West Science Agro
Vol. 4, No. 03, August 2026, pp. 281~293

Bibliometric Analysis of Circular Agriculture

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Article Info

Article history:

Received Aug, 2026
Revised Aug, 2026
Accepted Aug, 2026

Keywords:

Circular Agriculture
Circular Economy
Bibliometric Analysis
Sustainable Agriculture
Bioeconomy

ABSTRACT

Circular agriculture has become a significant research area where scholars explore ways to implement circular economy concepts in agriculture and promote resource efficiency, waste valorization, and sustainable food production. In this work, an attempt is made to analyze the evolution, intellectual structure, collaborative practices, and current research trends of circular agriculture publications through the application of a bibliometric approach. To achieve the stated objectives, the data collection process was conducted through the use of Scopus and relevant keywords concerning the area of interest, while VOSviewer software was employed to conduct citation analysis, co-authorship analysis, country and institutional collaboration mapping, keyword co-occurrence analysis, overlay visualization, and density analysis. It was revealed that the research area of circular agriculture had undergone a significant development and is strongly associated with such areas as circular economy, sustainability, bioeconomy, agricultural waste management, nutrient recycling, and resource recovery. Through the citation analysis, the most influential papers were found to be centered around topics such as transformation of agricultural supply chain, waste valorization, circular bioeconomy, and sustainable resource management. Collaboration analysis showed that there is a high level of international collaboration in the field of interest, while the key countries making their contributions to the development of circular agriculture include China, the USA, and several European countries. Through the analysis of keywords, it could be said that three key research dimensions are currently dominating in the field, namely circular resource management, sustainable agricultural transformation, and technological innovations in agriculture. Current research trends indicate growing interest towards bio-based solutions, circular supply chains, digital agriculture, and sustainable food systems.

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1. INTRODUCTION

The global agricultural system at the moment is under pressure as it needs to be able to ensure enough food production while addressing such issues as environmental degradation, depletion of resources, climate change, and socio-economic problems [1]. The traditional agriculture has contributed greatly to the increase of productivity. At the same time, the negative externalities created by the

traditional forms of agriculture include such as soil degradation, excessive use of water, loss of biodiversity, and the emission of greenhouse gases. The linear approach to agricultural production, "take-make-dispose," has resulted in the depletion of resources and increased waste production along the whole chain of the food provision [2]. Thus, there is a need for sustainable agricultural systems, in particular due to their resource efficiency, reduced waste production, and the ability to regenerate ecosystems [3]. Here comes the idea of the circular economy as an alternative to the traditional way of producing products.

Circular agriculture is the process of implementing circular economy strategies into agriculture through the reduction of resource loss, optimization of biological and technical cycles, and converting agricultural waste into inputs. While conventional sustainability strategies tend to focus mainly on limiting adverse environmental consequences, circular agriculture puts emphasis on the regeneration of resources in production cycles for as long as possible [4]. Circular agriculture waste utilization, nutrient recovery, composting, precision farming, agroecology, renewable energy implementation, and circular food supply chains are the key practices that have gained considerable importance to foster sustainable agriculture [5].

Growing academic interest in and application of circular agriculture is related to certain changes taking place within the world food system. Food waste and loss, higher input costs, use of nonrenewable inputs, and vulnerability to climatic changes have led researchers and practitioners in search of circular solutions. The recent research shows that circular agriculture could make a contribution to sustainable development through decreased dependence on external inputs, improved soil quality, enhanced agricultural networks, and rural economic development [6], [7]. Additionally, circularity is linked to technological innovation, such as digital agriculture, smart farming, biotechnological, and resource management practices that allow for efficient monitoring and resource use. That is why circular agriculture has become an interdisciplinary field that combines environmental science, agriculture, economics, management, and public policy.

Despite the significant amount of studies related to circular agriculture, this research area is quite fragmented because of the interdisciplinary nature of the topic and diversity of approaches applied in scientific investigations. Various aspects of circular agriculture have been studied by researchers in terms of sustainable farming techniques, nutrient management, bioeconomy development, circular food systems, waste management, and agricultural innovations. However, the fast growth in the number of research articles creates problems in analyzing the intellectual structure, major themes, influential studies, methodologies, and directions of further research in the sphere. Previously conducted literature reviews allowed for providing interesting conceptual discussions on circular economy application in agriculture, but there is an obvious lack of systematic quantitative analysis of the development of research in the area [8], [9].

The bibliometric analysis represents an efficient methodological tool for studying the evolution, structure, and development of scientific knowledge in a particular area of study. Thanks to the use of quantitative methods in analyzing scientific publications, bibliometric analysis allows identifying trends in publications, citation patterns, prominent authors, top journals, collaboration of institutions, connections between keywords, and emergent clusters of research [10]. It has been widely used in different areas related to sustainability, including the areas of circular economy, renewable energy, and sustainable development, due to the opportunity to comprehensively analyze extensive academic literature. In the area of circular agriculture, bibliometric analysis may help reveal important information about the development of this relatively new sphere of science, the gaps in knowledge, and the perspectives for further research in this sphere.

While there is a rise in the popularity of circular agriculture, the current research does not offer an in-depth investigation of the overall scientific landscape and intellectual progress of the research field. It is complicated to determine the core research topics, theories, contributions, and future research directions due to the multidisciplinary nature of the literature on the research topic. There is a scarcity of bibliometric studies focusing on the evolution, network analysis, and future directions of the research topic at the international level. Thus, there is a need for conducting a systematic study that can overcome these shortcomings and shed light on the research field.

The main objective of this study is to perform a bibliometric study on circular agriculture research, with the intention of analyzing the development of circular agriculture scientifically in terms of its intellectual structure and research trends. In other words, through this study we will try to analyze growth trends in publications, prominent authors and sources in circular agriculture, citation networks, international collaboration networks, and the main thematic clusters in circular agriculture. Through this, we will be able to understand how circular agriculture research has evolved into an inter-disciplinary research area.

2. METHODS

In this study, the use of bibliometric analysis method has been adopted to critically assess the process of development, intellectual structure, and emerging trends in research on circular agriculture. Bibliometric analysis is a quantitative research method where the use of statistical and visualization methods is made on scientific publications in order to determine patterns of knowledge development, research productivity, collaboration networks, and thematic change within a specific field [10]. The choice of the above method has been made considering the interdisciplinary nature of circular agriculture as it touches on areas such as agricultural science, environmental management, sustainability studies, technology, and economic development.

The process of data collection was carried out through the use of the Scopus database as the main source of scientific publications owing to its broad representation of peer-reviewed journals and high-quality academic literature. The search procedure was performed by employing certain keywords corresponding to circular agriculture and including such phrases as "circular agriculture," "circular farming," "agricultural circular economy," and other similar keywords. The search was limited only to research articles in peer-reviewed journals to guarantee the relevance and academic quality of the sample. Afterwards, the selected records were subjected to screening according to the inclusion and exclusion criteria that included such factors as the relevance of the publication, document type, language, and others.

Bibliometric analysis was carried out based on quantitative measures and science mapping approaches. The descriptive analysis was done in order to assess the publication trends, citation patterns, significant journals, prolific authors, and countries that have contributed to the circular agriculture research literature. In addition to this, network analysis was conducted in order to establish the intellectual relationships in terms of co-authorship analysis, co-occurrence of keywords, and citation analysis. Mapping was done using bibliometric tools like VOSviewer to develop visual maps of research networks and themes. These analysis techniques have enabled the study to find out the major research themes and trends in circular agriculture research literature.

3. RESULT AND DISCUSSION

3.1 Co-Author Analysis

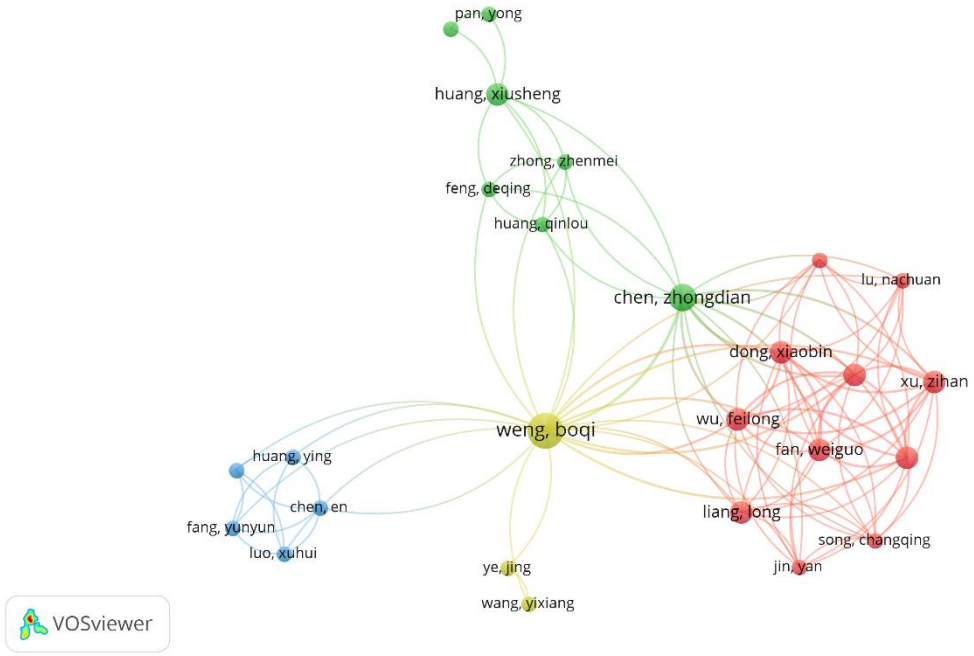

Figure 1. Author Visualization
Source: Data Analysis

The collaboration patterns among the researchers working in the circular agriculture domain have been illustrated through Figure 1. The network has been identified to be made up of many clusters, which clearly show the existence of research groups. Red cluster comprises the largest and highly collaborative group of authors, including Fan Weiguo, Xu Zihan, Wu Feilong, Dong Xiaobin, Liang Long, and Song Changqing. From this red cluster, it is clear that there exists high collaboration among the researchers, showing that this group is the central research community making significant contributions towards circular agriculture-related researches. High level of link density among the authors signifies frequent co-publication activity and knowledge sharing among them. Another major cluster is the green cluster, which comprises authors like Huang Xiusheng, Chen Zhongdian, Zhong Zhenmei, and Feng Deqing. Through the linkages among green and red clusters through authors like Chen Zhongdian and Weng Boqi, it can be said that knowledge exchange and interdisciplinary collaborations exist among the research groups.

The smaller clusters, including the blue cluster and yellow cluster, represent more specialized or emerging research groups within the circular agriculture domain. The blue cluster, involving authors such as Huang Ying, Chen En, Fang Yunyi, and Luo Xuhui, demonstrates a relatively isolated collaboration pattern, suggesting a focused research agenda or regional research collaboration. The yellow cluster, centered around Weng Boqi, acts as a bridging network connecting different research communities, indicating the potential importance of this author in facilitating knowledge integration among research groups.

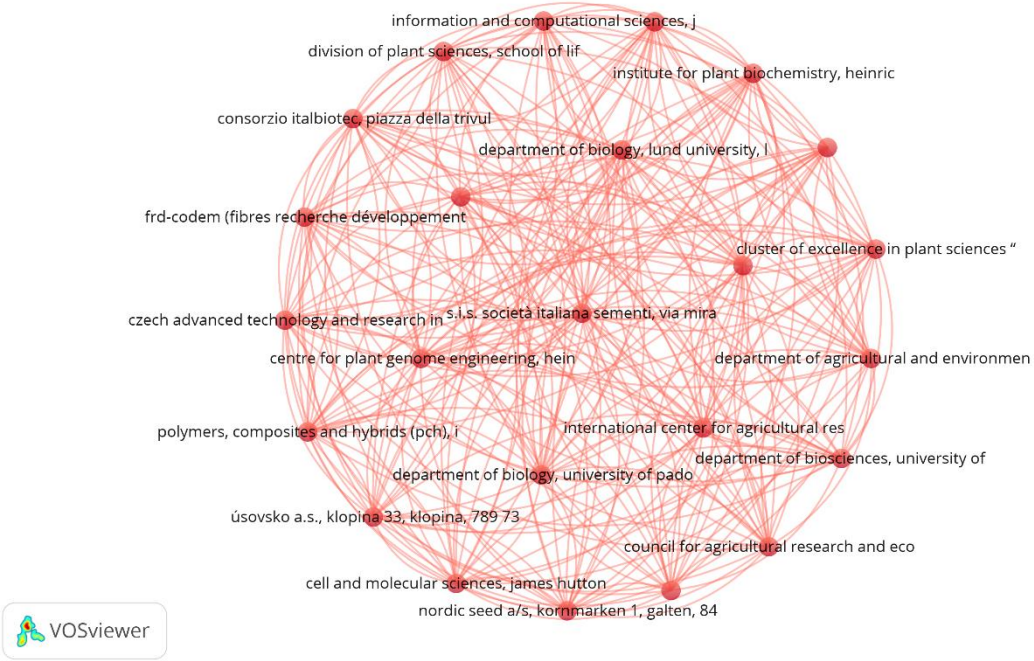

Figure 2. Institution Visualization
Source: Data Analysis

The network depicted in Figure 2 shows the intense focus of research activity on circular agriculture among the tightly knit cluster of academic and research institutions. In the case of this network, there exists only one dominant cluster, which means that there is intense collaboration and knowledge sharing among the institutions participating in research on this topic. There are many institutions, such as Institute for Plant Biochemistry, Heinrich Heine University, Department of Biology, Lund University, Department of Agricultural and Environmental Sciences, and International Center for Agricultural Research, which form important nodes of this network because of their dense connections with other institutions. The dense nature of the links reveals the collaborative nature of circular agriculture research, which also involves interdisciplinary research efforts in agricultural sciences, plant sciences, biotechnology, environmental studies, and computational sciences. The involvement of institutions from different countries, such as Italy, Germany, Sweden, the Czech Republic, and other parts of Europe, shows that the research agenda on circular agriculture has become an international phenomenon owing to the academic collaboration across borders.

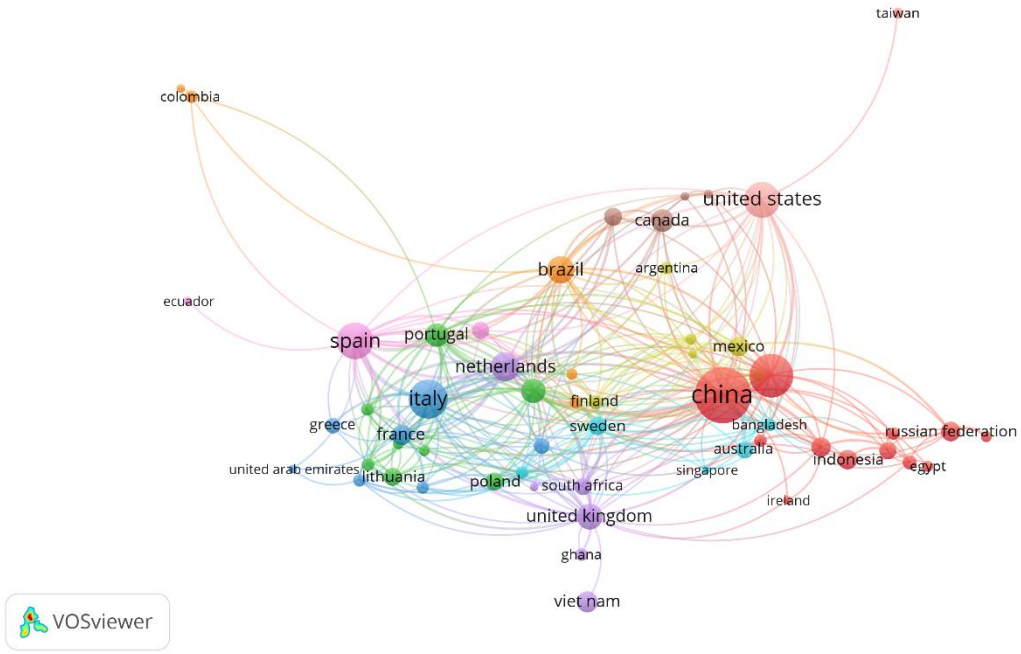

Figure 3. Country Visualization
Source: Data Analysis

Figure 3 presents the global research map of circular agriculture and proves that this domain of science is created through significant international collaboration. The research network is presented as a system of many interlinked clusters, where China, the US, Italy, Spain, and the Netherlands turn out to be the leading countries according to their node sizes and connectivity. China is one of the largest and the most influential nodes, which means that it contributes significantly to the research of circular agriculture and cooperates with many other countries, including Indonesia, Australia, Singapore, Bangladesh, and Russia. The US also turns out to be one of the key players by providing a wide network of links to European, Asian, and American countries because of its contribution to international research networks. The third group of countries collaborating with each other is European countries, including Italy, Spain, the Netherlands, Portugal, France, and the UK.

From the figure, one can see that there is an increasing trend for the diffusion of research on circular agriculture globally, moving away from scientific centers. Nations such as Brazil, Mexico, Argentina, South Africa, Vietnam, Colombia, and Ecuador are shown to be connected nodes but smaller in size, implying increasing participation in the global research community. There is evidence of connections between both developed and developing nations.

3.2 Citation Analysis

Table 1. Top Cited Literature

Citations	Authors and Year	Title
393	[11]	To identify industry 4.0 and circular economy adoption barriers in the agriculture supply chain by using ISM-ANP
393	[12]	Mapping of research lines on circular economy practices in agriculture: From waste to energy
221	[13]	AgroCycle - Developing a circular economy in agriculture
217	[14]	Agriculture waste valorisation as a source of antioxidant phenolic compounds within a circular and sustainable bioeconomy

178	[15]	Wastewater fertigation in agriculture: Issues and opportunities for improved water management and circular economy
175	[16]	A multi-criteria decision-making framework for agriculture supply chain risk management under a circular economy context
160	[17]	The management of agricultural waste biomass in the framework of circular economy and bioeconomy: An opportunity for greenhouse agriculture in Southeast Spain
145	[18]	Waste-derived nanobiochar: A new avenue towards sustainable agriculture, environment, and circular bioeconomy
143	[19]	Role of biochar in promoting circular economy in the agriculture sector. Part 1: A review of the biochar roles in soil N, P and K cycles
136	[20]	Circular nutrient solutions for agriculture and wastewater – a review of technologies and practices

Source: Scopus 2026

The top cited literature on circular agriculture demonstrates that research in this field has been primarily driven by efforts to integrate circular economy principles with agricultural sustainability, resource efficiency, waste management, and technological innovation. The most cited article by [11], with 393 citations, focuses on identifying barriers to Industry 4.0 and circular economy adoption in agricultural supply chains, highlighting the importance of digital technologies and systemic transformation in achieving circular agricultural practices. Similarly, [12], also receiving 393 citations, provides a comprehensive mapping of circular economy practices in agriculture, particularly emphasizing the transition from agricultural waste generation toward energy recovery and resource circulation. Other highly cited studies, such as [13] on the AgroCycle initiative and [14] on agricultural waste valorization, indicate that circular agriculture research strongly emphasizes the conversion of agricultural residues into valuable resources through bioeconomy approaches. Furthermore, studies by [15] and [20] expand the discussion toward circular water management and nutrient recycling, demonstrating the importance of closing resource loops within agricultural systems. The presence of research on biochar, waste-derived materials, supply chain risk management, and greenhouse agriculture, represented by studies such as [18], [21], and [22], shows that circular agriculture has evolved into a multidisciplinary research domain connecting environmental management, agricultural engineering, supply chain management, and sustainable production. Overall, the citation landscape indicates that the intellectual foundation of circular agriculture is built around three dominant themes: agricultural waste valorization, circular resource management, and technological and organizational transformation toward sustainable food systems.

3.3 Keyword Co-Occurrence

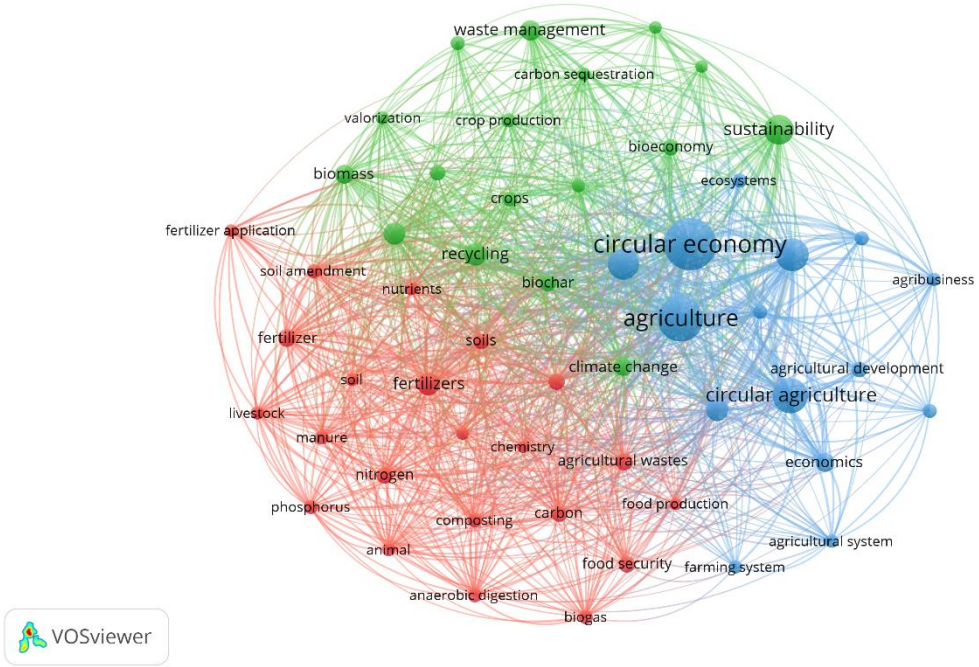

Figure 4. Network Visualization

Source: Data Analysis

Figure 4 presents the structural framework and key themes of research within the domain of circular agriculture. There are three prominent clusters in the network that reflect interconnected dimensions of research. Among them, the most significant and central keywords include "circular economy," "agriculture," and "circular agriculture." This signifies that these notions act as the intellectual basis of the research domain. The close connection of these keywords implies that the studies on circular agriculture are located predominantly at the intersection between the concepts of circular economy and agriculture. This means that scientists consider agriculture as both a production system and a circulation system where resources like waste, nutrients, energy, and biology can be recovered and recycled.

The blue cluster reflects the macro level view of circular agriculture which addresses the connection between the circular economy approach and agricultural development. Terms like circular agriculture, agricultural system, agricultural development, agribusiness, economics, farming system, food production, and food security suggest that this stream of research is concerned about the economic and systemic change in the process of agricultural activities. This cluster of studies focuses on the potential of circular approach in increasing the efficiency of agriculture, developing more resilient food system, and achieving the goal of sustainable development. The inclusion of economic and agribusiness terms in this cluster emphasizes the rising interest in the organizational and market aspects of circular agriculture.

The "green" cluster is concerned with the environmental/resource management side of circular agriculture research. Such keywords as waste management, recycling, bioeconomy, biomass, sustainability, ecosystem, carbon sequestration, crop production, and biochar indicate a high interest in closing the resource loops via biological/ ecological approaches. In the green cluster, there are many studies that show how scientists try to use agricultural wastes for something productive to improve the efficiency of nutrients, decrease impact on the environment and create sustainable farming. The link between circular agriculture and bioeconomy shows that scientists pay more attention to renewable biological resources.

The above-red cluster indicates the operations and technology related to the

recovery of resources in an agricultural setting. The keywords used to identify research focus include fertilizers, soil, nutrients, manure, nitrogen, phosphorus, composting, anaerobic digestion, agricultural waste, and biogas. This clearly shows that circular agriculture is highly linked with practical ways of handling agricultural waste and maintaining soil fertility through closed-loop methods.

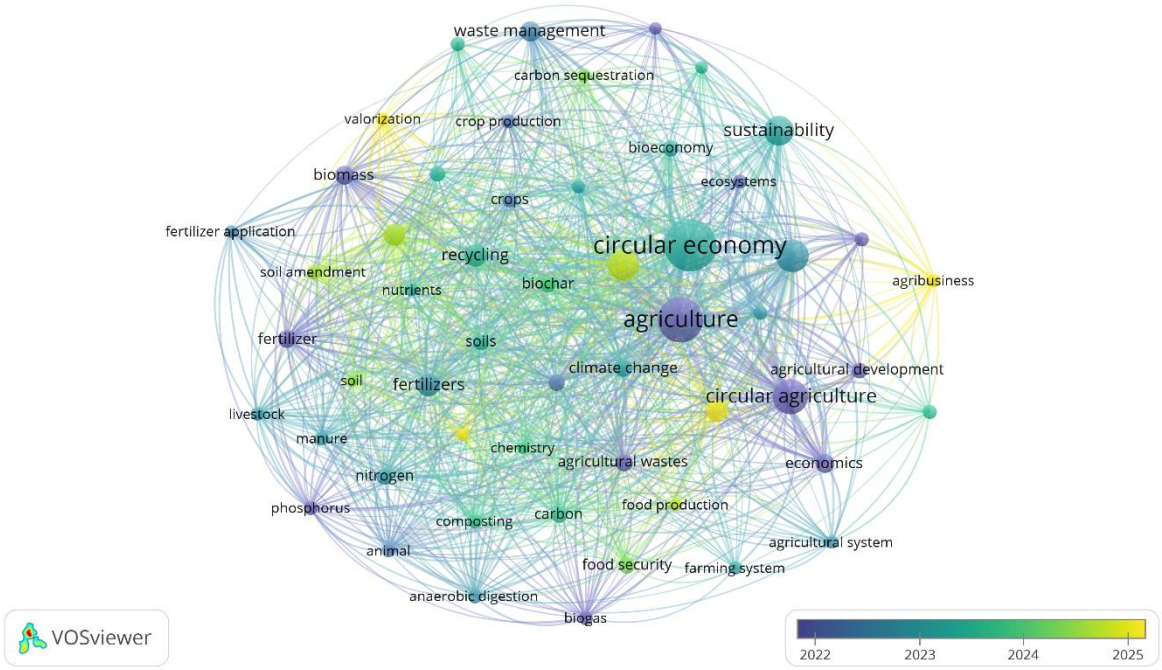

Figure 5. Overlay Visualization

Source: Data Analysis

Figure 5 illustrates the timeline of keyword development in circular agriculture from 2022 to 2025. Color coding in the visualization represents the average publication year of the keywords, where darker blue indicates earlier studies and yellow denotes recent emerging topics. The visualization demonstrates that keywords such as agriculture, circular economy, fertilizers, soil, nutrient management, and waste management have been studied through the years, indicating the key importance of these keywords in developing the knowledge structure of circular agriculture. The keywords exhibit high connectivity with other keywords, showing that the early studies were mostly concentrated on developing the connection between the circular economy and agricultural resource management.

Trends in more recent research papers can be observed in those keywords that have yellow and green color tones: circular agriculture, agribusiness, agricultural development, recycling, biochar, biomass, and agricultural waste valorization. The usage of these keywords demonstrates the tendency for discussion about the general concept of sustainability to move towards practical application of the circularity concepts to the field of agriculture. The recent research seems to focus on practical methods to make the use of the residues of agriculture as a valuable resource and other aspects of resource efficiency in agriculture.

Temporal mapping shows that research in circular agriculture has evolved from concerns with environmental management to systemic change. Research in recent years has shown an increasing concern for circular agriculture and its economic aspects like agribusiness, agricultural development, food production, and agricultural systems, suggesting that the scope of circular agriculture is shifting from environmental sustainability towards

sustainable businesses and food systems. The future scope of research may include digital agriculture, circular supply chains, precision farming, and policies related to the wide implementation of circular agriculture practices.

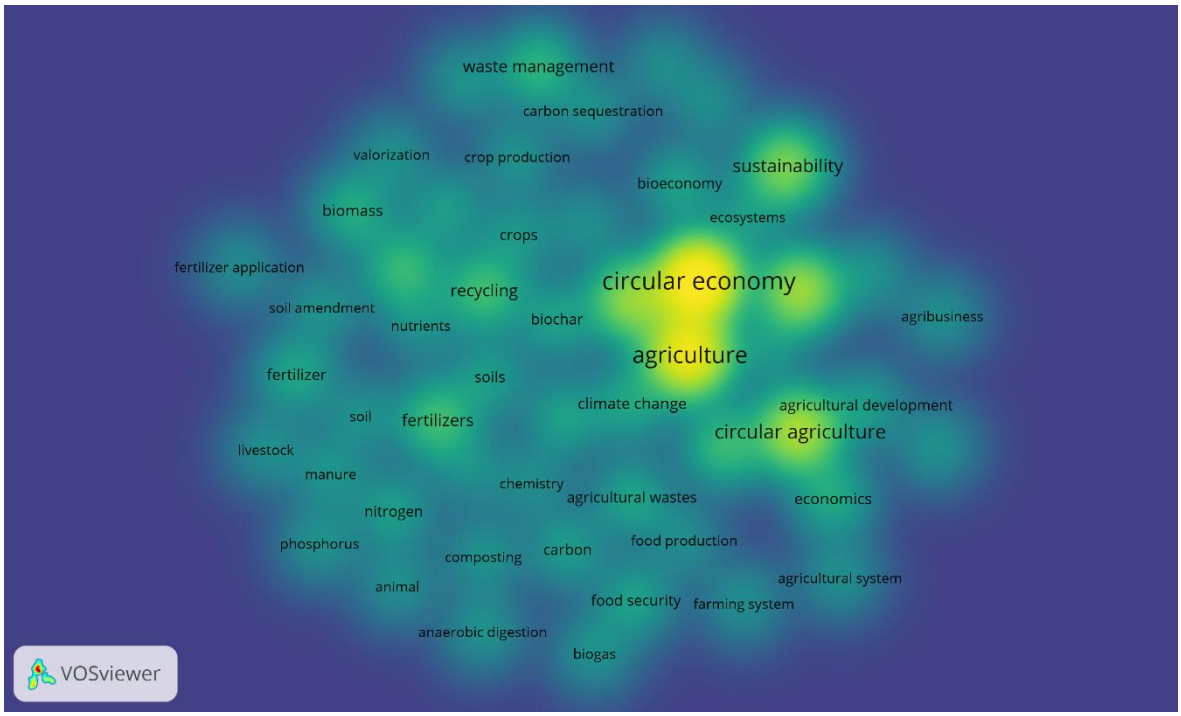

Figure 6. Density Visualization

Source: Data Analysis

Figure 6 emphasizes the concentration and focus of research interest in the field of circular agriculture. Those zones with the greatest density of occurrences can be observed in the keywords "circular economy," "agriculture," and "circular agriculture," meaning that such terms reflect the basic knowledge base of the research field. The intense yellow and green coloring around these keywords indicates high frequency and interconnection of the keywords among themselves. This proves the statement that the main positioning of circular agriculture research lies in the application of circular economy principles to agriculture, namely to the circulation of resources and sustainability in agriculture.

In addition to the main themes, the visualization also shows a number of secondary research areas with medium density, which include waste management, sustainability, bioeconomy, recycling, biomass, fertilizers, soil management, agricultural waste, and nutrient recovery. This set of topics suggests that there is increasing research into finding ways to create closed material flows via waste valorization, nutrient recovery, and biological resource use. There are also some low-density topics, such as biogas, anaerobic digestion, food security, farming systems, and agribusiness, which are rather specific research areas within the circular agriculture paradigm.

Discussion

It can be seen from the results of the bibliometric analysis carried out that circular agriculture has turned into an interdisciplinary field of study where the principles of the circular economy have been incorporated into sustainable agriculture, resource efficiency, and food system transformation. As it follows from the keyword co-occurrence analysis, circular economy, agriculture, and circular agriculture have become the key intellectual pillars of this field, showing that the concept of agriculture has become associated not only with agricultural products but also with the idea of creating a system that would allow for closing

the resource loop. It is obvious that the existing problems, such as climate change, resource depletion, and food security, cannot be solved by traditional linear agricultural models that imply resource extraction, intensive production, and waste creation. Thus, circular agriculture can be considered an important strategy aimed at recovering and reusing agricultural resources.

The thematic framework derived from this study reflects three main research directions in circular agriculture: recovery of resources and valorization of waste; sustainable agriculture management; and systemic transformation of food production systems. High citation articles show the relevance of creating value from agricultural waste through different methods like biochar creation, biomass use, composting, anaerobic digestion, and nutrients recycling. Based on the results, it is evident that current research of circular agriculture is not limited to waste management and has evolved towards the creation of value from agricultural ecosystems. Furthermore, the connection between circular agriculture and bioeconomy shows that researchers investigate biological resources as renewable inputs for sustainable production and decreasing the pressure on the environment.

In addition, both time and collaboration analysis imply fast development of circular agriculture research in an international setting, driven by the increasing cooperation between different countries, organizations, and scientific communities. The trends in recent research reveal the shift from the focus on purely environmental issues to wider factors of agribusiness, agricultural development, logistics and innovations. The occurrence of such issues as digital agriculture, circular logistics, and sustainable food system indicates that future research will be devoted more and more to practical ways of introducing circularity into different organizational, industrial, and governmental processes. Even though there is a significant amount of research carried out in this area already, future studies should focus on practical problems of introduction, economics, stakeholder cooperation, and new technologies for accelerating transition to circular agriculture.

4. CONCLUSION

This bibliometric analysis presents an extensive review of the evolution, intellectual structure, and current trends in circular agriculture research. From the results obtained, circular agriculture has grown to be a multidisciplinary field combining concepts of circular economy, sustainable agriculture, resources recovery, and food system transition. With respect to the trend analysis, citation analysis, collaborative networks, and keyword analysis, it is evident that the research domain mainly focuses on the integration of circular economy concepts in agriculture through waste valorization, nutrient recycling, development of bio-economy, and resource sustainability management. Increasing contributions of countries, institutions, and international research collaborations show that circular agriculture has gained global research interest in solving environmental and agricultural issues. In addition, new themes show a transition to broader uses of agribusiness, agricultural innovations, digital technologies, and sustainable food systems. This paper adds to the existing literature on the evolution and future directions of circular agriculture research, and the opportunities for further research are identified in relation to implementation policies, technological integration, and adoption of circular practices in various agricultural contexts.

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