agriculture	Cacao	LCA	Meso
Giraldi-Dìaz et al. (2018)	Mexico	Agriculture	Coffee	LCA	Meso
Owusu-Sekyere et al. (2016)	South Africa	Agriculture	Milk	WFA	Meso
Grönroos et al. (2006)	Finland	Agriculture	Milk	LCI	Meso
Bava et al. (2018)	Italy	Agriculture	Grana Padano	LCA	Micro
Garcìa-Gaudino et al. (2020)	Spain	Livestock farming	Swine	LCA	Meso
Presumido et al. (2018)	Portugal	Livestock farming	Beef	LCA	Meso
Philis et al. (2019)	Sweden	Fish breeding	Salmon	LCA, LCIA	Macro

At the micro level, in agriculture production, scholars have proposed LCA, WFA and CFA assessment methodologies. In particular, Salomone and Ioppolo [46] highlighted that the use of the LCA methodology could support the decision-making process connected to "the definition of an environmental chain strategy" [47]. Concerning the WFA, Antonelli and Ruini [77], focusing their analysis on water management in the pasta production process, analysed some corporate strategies to achieve more sustainable water use, showing also that "the largest share of the water footprint of pasta relates to the cultivation phase". This level of analysis encourages companies in the adoption of CE tools with the aim of directing production and business models towards a sustainable approach. However, some scholars have stressed the need for a paradigm shift at a SC level rather than individual company level [78]. Consistent with this assumption, most researchers have focused their work at a meso level, analysing the whole production chain in a wider area. In this perspective, LCA emerges as the most suitable tool used by scholars to assess the environmental impacts both of agriculture and the livestock sector. However, it seems necessary to underline that this result is a consequence of the theoretical approach adopted ex ante in the developed framework.

Scholars have used LCA to investigate agriculture supply chains as follow. Martínez-Blanco et al. [37] used LCA to assess the environmental impact of compost use in tomato cultivation in Barcelona, highlighting that it provides less impact than mineral fertilizer. Concerning olive oil production, Arzoumanidis et al. [38] investigated the use of a simplified LCA, such as BilanProduit, CCaLC, and VerdEE, suitable for the small- and medium-sized enterprises (SMEs) characterized by a lack of resources, highlighting that the results from the simplified LCAs are not always in line with the standard LCA. The minimization of negative impacts on the environment through the implementation of precision viticulture techniques is explored by Balaufotis et al. [78], who use LCA to identify the effects of variable rate applications on vineyard agro-ecosystems. The cereal sector has been analysed from a carbon footprint perspective by Wang et al. [79], who provide a clear understanding of the carbon footprint of maize production through the use of LCA. Concerning the social aspects of sustainability, Martucci et al. [80] provided a comprehensive overview of the VIVA project and of the S-LCA methodology to assess the negative and positive social impacts generated by wine production from a life-cycle perspective [60,80]. The combined use of assessment tools is less used by scholars. However, some contributions have been detected from the reviewed articles. In particular, Stillitano et al. [61], basing their analysis on the economic and environmental impacts of innovative technologies in olive oil production, have implemented both the LCA and Life Cycle Costing (LCC) methodologies. Meanwhile, combining LCA, LCC and Multicriterial Analysis (MA), Falcone et al. [37] presented a sustainability assessment of different wine-growing scenarios in Calabria that combined environmental and economic insights.

At the macro level, the analysis of the sample shows a literature gap concerning this dimension. Indeed, only one article has investigated the fish breeding SC from a macro-level perspective; it did this by comparing the environmental impacts of different salmon aquaculture production systems [81]. This shortage of contributions should be justified by the direct proportionality between the dimension of analysis and the complexity in implementing CE tools [32].

Starting from the state-of-the-art research provided, future research directions are presented in the following section.

5. Discussion

To reveal the potential areas of research to be developed in future, the results of the present SLR have been critically analysed. Starting from the results presented above, the limits and possible lines of research emerging from the examination of scientific literature have been highlighted.

First, the majority of the examined articles have focused on the evaluation of CE tools applied to some products. In tomato production, studies on environmental assessment have shown, on one hand, concerning the implementation of Pulsed Electric Field (PEF) technology, a reduction in energy consumption and its associated impact as measured by environmental indicators (e.g., climate change,

ozone depletion, and terrestrial acidification) from a gate-to-gate perspective. However, these results are linked exclusively to the analysis of the thermo-physical peeling stage. For these reasons, other industrial tests on tomato varieties could be beneficial, with particular attention devoted to the varieties that are difficult to peel even in conventional treatments. On the other hand, the production of compost to be used as a fertilizer in cultivation generates a significant environmental impact but does not affect the harvest or product quality. To optimize the use of compost as a fertilizer, new indicators, such as erosion and water consumption, should be provided for a more accurate impact assessment [37]. Concerning olive oil, the literature has highlighted the lack of data related to the measurement of some processes and the quantification of the environmental emissions of the olive oil production system [47]. Furthermore, from the analysis of the literature, the need to increase oil yields and reduce environmental impacts and operational costs from a life cycle perspective has emerged [61]. Following this approach, future studies could concentrate on generating a set of LCAs linked to local olive oil production to understand the factors influencing the variability in this sector [47]. In addition, many studies have provided insights into the use of socio-environmental assessment tools for wine production. In this field, on one side, the water footprint assessment should be carried out using analytical and computer-based tools to optimize water resource management [60]. On the other side, the grey water footprint should also be monitored to assess how it changes according to the fertilizers and agrochemicals used for grape cultivation [61]. In addition, future research may concentrate not only on the resource efficiency but also on the reduction of emissions [78]. Concerning the evaluation of social impacts linked to wine production, a strong fragmentation related to the S-LCA methodology has emerged. However, this assessment is essential for the definition of business policies and strategies for minimizing the negative effects of production. For this reason, an integration between a multiple set of indicators would be beneficial as it would enable the different programmes developed by the public and private sectors that aim to integrate an S-LCA analysis to be explored [81]. Finally, from the analysis conducted, homogeneous results have not been received because the use of different assessment tools provides heterogeneous outputs that are difficult to compare with each other [38]. Future research could also concentrate on the use of decision support models to compare the environmental performance with the economic variables. In addition, regarding the livestock sector and fishing sector, it would be interesting to deepen the use of alternative resources in feed production [66]. Furthermore, scholars are called to increase the quantity and reproducibility of the LCA data to drive the sustainable development of products and services [81]. Concerning other agro-food products, there is a lack of scientific input. Hence, this gap in the literature could be filled through future product-based studies.

Second, many studies have provided insights into the CE models applied to the whole ASC.

According to this perspective of analysis, some scholars argue that the involvement of all stakeholders, and in particular of consumers in the SC, is essential to make the transition from a linear economy to a CE. In addition, this engagement allows to identify the potential determinants and barriers for by-product SC creation. For this reason, future researchers could investigate, on one hand, personal attitudes to the collective action of stakeholders to enhance the implementation of bio-economy strategies [41]. On the other hand, they should examine the food waste and loss reduction schemes related to the historical, political and cultural context and its related implications [49,75]. From this perspective, involving all the actors of the supply chain, it would also be beneficial to analyse the sustainable management of inorganic waste (both homogeneous and heterogeneous materials), which could drive the development of a reference framework [75,81]. In relation to the technologies for food waste processing, the reviewed articles provide research ideas for future insights. In particular, following Morales-Polo et al. [74], who claim that anaerobic digestion represents the best waste management technology due to the lowest emissions provided by the renewable energy generated, studies on the origin and composition of food waste are suggested. This is due to the need to combine residues in the appropriate proportions to improve biogas production [74]. Hence, the energy recovered from food waste should contribute to global energy efficiency through the reduction of environmental costs. To this end, the development of local strategies and policies adapted to each

stage of the agri-food supply chain are needed [68]. Another particularly efficient food waste recycling solution is the production of animal feed, which can contribute to the mitigation of food insecurity [63]. Among the technologies adopted for the transformation of food waste into animal feed, composting technology, "insect as a feed" technology [41], pelletization [52] and the Cornell Net Carbohydrate and Protein System [53] emerge. Following these CE models, future research should concentrate on the analysis of the nutritional composition of food waste and on the effects, in quality and quantitative terms, on the animal production linked to the use of food waste for animal nutrition [41]. In addition, to respond to safety requirements, it seems necessary to develop controlled systems for the collection and management of food surplus [52]. Finally, recycling food waste into animal feed may contribute, on one hand, to the reduction of the environmental impact and, on the other hand, may provide lower production costs in the ASC.

Moreover, from the discussion it emerges that, given the complexity of the sector, each supply chain has some peculiarities that require suitable tools. For this reason, it is difficult to identify a common tool for the implementation of circular practices. However, the use of a shared assessment tool should enable comparison of circular performances and practices among the different stages and supply chains and involving all the actors of the AFS. This collaborative approach is required both vertically (among the stages of the supply chain) and horizontally (among the different supply chains) in order to catalyse the transition towards circular business models and to efficiently implement circular practices.

6. Conclusions

The agro-food sector will face new challenges in a future business scenario in which resource efficiency and innovative technologies to reduce food loss and waste along the supply chain provide opportunities for promoting the transition towards more sustainable performance and an economically viable future. In particular, it is necessary to consider the combined environmental and socio-economic benefits of food waste and loss reduction.

According to a study conducted by the FAO, reducing food loss and waste have a positive impact on the decrease in GHG emissions and on lowering pressure on land and water resources but also on suppliers' profits and consumers' well-being. Food suppliers, for example farmers, processors, transporters, retailers and food service providers, can increase their productivity by reducing food loss and waste, and they may also improve their reputation for environmental stewardship and strengthen customer relations. Consumers who reduce their food waste save money to spend elsewhere [4].

Moreover, reducing food loss and waste presents unique opportunities to create value, local businesses and jobs, and thus new economic avenues.

The results presented here highlight the necessity of a collaborative approach among the business community, policy makers and institutions in order to embrace sustainability as a business imperative and of adopting models that create shared value and drive systemic change towards circular economy goals.

However, this study has several limitations. The main limitation is the subjective component in the choice of keywords, which has conditioned the results. In addition, the inclusion and exclusion criteria defined ex ante in the search strings may have also influenced the results, excluding some relevant articles.

Since the analysis provides a general framework of the AFS, the study presents limitations related to the specific SC's peculiarities. Therefore, it is almost utopian to define CE models that can be adopted homogeneously by the whole AFS. For this reason, product-based research can provide the basis for a more detailed analysis to investigate the most appropriate models and tools for each SC.

Moreover, despite the pivotal role of retailers and consumers in the agri-food supply chain to efficiently implement CE models, future research should be more focused on retail and consumption.

Furthermore, considering these reflections, it is clear that the ASC is a highly complex network, and it would be important for future research to concentrate on the integration of different stages

of the SC [58] with CE models and tools provided by the scientific literature to create a closed-loop agro-food system.

In conclusion, some questions may be asked. What could be the approach to facilitating vertical and horizontal cooperation in the agri-food sector? After the pandemic generated by the COVID-19 virus, how can policy makers support companies in adopting sustainable CE models? Starting from these questions, scholars could conduct more in-depth research in the future. In particular, the research could concentrate on the final stages of the agri-food supply chain, which is less explored in scientific literature, to investigate potential opportunities from a circular economy perspective.

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