





Article

An Evolutionary Approach on the Framework of Circular Economy Applied to Agriculture

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Abstract: In this current and global context led by scarcity of resources, environmental degradation, global climate change, and a progressive demand for food, the circular economy (CE) represents a key economic model or framework for sustainable, restorative, and regenerative agriculture. Hence, CE applied to agriculture seeks to close the life cycle of products, services, waste, water, and energy to obtain a better use of resources and a reduction of the ecological impact. An initial review of the literature corroborates the hypothesis that the CE framework has not yet been comprehensively adapted to the field of agriculture. This research seeks to overcome this gap in relation to the performance of the circularity of agricultural production systems in support of decision-making processes. A bibliometric analysis of 1060 documents was carried to synthesize the knowledge base on this topic. The results show recent studies that identify weaknesses derived from food production, such as waste generation, biomass, water pollution, and greenhouse gas emissions. It has been identified how their analysis has developed to date and what terms allow us to visualize new approaches; consequently, it is a useful tool for researchers and sponsors who provide financial resources for the development of new lines of research.

Keywords: circular economy; agriculture; circular agriculture; food security; ecological impact



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1. Introduction

1.1. Background and Conceptual Framework

In recent years, the high demand for food globally coupled with climate change and environmental degradation urged considering the circular economy (CE) as a key strategy to support sustainable and regenerative agriculture [1–3].

The environmental impact of agriculture is the effect that different agricultural practices have on the environment and varies according to the methods, techniques, and technologies used, as well as the scale of agricultural production. Therefore, agriculture impacts soil, water, air, biodiversity, people, plants and their genetic diversity, and the quality of food and habitats [4,5]. Indeed, intensive agriculture is a major producer of the emissions associated with fertilizers, pesticides and manure, the main source of pollution of freshwater, and the primary cause of biodiversity loss through land-use change and environmental degradation [6–9].

Society has reconciled new sustainable solutions and models of agriculture, such as precision agriculture, permaculture, regenerative agriculture, sustainable soil management, or organic agriculture. In this order, the alliance of agriculture with sustainability makes it possible to move from regenerative agriculture, sustainable soil management, and organic farming to the CE [10,11].

CE arises as an economic approach within the framework of sustainable development, which aims to produce goods and services while reducing the consumption and waste of

raw materials in the production chain, water, and sources of energy. Hence, as defined in [12,13], CE is a model of production and consumption that contrasts with linear models and aims at the efficient use of resources through waste minimization, long-term value retention, a reduction of primary resources, and closed loops of products, product parts, and materials within the boundaries of environmental protection and socioeconomic benefits. In relation to the principles of sustainable production, it focuses on the reuse of waste to create new products, the reduction of the environmental impact of production, and the regeneration of natural systems [14,15].

Agriculture is well adapted to the precepts of the CE as an economic concept included in the framework of sustainable development [16–18]. This comprises a set of human actions dedicated to the transformation of the natural environment to provide the world's food, which depends on both the climate and the techniques implemented to make the land fertile. It is an activity of great strategic importance for the self-sufficient development and capital of the countries [19,20].

1.2. Theoretical Framework: Circular Economy Applied to Agriculture

In recent years, different organizations worldwide are investing in sustainable bioeconomy, which refers to the set of economic activities focused on obtaining products and services that generate economic value using biological resources as raw material, and that represents a more viable opportunity to direct current economies toward greater sustainability in the use of natural resources both in agriculture and industry, and in economic growth [21–23]. In this context, economies are being directed toward greater sustainability in the use of natural resources both in agriculture and industry, and for economic growth.

According to the UN, circular agriculture focuses on using minimal amounts of external inputs to regenerate soils and minimize the impact on the environment. Likewise, it helps to guarantee a reduction in land use as well as limits the use of chemical fertilizers and the production of waste in order to reduce global emissions and contribute to the fight against climate change [24,25]. In any activity framed within CE, the reuse and recycling of materials become part of the usual production decisions. On the other hand, this type of action encourages the creation of new job opportunities for those who work with the materials to be recycled.

At a global level, fruit and vegetable production is a key sector in bioeconomy and must be kept economically, socially, and environmentally sustainable [26]. In the fruit and vegetable sector, the development of new varieties is common, thus the efficiency in the use of fertilizers, organic amendments, water and energy, the integrated pest control systems, disease and weeds, as well as the precision agriculture are key [27] for both a better use and, especially, a reduction of the impact on sustainability in relation to the economic approach of the CE.

New biofertilizers and phytosanitary products allow crops to adapt to new agroecological conditions, resist biotic and abiotic stresses, or incorporate new functionalities. The reuse of their own waste and by-products from their environment to obtain fertilizing products with added value suitable for fruit and vegetable crops will lead to an improvement in the efficiency and sustainability of these activities [3].

For these reasons, the main question is to determine how CE is implemented in agriculture. Therefore, recycling and reuse are tools that enable agriculture to achieve circularity from the use of organic waste or recycling plastics and packaging. The reuse of water is also key in the process of implementing circular agriculture since in many regions around the world, this resource is used for agricultural irrigation, improving the ecological flows of rivers or recharging aquifers and wetlands [28–30].

Circular agriculture seeks to close the life cycle of products, services, waste, water, and energy in order to seek better use and a reduction of the ecological impact [31,32]. Hence, the review of the literature makes it possible to elucidate that the CE framework has not yet been comprehensively adapted to agriculture. Consequently, this research

seeks to overcome this gap in relation to the performance of the circularity of agricultural production systems in support of decision-making processes.

The article's structure is as follows: Section 2 presents the data and the applied methodology; Section 3 consists of empirical findings and their discussion in a broad context; and, finally, the conclusion is presented in Section 4.

2. Materials and Methods

2.1. Research Questions and Objective

The main aim of this paper is to collect all the research registered in the Scopus database to analyze its characteristics and to use it as a reference for both researchers and stakeholders interested in the field of CE applied to agriculture. The exploration of this literature allowed us to find works that address this issue with different approaches, thus the research questions on this topic attempt to determine: (1) the evolution of research from the publication of the first article to the present; (2) who the most productive authors, organizations, and countries are; and (3) the thematic axes developed by this research topic and towards which they are evolving to conform and update the reference framework.

For this purpose, the search for terms to carry out the study in the field of CE and agriculture, as well as the downloading of data and delimitation of variables were supported by Scopus. Among the various tools available, this database was chosen for its easy access as well as its download utilities [33].

2.2. Systematic Review

The first stage of this methodology has focused on a qualitative systematic review of the literature published in English, which has consisted of identifying all the publications on this line of research. This type of review allows for the synthesis of information on a specific topic [34] and makes readers aware of the process followed by researchers to produce their findings [35]. The search for publications focused on CE and agriculture for this first review has, in turn, followed the "snowball" or "reference chain" technique, which consists of collecting data when there is difficulty in finding a representative sample in the sources officers used, i.e., in this case, Scopus [36]. For this reason, it contributes to the development of a theoretical framework with government documents that are not considered in the database used. Even so, due to the specific nature of this study, this technique has not been applied for the second analysis, although it is important to mention the vital relevance of these documents to understand the state of the art from a complete perspective.

2.3. Bibliometric Analysis and Sample Selection

The second stage of this methodology was designed to delimit the sample based on parameters of interest such as the terms to be included, the search time horizon, or the type of publication to be analyzed. This was carried out by applying a bibliometric review recognized for being a widely extended technique when analyzing variables of interest among the publications that make up the study sample [37]. In fact, this type of analysis is capable of identifying the relative importance of published research in a specific research field based on the number of citations received, the H-index, and the Scimago Journal Rank (SJR) impact factor [38–41].

In this context, the search has included terms that refer to CE, such as "circular economy", "CE", or "circul * econom **", and to agriculture, such as "agricult *". The search introduced in the Scopus database initially considered all the publications carried out in this field, that is, from 2005 to 2021, with a total of 1572 publications. However, to obtain a sample free of duplications, it was subsequently decided to limit the publications only to those that were articles, book chapters, or books. In this way, after cleaning the initial sample obtained, there was a total of 1060 documents on which the authors of this paper have based their conclusions.

2.4. Data Processing

This phase consisted of the purification of the sample since, normally, the signature of the authors with different names or the abbreviations of certain variables lead to recording the data erroneously. To do this, thanks to the possibility of downloading a complete record in RIS format from Scopus, the sample was processed in the Science Mapping Analysis Tool (SciMAT), thus avoiding duplications and errors in the sample to be analyzed. Among the variables studied, some of the examples considered in the analysis included the main research countries, the most prolific authors, the keywords used, or the thematic areas in which they are all framed. Furthermore, to complete the study, network maps were prepared using the VOSviewer tool [42], whose robustness for mapping scientific results has been satisfactorily verified [43]. The mentioned phases are synthesized in Figure 1.

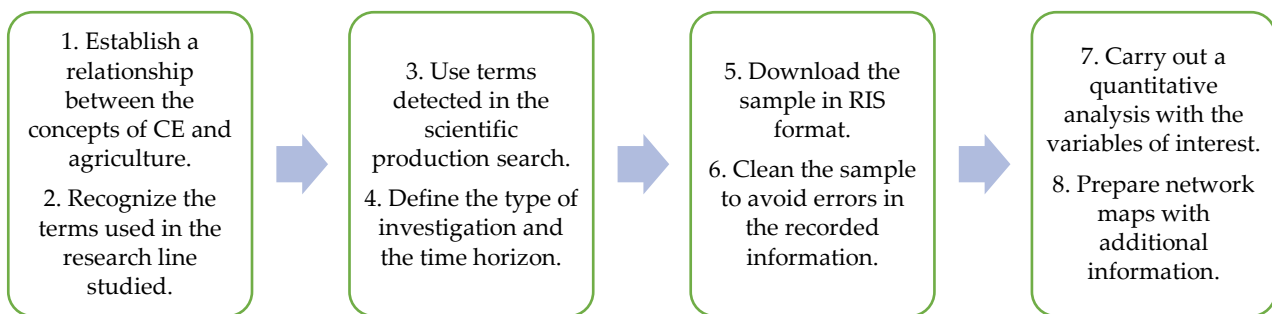


Figure 1. Graphic representation of the methodology used.

3. Results and Discussion

3.1. Evolution of the Main Characteristics in the Field of CE and Agriculture

This work analyzes all the publications made in the field of CE applied to agriculture. The time horizon considered ranges from the first year in which investigations are registered (2005) to the present (2021). Likewise, the seventeen years studied were divided into three periods, one of seven years, namely 2005–2011, and two of five years each, namely 2012–2016 and 2017–2020. The main reason for this classification is that in the first period (2005–2011), no publications were recorded in 2006 and 2008, thus by including two more years, it was possible to obtain three periods with the same number of years.

Table 1 shows the main characteristics of this line of research, which has a sample of 1060 total investigations. The first period, between the years 2005 and 2011, recorded a total of 14 publications, while the last period (2017–2021) had 1005 documents. Regarding the authors, from 2005 to 2011, 40 participated compared to the 4208 between 2017 and 2021, which represents a percentage of representation of 0.92% and 96.78% of the total of the authors that make up the sample, respectively. In addition, if the two mentioned variables are related (active authors in the line of research and published documents), it is possible to calculate the average number of authors, which rises from 2.9 authors per article between 2005 and 2011 to a total of 4.2 between 2017 and 2021.

Table 1. CE in the agricultural context: major characteristics (2005–2021).

Period	A	AU	C	TC	TC/A	J
2005–2011	14	40	3	27	1.93	13
2012–2016	41	146	15	98	2.39	31
2017–2021	1005	4208	95	8761	8.72	401

A: articles per period; AU: number of authors; C: number of countries, TC: total citations in articles; TC/A: total citations per article; and J: number of journals.

The countries also increase their participation in this line of research, which goes from three countries in the first period (China, Hong Kong and the USA) to registering 95 countries in the last period. In fact, the total sample is made up of 95 countries, thus

the last period analyzed represents 100% of the countries active in this line of research. The latent interest in CE and agriculture is also reflected in the number of total citations since if all those made so far are counted, a total of 8886 citations are obtained. In this case, the first period (2005–2011) has 27 citations and the last period (2017–2021) has a total of 8761 citations. These values indicate that the first period has 1.93 citations per article, while the last one reaches an average of 8.72 citations per research document. On the other hand, the number of journals that publish on this subject rose from 13 in 2005–2011 to 401 journals between 2017 and 2021. Finally, special mention should be made of the last period analyzed, namely 2017–2021, as it has the largest percentages of variation in all the variables considered in the Table.

Figure 2 graphically represents the number of publications that have been made annually to make up the total sample of 1060 documents. The first year analyzed (2005) has three publications [44–46], the first of the entire sample being identified under the name “Practical and theoretical issues on the sustainable development of Chinese ecological agriculture”. Additionally, the year 2021 recorded 440 documents. It must be clarified that the study was being carried out without having finished 2021, thus the number of investigations is likely to increase when considering the full year. From 2018, more than 100 annual investigations began to be published and the highest number of publications occurred in the last year analyzed (2021), with a total of 400 investigations. The year with the highest percentage of variation (231%) is 2017, with 53 publications, due to the increase produced when compared to the previous year (2016), which had 16 publications. Next, 2018 went on to register 113 publications with an increase of 113% compared to the previous year. On the contrary, the years with the lowest percentage of variation are 2006 and 2008 since they did not have publications. Finally, if reference is made to the established time periods, the variation that occurs in published research is 192% for the second period (2012–2016) and 2.351% for the third period (2017–2021).

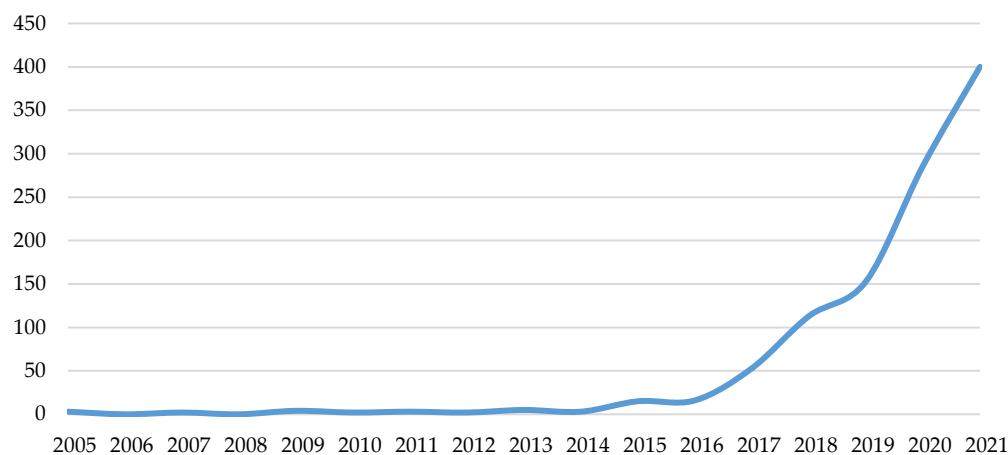


Figure 2. Number of documents published from 2005 to 2021.

3.2. Analysis by Subject Area

The investigations carried out may be classified in several thematic areas simultaneously depending on the interests of the authors and the publisher themselves. For this reason, it is common to find publications that are grouped into several categories due to the various topics of interest investigated. In this study, we highlight those that registered the highest number of publications regardless of whether they are classified only in this discipline or in others at the same time. In this case, the sample of 1060 documents was classified in the Scopus database into a total of 26 subject areas. Figure 3 represents the evolution of the main categories, that is, those that exceed 5% representation of the total sample. In total, 1718 documents are grouped among the five main disciplines and represent 74.05% of the total sample.

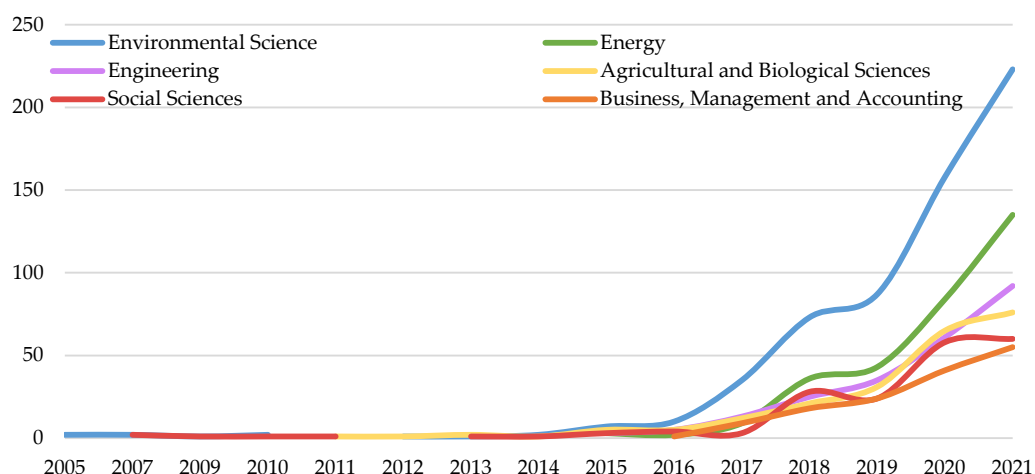


Figure 3. Comparison of the growth trends of the main subject areas (2005–2021).

The category that Lead Figure 3 is Environmental Science with 604 investigations and a representation percentage of 26.03%. It is considered a reference topic in the research line since publications are framed from the first year analyzed (2005). In addition, in regard to the last period (2017–2021), a percentage increase of 2.643% was experienced since it went from 21 investigations in the previous period to a total of 576 publications. In second position, with 312 documents and a 13.45% representation, is Energy. This discipline stands out for its late incorporation into the topics of interest; its first investigation was framed in 2015. However, due to the growing interest in this category, the number of investigations went from five in the period (2012–2016) to 307 between 2017 and 2021. The discipline that follows, in third position in the ranking, is Engineering. This subject area has a total of 241 publications and represents 10.39% of the total sample analyzed.

During the first period (2005–2011), six publications were framed in this category; in the second period (2012–2016), nine investigations were reached; and in the last period (2017–2021), the total number of registered documents amounted to 226. These values represent the exponential increase that is taking place in the investigation of subjects focused on engineering. Fourth, indicated in yellow in Figure 3, is Agricultural and Biological Sciences. This thematic area registered 223 publications and a representation percentage of 9.61% with respect to the total sample analyzed. The year 2005 recorded the first three publications; it is from the year 2011 when it began to be considered annually in the documents. The succeeding discipline is Social Sciences with 187 investigations and an 8.06% representation. This category, which in the first period registered two publications, reached 147 in the last (2017–2021). Finally, Business, Management and Accounting occupies the sixth position. This discipline has 6.51% and 151 investigations. As can be seen in the Figure, it is at the bottom of the rest of the main categories, although it also registered an exponential increase for the last years analyzed.

The rest of the disciplines are not represented graphically since their representation percentage is under 5%. Even so, variety is mentioned in the rest of the disciplines framed since there are publications in the field of Nursing, Veterinary, or Neuroscience [47,48]. Finally, to obtain an overview of the number of categories in which the investigations are classified, it must be said that a total of 2320 documents are registered for the 26 categories. These data imply that each investigation is classified into an average of 2.19 disciplines.

3.3. Identification of the Most Prolific Journals

This section presents the 20 most active journals in CE research in the agricultural field out of the 429 that make up the sample. Table 2 refers to the publications made by each journal, the citations received, the average number of citations, the H-index [38,49], the nationality, or the impact factor according to the Scimago Journal Rank. Moreover, in relation to the publications in the sample, the H-index of the documents was analyzed as

well as the publication date of the first and last article. According to the data provided, the countries with the highest percentage of representation are Switzerland and the Netherlands, registering seven and four journals, respectively. Regarding the year of publication, all the journals are still publishing to this day, that is, in 2021. If reference is made to the quartile to which they belong, 13 journals are classified in the first quartile, representing 65% of the journals in the table; six journals in the second quartile (30%), and only one in the third quartile (5%).

Table 2. The most active journals in CE and agriculture research (2005–2021).

Journal	A	TC	TC/A	H-Index Articles	H-Index Journal	SJR	Country	1st Article	Last Article
Sustainability	83	907	10.93	16	85	0.61 (Q1)	Switzerland	2015	2021
Journal of Cleaner Production	82	1282	15.63	21	200	1.94 (Q1)	UK	2017	2021
Science of the Total Environment	35	472	13.49	14	244	1.80 (Q1)	Netherlands	2016	2021
Resources Conservation and Recycling	26	613	23.58	15	130	2.47 (Q1)	Netherlands	2016	2021
Energies	23	184	8.00	5	93	0.60 (Q2)	Switzerland	2019	2021
Journal of Environmental Management	21	213	10.14	8	179	1.44 (Q1)	USA	2017	2021
Agronomy	17	57	3.35	4	30	0.71 (Q1)	Switzerland	2019	2021
Waste and Biomass Valorization	16	91	5.69	5	41	0.62 (Q2)	Netherlands	2015	2021
Waste Management	14	238	17.00	9	161	1.81 (Q1)	UK	2013	2021
Environmental Science and Pollution Research	12	73	6.08	5	113	0.85 (Q2)	Germany	2017	2021
Applied Sciences	11	45	4.09	3	52	0.44 (Q2)	Switzerland	2018	2021
Nongye Gongcheng Xuebao	10	27	2.70	4	51	0.45 (Q2)	China	2005	2021
Transactions of the Chinese Society of Agricultural Engineering	10	16	1.60	2	8	0.32 (Q3)	Romania	2015	2020
Procedia Environmental Science Engineering and Management	10	73	7.30	5	55	0.72 (Q1)	Switzerland	2017	2021
Water	10	73	7.30	5	55	0.72 (Q1)	Switzerland	2017	2021
Industrial Crops and Products	9	64	7.11	4	129	1.07 (Q1)	Netherlands	2017	2021
Renewable and Sustainable Energy Reviews	9	148	16.44	5	295	3.52 (Q1)	UK	2019	2021
ACS Sustainable Chemistry and Engineering	8	67	8.38	4	109	1.88 (Q1)	USA	2019	2021
Frontiers in Sustainable Food Systems	8	11	1.38	2	14	0.73 (Q1)	Switzerland	2020	2021
Bioresource Technology	7	78	11.14	4	294	2.49 (Q1)	UK	2018	2021
International Journal of Environmental Research and Public Health	7	36	5.14	4	113	0.75 (Q2)	Switzerland	2019	2021

A: number of articles; TC: total citations for all articles; TC/A: number of citations by article; SJR: Scimago Journal Rank (quartile that occupies the journal; see in <https://www.scimagojr.com/>, accessed 25 February 2022); C: country; UK: United Kingdom; and USA: United States of America.

The journals are ordered according to the number of published investigations; hence, Sustainability is the journal that leads the ranking, with 83 investigations. This journal is Swiss and ranks in the first quartile with an impact factor of 0.61. The Journal of Cleaner Production, in second place, is the journal with the highest values for the total citations received (1282) and H-index for articles (21). Some publications made by this journal with a high number of citations are “Remanufacturing challenges and possible lean improvements” and “Redesigning a bioenergy sector in EU in the transition to circular waste-based Bioeconomy-A multidisciplinary review” with 84 and 57 citations, respectively [50,51]. Regarding the average number of citations per article, the journal with the highest value (23.58) is Resources Conservation and Recycling, ranked fourth. By way of addition, the journal with the lowest values for the three variables mentioned, namely total citations (11), average citations (1.38), and H-indices for articles (2), is Frontiers in Sustainable Food

Systems. This discipline, which is in position 18, registered these values due to its short history since its first two publications were made in 2020, entitled “Co-benefits and Trade-Offs From Agro-Food System Redesign for Circularity: A Case Study With the FAN Agent-Based Model ”and“ Sustainability Assessment of Biorefinery Systems Based on Two Food Residues in Africa” [52,53]. On the contrary, Nongye Gongcheng Xuebao Transactions of the Chinese Society of Agricultural Engineering is characterized by its long research activity since it is the only journal in Table 2 that publishes in the first period analyzed, specifically in 2005. Finally, in terms of the characteristics of the journals themselves, Renewable and Sustainable Energy Reviews registered the highest value in the journal’s H-index and in the impact factor, with 295 and 3.52, respectively.

3.4. Most Prolific Authors

The total sample was made up of 4348 authors. Table 3 shows the 10 most prolific authors for having the largest number of investigations carried out on CE applied to the agricultural context. Together, these groups have a total of 68 articles, which represents a percentage of 6.42% compared to the total sample analyzed. Table 3 provides the total citations received by each author [54,55], the average number of citations, the H-index [56], the institution to which they belong, the nationality, and the first and last year of publication on this topic. As can be seen, the European nationality predominates among the most active authors with a percentage of 90% representation. Regarding the period of publication, all the authors registered research from the second period analyzed (2012–2016), Sergio Ulgiati being the one with the longest career. In addition, all authors continue to publish today in the year 2021. This section was analyzed with the aim of identifying outstanding authors since they can serve as a reference for political decision-makers or individuals who want to expand their knowledge on this line of research. In this case, its commitment to updating the state of the art and contributing significantly to scientific advancement is detailed in the table.

Table 3. Authors who have contributed the most (2005–2021).

Author	A	TC	TC/A	Organization	Country	1st Article	Last Article	H-Index
Gabarrell, X.	10	113	11.30	UAB Institute of Environmental Science and Technology (UAB Instituto de Ciencia y Tecnología Ambientales)	Spain	2019	2021	6
Ulgiati, S.	8	114	14.25	Beijing Normal University	China	2014	2021	4
Belmonte-Ureña, L.J.	7	60	8.57	University of Almeria (Universidad de Almería)	Spain	2020	2021	4
Petit-Boix, A.	7	100	14.29	University of Freiburg (Universität Freiburg)	Germany	2019	2021	5
Villalba, G.	7	63	9.00	UAB Institute of Environmental Science and Technology (UAB Instituto de Ciencia y Tecnología Ambientales)	Spain	2020	2021	4
Bernini, R.	6	137	22.83	University of Tuscia (Università degli Studi della Tuscia Viterbo)	Italy	2016	2021	3
Romani, A.	6	137	22.83	University of Florence (Università degli Studi di Firenze)	Italy	2016	2021	3
Valenti, F.	6	26	4.33	University of Catania (Università degli Studi di Catania)	Italy	2020	2021	3
Zabaniotou, A.	6	206	34.33	Aristotle University of Thessaloniki	Greece	2015	2020	6
Barbi, S.	5	24	4.80	University of Modena and Reggio Emilia (Università degli Studi di Modena e Reggio Emilia)	Italy	2020	2021	2

A: number of articles; TC: total citations for all articles; TC/A: number of citations by article; and Organization: named in English and in the original language.

The ranking of the most active authors is headed by Xavier Gabarrell i Durany with a total of 10 investigations. This Spanish author works for the Autonomous University of Barcelona (UAB) Institute of Environmental Science and Technology and has an H-index of six. In second place, Sergio Ulgiati, recorded eight investigations and is the only prolific author from China. In third position, with a total of seven publications and 60 total citations, is Luis Jesús Belmonte-Ureña. This Spanish author, who works for the University of Almeria, registered an H-index of four. Among the research he has, “The management of agricultural waste biomass in the framework of circular economy and bioeconomy: An opportunity for greenhouse agriculture in Southeast Spain” and “Effects of circular economy policies on the environment and sustainable growth: Worldwide research” are the two papers with the highest number of citations [3,28]. Furthermore, Anastasia A. Zabaniotou stands out for being the author with the highest number of total citations (206) and average number of citations (34.33). This Greek author works for the Aristotle University of Thessaloniki and registered the highest H-index (six) together with Xavier Gabarrell i Durany.

Finally, special mention must be made to the research developed by the authors Roberta Bernini and Annalisa Romani since both recorded the same data in the published publications (6), total citations (137), average of citations (22.83), nationality (Italy), and H-index (3). The only difference between Roberta Bernini and Annalisa Romani is the institution, as they work for the University of Tuscia and University of Florence, respectively.

The VOSviewer tool allows for organizing groups with different topics. In this case, it was carried out according to the activity of the main authors. Therefore, Figure 4 represents a collaboration map based on co-authorship. The colors indicate the different collaboration groups and the size of each author’s contribution, as well as the number of investigations carried out in the line of research on CE applied to agriculture. Figure 4 distinguishes seven clusters, although there are connections between authors from different clusters.

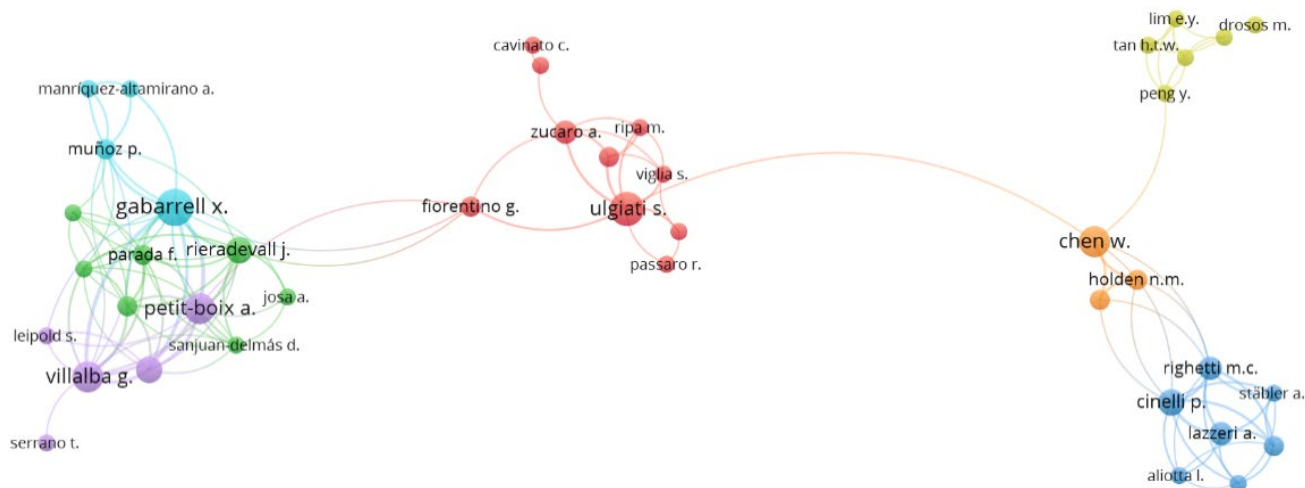


Figure 4. Network of cooperation based on co-authorship of the main authors (2005–2021).

The first collaboration group appears in purple. This cluster is directed by Anna Petit-Boix and Gara Villalba Méndez, both with seven published articles. The other three authors that make up the group are Tarik Serrano, Sina Leipold, and Martí Rufi-Salis. These five authors publish numerous investigations focused on CE and agriculture, such as “Recirculating water and nutrients in urban agriculture: An opportunity towards environmental sustainability and water use efficiency?”, among many others [57–59]. The second group of authors is represented by Joan Rieradevall I. and Felipe Parada, and has other collaborators such as Verónica Arcas-Pilz. In fact, these three authors share their institution of origin since they all belong to the UAB Institute of Environmental Science and Technology. The publication “Comparison of organic substrates in urban rooftop agriculture, towards improving

crop production resilience to temporary drought in Mediterranean cities” [60] is one of the investigations carried out by said authors; some of those that make up the purple cluster can also be found in this publication. The light blue and orange clusters are the smallest, with four and three authors, respectively. The light blue one is represented by Xavier Gabarrell i Durany and has the participation of Pere Muñoz, Ana Manríquez-Altamirano, and Jorge Sierra-Pérez [61,62]. The orange one, made up of Wenhao Chen, Nicholas M. Holden, and Thomas L. Oldfield, recorded three joint investigations, namely one from 2019 and two from 2020 [63–65]. In addition, the red cluster is the largest, registering the collaboration of 10 authors. Among the members who collaborate in the investigation are Sergio Ulgiati, from China, and Gabriella Fiorentino, Amalia Zucaro, and Cristina Cavinato, from Italy [66].

The sixth cluster, identified in yellow, is made up of a total of six authors. Two of the investigations carried out by this collaborative group are “Gasification biochar from horticultural waste: An exemplar of the circular economy in Singapore” and “Closing the food waste loop: Food waste anaerobic digestate as fertilizer for the cultivation of the leafy vegetable, xiao bai cai (Brassica rapa)” [67,68], which have the collaboration of Yen Wah Tong, Hugh TWTan, and Ee Yang Lim. Finally, the sixth cluster is identified in dark blue and records numerous investigations on CE applied to agriculture [69,70]. Of the five authors that make up the cluster, the authors Maria Cristina Righetti, P. Cinelli, and Andrea Lazzeri are the ones with the highest number of publications.

3.5. Characteristics of the Main Organizations from 2005 to 2021

Table 4 lists the 10 most prolific organizations in this line of research. The information provided is the nationality, articles produced, total citations, average citations, H-index, percentage of international collaboration, and total citations for international and national research. These organizations produced 178 publications and this translates into a representation of 16.79% of the total sample analyzed. In addition, they are all of European origin and, with a representation percentage of 60%, Italy stands out over the rest of the countries.

Table 4. Characteristics of the most outstanding organizations (2005–2021).

Organization	Country	A	TC	TC/A	H-Index	IC (%)	TCIC	TCNIC
National Research Council of Italy (Consiglio Nazionale delle Ricerche)	Italy	25	231	9.24	9	48.00%	13.25	5.54
University of Catania (Università degli Studi di Catania)	Italy	20	58	2.90	4	5.00%	6.00	2.74
Autonomous University of Barcelona (Universitat Autònoma de Barcelona)	Spain	19	207	10.89	9	57.89%	11.73	9.75
Wageningen University and Research	Netherlands	18	287	15.94	8	88.89%	17.50	3.50
University of Almeria (Universidad de Almería)	Spain	18	101	5.61	5	38.89%	4.57	6.27
National Research Institute for Agriculture, Food, and the Environment (Institut national de recherche pour l’agriculture, l’alimentation et l’environnement (INRAE))	France	18	213	11.83	7	50.00%	13.00	10.67
University of Tuscia (Università degli Studi della Tuscia Viterbo)	Italy	17	293	17.24	8	5.88%	0.00	18.31
Parthenope University of Naples	Italy	15	155	10.33	6	73.33%	12.73	3.75
University Of Naples Federico II (Università degli Studi di Napoli Federico II)	Italy	14	190	13.57	5	42.86%	19.83	8.88
University of Florence (Università degli Studi di Firenze)	Italy	14	167	11.93	5	28.57%	1.25	16.20

Organization: named in English and in the original language; A: number of articles; TC: total citations; TC/A: total citations per article; IC (%): percentage of articles made with international collaboration; TCIC: number of citations in articles with international collaboration; and TCNIC: number of citations in articles without international collaboration.

The first in the ranking is the National Research Council of Italy, which has 25 articles and 231 total citations. This Italian organization registered 9.24 citations per article and has the highest H-index (9) together with the Autonomous University of Barcelona. In second place, the University of Catania, which has the lowest values in the total citations (58), average citations (2.9), and H-index (4), is the organization to which the prolific author Francesca Valenti belongs. The said Italian institution has the lowest values in the total citations (58), average of citations (2.9) and H-index (4). On the contrary, the one with the highest values in total citations (293) and average citations (17.24) is the University of Tuscia, to which the author Roberta Bernini belongs.

Regarding the international cooperation, it is possible to ascertain which ones carry out numerous investigations with the collaboration of other countries and which ones opt for national publications. The second in Table 5, University of Catania, once again positioned itself with the lowest values in percentage of collaboration (5%) and in total citations in national articles (2.74). The highest percentage of collaboration, with a value of 88.89%, was registered by Wageningen University and Research, carrying out 16 investigations internationally out of the 18 published. Finally, the University of Naples Federico II registered the highest number of total citations for international articles, with 19.83, and the University of Tuscia has the highest value for citations in national articles, with 18.31. This last organization, of Italian origin, also stands out for not registering citations in international articles since, out of the 17 publications, 16 were prepared without other countries.

Table 5. The most relevant countries and their international collaboration (2005–2021).

Country	A	TC	TC/A	NC	Main Collaborators	IC	TCIC	TCNIC	H-Index	1st Article	Last Article
Italy	251	2552	10.17	51	Spain, China, Germany, France, and Greece	32%	10.81	9.86	26	2014	2021
Spain	165	1163	7.05	45	Italy, Portugal, Germany, UK, and USA	42%	6.84	7.20	20	2016	2021
China	112	739	6.60	37	Italy, USA, Australia, Singapore, and Denmark	42%	10.51	3.77	14	2005	2021
UK	78	754	9.67	43	Spain, Brazil, Italy, USA, and Germany	69%	9.44	10.17	16	2015	2021
Germany	61	637	10.44	47	Italy, Spain, Netherlands, Switzerland, and UK	69%	10.86	9.53	18	2016	2021
Brazil	59	275	4.66	29	Portugal, UK, Spain, France, and Germany	44%	4.65	4.67	10	2017	2021
France	58	783	13.50	38	Italy, Switzerland, UK, Australia, and Brazil	55%	11.84	15.54	16	2017	2021
USA	57	522	9.16	43	China, Spain, Italy, UK, and Germany	68%	7.15	13.50	12	2007	2021
Portugal	54	340	6.30	30	Spain, Brazil, Italy, Greece, and Serbia	61%	7.55	4.33	9	2017	2021
Poland	47	365	7.77	16	Sweden, South Africa, Austria, Belarus, and Czech Republic	26%	12.83	6.03	11	2014	2021

UK: United Kingdom; USA: United States of America; A: number of articles; NC: number of collaborators; IC: percentage of articles made with international collaboration; TC/A: number of citations by article; IC: international collaboration; NIC: no international collaboration; and TC: total citations for all articles.

3.6. Main Countries in the Field of CE and Agriculture Research

In total, 95 countries made up the sample studied. However, Table 5 only considers the 10 most active in research on CE applied to agriculture. In total, these countries group 942 publications of the total sample, which represents 88.87%. Of the 10 countries considered, all are currently publishing in 2021 and that with the longest research history is China, specifically with its first publication in 2005.

The first country, Italy, has the highest value in the number of total citations received (2552) and the H-index (26). This European country possesses the largest number of collaborating countries, with a total of 51, of which Spain, China, Germany, France, and Greece stand out due to the close research relationship established. In addition, it is among the main collaborators of the rest of the countries in the Table, except for Brazil and Poland. Spain is in second place with a total of 165 publications and 1163 total citations received. The prolific authors Xavier Gabarrell i Durany, Luis Jesús Belmonte-Ureña, and Gara Villalba Méndez belong to this country, which explains their second position in the ranking of the most active countries. In this case, the number of collaborators amounts to 45 and the countries with which it conducts more research on CE and agriculture are Italy, Portugal, Germany, the UK, and the USA. On the other hand, Brazil, in sixth position, registered the lowest values for total citations and average citations, with 275 and 4.66, respectively.

In relation to cooperation in these countries, the percentage of international collaboration, total citations in international research, and total citations in national publications are also mentioned. The highest percentage of international collaboration is held by the UK and Germany, both with 69%, and the lowest by Poland with 26%. In addition, the latter also has the smallest number of collaborators, specifically with a total of 16 countries. The average of the total citations is balanced in national and international research, as five countries receive more citations in international articles and five other countries receive more citations in articles of a national nature. Finally, the highest average of citations in international research is received by Poland with 12.83 and France with 15.54 in national publications.

Figure 5 was made with the VOSviewer tool, in which the international cooperation of the countries is graphically represented through co-authorship. The 45 countries that make up Figure 5 are represented in different colors depending on the cluster to which they belong and the size in relation to the investigations carried out by each.

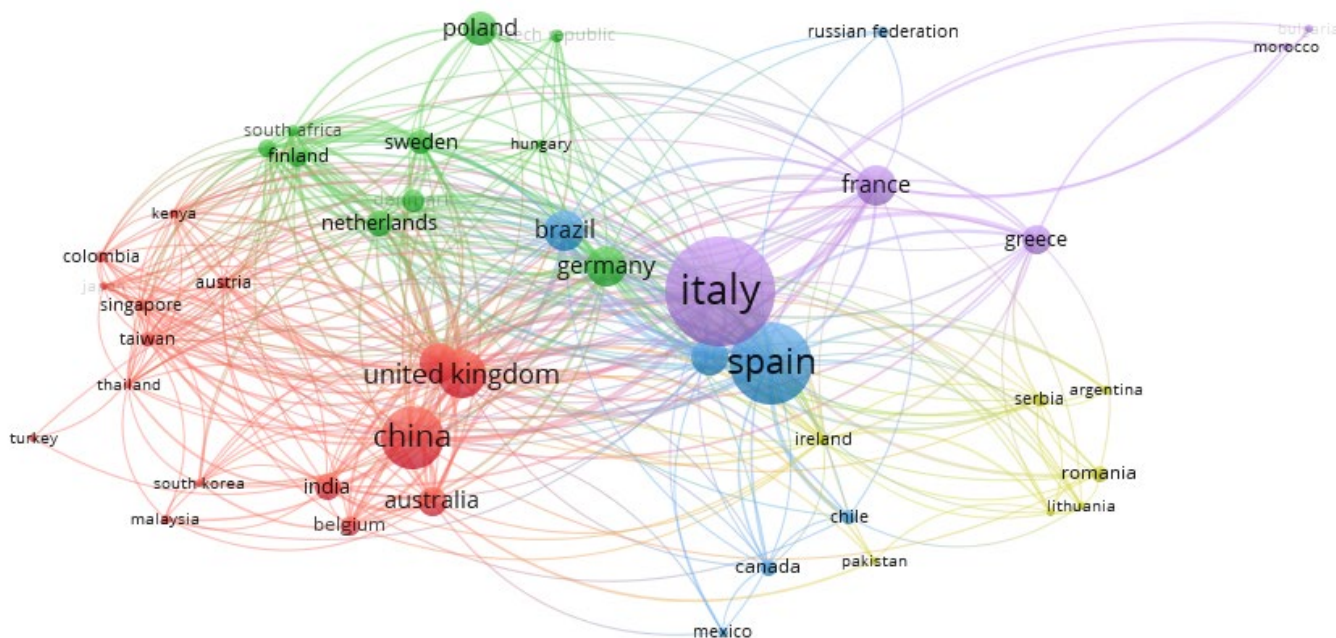


Figure 5. International cooperation based on co-authorship between countries (2005–2021).

The first red cluster is led by the UK, China, and India. The countries that make up this collaboration group are Australia, Belgium, Austria, and Japan. In total, they produced 427 articles and represent 40.28% of the total sample. Its publications are characterized by being framed in greater presence in the categories of Environmental Sciences, Energy, and Engineering.

The second cluster, which is green in color, is represented by Germany, the Netherlands, Finland, Sweden, and Poland. The rest of the countries that make up this collaboration

group are South Africa, the Czech Republic, Denmark, Hungary, and Switzerland. In total, these 10 countries that constitute the cluster produced 263 investigations and represent 24.81% of the total sample. In addition, among the main categories of this line of research, the publications made by this group of countries are mainly framed in Environmental Sciences, Energy, and Social Sciences.

The third collaboration group, in blue, is made up of seven countries, specifically Canada, Chile, Mexico, Portugal, Russia, Brazil, and Spain. The last two countries mentioned are the most representative due to the number of investigations carried out and in total, with a representation percentage of 31.13%, they produced 330 articles, most of them belonging to the disciplines of Environmental Sciences, Agricultural and Biological Sciences, and Energy.

The fourth cluster in yellow and directed by Italy, France, and Greece has 67 investigations and represents 6.32% of the total sample. These last two collaboration groups have the same number of active countries, however, the number of publications made by both differs significantly.

The last cluster, in purple, is the smallest in terms of the countries that it comprises, as it only has five, specifically Bulgaria, France, Greece, Italy, and Morocco. Even so, their research activity is quite strong since they have carried out a total of 361 investigations together, which represents 34.06% of the total. This is largely thanks to Italy since it is the country that publishes the most in this line of research. These countries have Environmental Science, Energy, and Engineering as the most representative subject areas of the publications made. Finally, it should be clarified that the countries that make up the collaboration groups not only carry out research among themselves but also documents that include countries belonging to different clusters can be registered.

To conclude this section, Figure 6 is presented. This world map indicates, based on color, the number of publications with which it has contributed to CE research in the agricultural field. In this sense, the three most prolific countries (Italy, Spain, and China) are identified in dark red because they registered the highest numbers. On the contrary, the countries indicated with light and dark green stripes are those that publish the least. This group, made up of a total of 43 countries, is consolidated as the most numerous, with each country registering between one and five investigations for the entire period analyzed. Finally, those countries indicated in gray do not have any publications to date for this line of research.

3.7. Keywords from 2005 to 2021

The terms used to investigate CE in agriculture have evolved. In this sense, it is common to find keywords in the first years of research, completely different from those used today. This is due to the evolution in the research line and to the interests according to the moment of study. Table 6 shows the 20 keywords with the highest number of occurrences, that is, those that appear most frequently in the total sample of 1060 documents. The concepts are used in research to define the fields of study and interest of the article. Therefore, it is common to find more than one keyword in each of the analyzed publications. In this case, the total keyword sample is 8565, which would reflect the use of an average of eight keywords per published document. Table 6 indicates some concepts with a high number of occurrences due to their interest throughout the entire time horizon, while others are among the most used due to their high current interest. This allowed us to know if the study topics have evolved over the years or if, on the contrary, an attempt is still being made to answer the same initial questions. In addition, the study eliminated words that did not add value to the analysis, such as those that were used in the search itself (circular economy and agriculture) or those that refer to characteristics of no great significance (priority journal, article, humans, etc.).

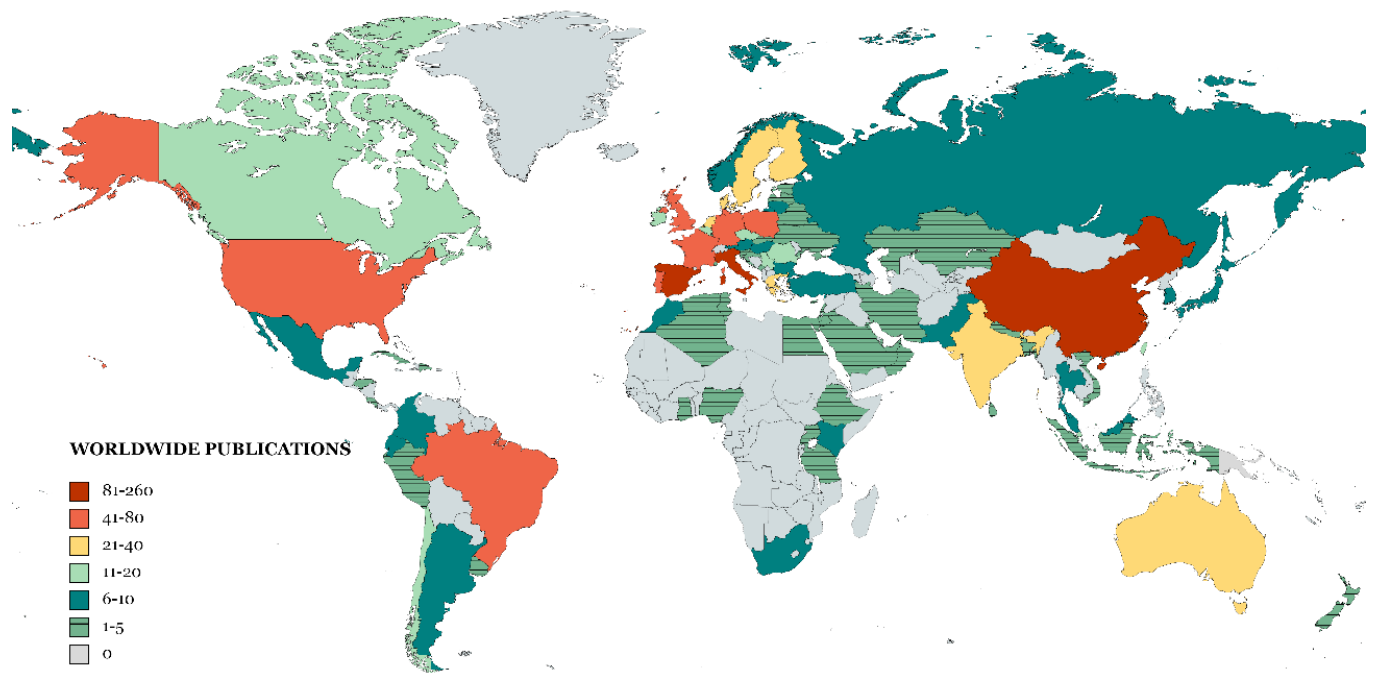


Figure 6. Publications by countries on CE applied to agriculture (2005–2021).

Table 6. Main keywords used in research from 2005 to 2021.

Keyword	2005–2021		2005–2011		2012–2016		2017–2021	
	A	%	R (A)	%	R (A)	%	R (A)	%
Sustainable development	148	13.96%	14 (2)	14.3%	3 (7)	17.1%	1 (139)	13.8%
Sustainability	132	12.45%	148 (1)	7.1%	32 (3)	7.3%	2 (128)	12.7%
Recycling	119	11.23%	137 (1)	7.1%	2 (9)	22.0%	4 (109)	10.8%
Agricultural robots	110	10.38%	21 (1)	7.1%	0	0.0%	3 (109)	10.8%
Waste management	108	10.19%	0	0.0%	34 (3)	7.3%	5 (105)	10.4%
Biomass	106	10.00%	0	0.0%	41 (2)	4.9%	6 (104)	10.3%
Fertilizers	94	8.87%	0	0.0%	24 (3)	7.3%	7 (91)	9.1%
Economics	82	7.74%	12 (2)	14.3%	1 (13)	31.7%	11 (67)	6.7%
Anaerobic digestion	80	7.55%	0	0.0%	0	0.0%	8 (80)	8.0%
Biogas	72	6.79%	0	0.0%	40 (2)	4.9%	9 (70)	7.0%
Wastewater treatment	69	6.51%	0	0.0%	539 (1)	2.4%	10 (68)	6.8%
Environmental impact	63	5.94%	0	0.0%	54 (2)	4.9%	13 (61)	6.1%
Food waste	63	5.94%	0	0.0%	265 (1)	2.4%	12 (62)	6.2%
Phosphorus	63	5.94%	0	0.0%	13 (4)	9.8%	14 (59)	5.9%
Agricultural wastes	61	5.75%	0	0.0%	4 (5)	12.2%	15 (56)	5.6%
Life cycle	58	5.47%	104 (1)	7.1%	30 (3)	7.3%	16 (54)	5.4%
Economic aspect	54	5.09%	0	0.0%	47 (2)	4.9%	17 (52)	5.2%
Climate change	52	4.91%	36 (1)	7.1%	17 (3)	7.3%	20 (48)	4.8%
Nutrients	52	4.91%	0	0.0%	376 (1)	2.4%	19 (51)	5.1%
Nitrogen	51	4.81%	0	0.0%	0	0.0%	18 (51)	5.1%

A: number of articles where it appears; %: percentage of total articles; and R: ranking.

Of the total sample of keywords (8565), that with the highest number of occurrences (148) in all research is sustainable development. This term represents 13.96% of the total sample analyzed and was used in the three periods. During the years 2005 and 2011, a total of two investigations mentioned this term compared to 139 publications between 2017 and 2021. The data indicate that it is from the last period that this concept began to gain relevance in the field of study. The term sustainability ranks second with a total of 132 occurrences. This concept, which represents 12.45%, has registered its greatest presence in

the last period (2017–2021), with a total of 139 investigations. In fact, all the terms recorded in Table 6 reach the highest percentage of variation when moving from the second period (2012–2016) to the third period (2017–2021). The terms with the latest incorporation in the research line are anaerobic Digestion and nitrogen. The two terms registered their first publications as of 2017 and, therefore, are framed in the last period. On the other hand, agricultural robots is the only concept that registered an occurrence between 2005 and 2011, and did not register any in the second period (2012–2016). In this sense, the next investigation that registered this concept dates to the year 2017, reaching 109 investigations for the last period analyzed (2017–2021).

It is common to find publications that combine keywords from different clusters, such as, for example, those that contain the concepts of “Wastewater Treatment” and “Sustainability”. Both terms belong to different topics of study and therefore to clusters of different color, although joint investigations can be identified, such as those entitled “Hybrid life cycle assessment of agro-industrial wastewater valorization” or “Reuse of Treated Effluents in a Food- Processing Industry” [64,71]. However, this study aims to identify future research trends, thus it analyzed the 330 keywords with the highest number of occurrences. In Figure 7, five clusters are identified in different colors depending on the group to which they belong and the size based on the investigations registered for each term. Each cluster represents a topic of interest within the line of research analyzed. In this sense, the relationships established between the terms refer to the times that they were included together in the articles, reflecting the affinity between these concepts. Therefore, to easily identify the relationships established between the most used keywords, the analysis was limited to those that registered the most occurrences and not to all that were considered in the entire time horizon.

The first group of keywords is represented in red. This cluster registered a total of 98 keywords and is represented by the terms “Sustainable Development”, “Sustainability”, “Food Waste”, “Food Production”, and “Recycling”. These terms are directly related to the subject of study since they record research on practices that ensure a future framed in circularity. Among the proposed approaches are studies focused on presenting sustainable food value chains as well as alternatives to reduce waste in the agricultural sector [13,72,73].

The second cluster, which is green in color, is defined by the terms “Chemistry”, “Biomass”, “Agricultural Robots”, “Fermentation”, and “Biodegradation”, and is made up of a total of 98 concepts. Research in this group of words focuses on proposing alternatives to managing the biomass created throughout the agricultural production process and, thus, that contribute favorably to EC. An example of this are the investigations “Circular economy in olive oil production-Olive mill solid waste to ethanol and heavy metal sorbent using microwave pre-treatment” and “From Agricultural Waste to Biofuel: Enzymatic Potential of a Bacterial Isolate *Streptomyces fulvissimus* CKS7 for Bioethanol Production” [74,75].

The third group of terms that registered the most occurrences is the one indicated in yellow. This cluster contains 44 concepts and publications that have the object of study of water treatment. In this case, the concepts “Wastewater Treatment”, “Water Conservation”, “Chemical Removal (water treatment)”, “Effluent Treatment”, or “Nutrient Recovery” are some of those framed in this object of study [76–79]. This issue is of vital importance in the line of research studied since agricultural activity is the one that consumes the most water worldwide. In this sense, the study of alternatives to be able to use wastewater in agriculture are far-reaching measures since they will reduce the harmful consequences derived from dumping wastewater while increasing the availability of water.

The fourth cluster appears in purple. This group of words, represented by the keywords “Fertilizers”, “Anaerobic Digestion”, “Biogas”, and “Biofuels”, focuses on finding answers to toxicity problems. In fact, the keywords used in this cluster suggest this subject of study [80,81]. This issue is considered of vital importance in agriculture since the uncontrolled use of insecticides and chemical products negatively affects the environment. For this reason, it is common to find publications that focus on presenting solutions to these problems based on more sustainable actions.

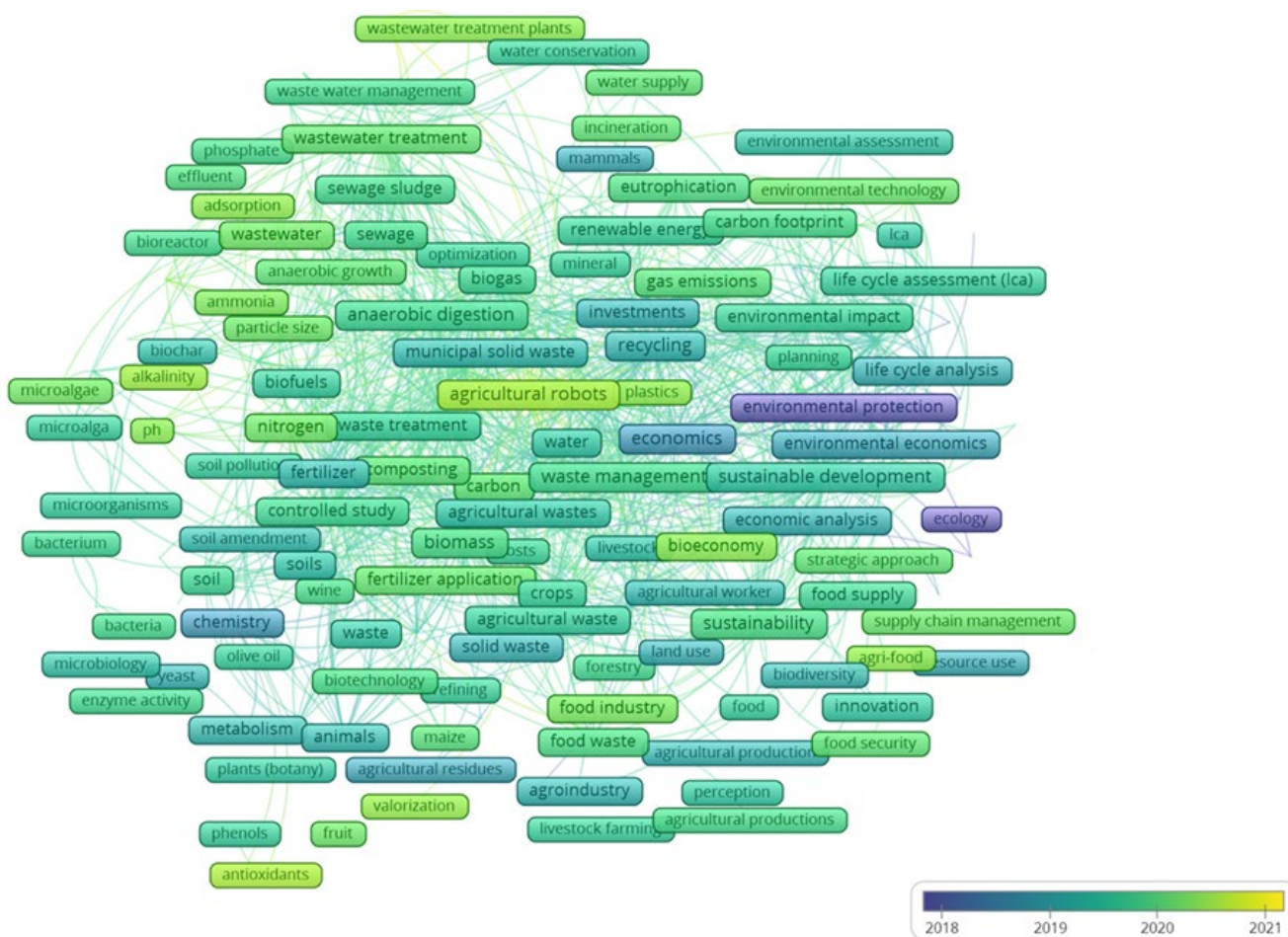


Figure 8. Timeline for the main keywords.

In the first period analyzed, namely 2005–2011, the investigations include the terms of environmental protection, pollution, air pollution, and cleaner production. Neither of these concepts receives numerous occurrences in the other two periods, hence, in Table 6, they are not among the most prolific keywords. In the second period, namely 2012–2016, the research object is extended to other topics associated with the terms of recycling, agricultural wastes, and sustainable development. However, it is not the only interest that arises in this period since economic terms begin to draw attention, such as economics and social effects, industrial economics, and economic development. In the third period (2017–2021), the aforementioned concepts are maintained and new ones are incorporated, such as fertilizers, phosphorus, biogas, or nitrogen. In addition, numerous publications begin to be registered with the concepts of agricultural robots, innovation, energy utilization, or energy efficiency; these terms are indicated in yellow and light green due to their low maturity in the research, which means that they are new terms that are emerging.

3.8. Discussion

The variables that have been analyzed in this results section show the current interest of the documents published in Scopus on CE applied to agriculture. Throughout the 17 years analyzed, scientific production research has been increasing exponentially and the last year (2021) is the one with the highest number of annual publications. The line of research studied is characterized by having a multidisciplinary nature since it registers very diverse thematic areas. In addition, the research framed in the main categories is directly related to the main groups of keywords used. In the case of environmental science, the terms of sustainable development and agroecology are framed among other concepts

since the purpose of this field of study is to ensure a sustainable future [13,72,73]. On the other hand, the terms energy and engineering are related to the search for actions that optimize waste management processes [84–86]. Therefore, both subject areas represent the terms of agricultural robots or nutrient recovery. Finally, if the disciplines of agricultural and biological sciences, Business, Management, and Accounting are addressed, reference should be made to the line of research analyzed, that is, to agricultural activities and food production, as well as to the possibility of implementing CE [74,75].

The journals that stand out for their contribution are Sustainability and the Journal of Cleaner Production. These two registered the highest values for their number of investigations. Even so, other journals are registered with high values in other variables, such as the average of citations (23.58) in Resources Conservation and Recycling, or the H-index (295) in Renewable and Sustainable Energy Reviews. As for the most active authors in CE research in the agricultural field, Xavier Gabarrell i Durany is worth mentioning, in first position, together with Sergio Ulgiati, in second position, and Luis Jesús Belmonte-Ureña, in third position. In addition, it is interesting to pay attention to the nationality of the most prolific authors since those of Italian and Spanish origin stand out. This is the reason, among others, why out of the 95 countries that publish, Italy and Spain are the most active. On the other hand, in regard to the country with the highest number of international publications and, therefore, with the highest percentage of the collaboration index, the UK and Germany are noteworthy, both with a value of 69%. Next, with a similar value, specifically 68%, is the USA.

These commented variables provide information about the interests that currently represent the line of research. Hence, the latest network map (Figure 8) reveals the new issues that arise, which are related to energy efficiency and innovation [87,88]. These relevant issues can bring together several areas and obtain favorable results since the incorporation of efficient and intelligent processes can satisfactorily promote the introduction of CE in agricultural activity and thus improve not only the production of the food that is grown, but also the reduction of the biomass and waste generated [89,90].

4. Conclusions

The objective of this research was to show the current status and evolution of research published in Scopus on CE and agriculture. To identify the main terms framed in the study area, a systematic review was carried out through the “snowball” technique, and to identify the most representative variables of the line of research, a bibliometric analysis was performed as well. The time horizon was 17 years, from the first publication made in 2005 to the present (2021). The total sample has included 1060 documents and recorded all the publications framed in the categories of books, book chapters, and original articles. In addition, to study the evolution in the line of research, the variables analyzed have been countries, authors, journals, organizations, subject areas, and keywords used.

The evolution of research suggests that the latent interest in presenting new alternatives that can promote CE in the agricultural field has experienced a steady increase over the past few decades, mainly from 2014 onwards. According to the analysis of disciplines provided in the results section, this line of research has a multidisciplinary nature; hence, different thematic areas are required to define the scope of the study. This can be considered from a favorable point of view since the more disciplines that are interested in and associated with the implementation and application of CE in agronomy, the more advances and improvements can be made sooner. In this context, recent studies of the sample identify the weaknesses derived from food production, such as waste generation, biomass, water pollution, and greenhouse gas emissions. For this reason, the scientific community is trying to introduce new actions that can progressively alleviate these negative effects on society, such as the use of chemical processes that give waste a second life, the cleaning of wastewater for use in other disciplines, or the relationship between energy and engineering to adopt production processes from a technically efficient perspective.

This relationship of concepts that clearly describes a problem–solution or weaknesses–actions dynamic can be located in the keywords section since the display map made represents the most widely used terms in the research and some of the publications framed in each group of words (cluster). As for the new lines of research that are making their way into this topic of study, their interest is revealed in knowing the results derived from technologically innovative processes, reconsidering the processing of generated waste and even expanding CE to other disciplines that can make an effective use of waste generated in agricultural activity. Examples of these interests are the various publications that have been mentioned throughout the paper in which it is intended to change the composition or processes of biomass to be used in other spheres, such as food for livestock, fertilizer in other farms, generation of energy, etc.

Regarding the future publications that can be made in this field of study according to the interests that are currently being raised, it would be essential to have practical applications and theoretical reviews that provide encouraging results about the extension of the life cycle of products. To do this, it would be essential to analyze all government documents, reports, and action plans that focus on this objective, which could significantly improve the understanding of the state of this line of research. From a theoretical point of view, it would be advisable to have publications that carry out a theoretical review on CE and agriculture. In this case, it would not be so much a matter of seeing the concepts studied in research but a matter of reviewing all these European and national regulations of the country of study to lay the foundations as to how measures and practices can improve and ensure a more sustainable future.

On the other hand, from a practical perspective, one could analyze the economic viability of introducing technical processes that reduce waste derived from food production or the commitment by companies of different productive activities to extend the useful life of a product, among others. In this sense, it is true that there are pilot studies which generate inspiring results, although they would have to be carried out under real conditions to provide valuable information for other sectors. In fact, the current results of this field of work could allow for broadening and improving the current vision on the difficulty of introducing CE in agricultural activities, giving way to an improvement in the willingness to pay attention to and improve the actions carried out in the field of agronomy so far.

This research study has some limitations that should be mentioned for future studies. The first refers to the methodology used. In this case, the current study may be completed with other qualitative or quantitative techniques that would contribute valuable information to the subject and allow for a complete vision of what is being analyzed. On the other hand, research could be developed in such a way that it not only studies the application of CE to agriculture but also all activities that imply a sustainable contribution, such as green economy, bioeconomy, or collaborative economy. For example, transactions between workers of different productive activities could be considered, which could entail tangible benefits for the entities involved. In addition, it would be ideal to consider the rest of the thematic areas involved, such as energy or engineering to optimize waste.

To conclude, the contribution of this research is highlighted by providing an up-dated synthesis of everything published in the Scopus database in the field of CE applied to agriculture. Thus, these results are encouraging to continue advancements in the introduction and design of new practices, while offering an updated vision of the state of the research. Finally, the close relationship established between this study and environmentally responsible policies may be an advance for policy makers who wish to introduce measures or reformulate programs according to the needs and interests.

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