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Bibliometric Review of Research on Green Farming Practices in Agriculture: A Global Literature Overview 2010–2024

Loso Judijanto
IPOSS Jakarta, Indonesia

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ABSTRACT

Green farming practices have emerged as a critical approach to addressing the interconnected challenges of food security, environmental degradation, climate change, and sustainable agricultural development. As global interest in environmentally responsible farming continues to expand, a comprehensive understanding of the evolution and intellectual structure of this research field becomes increasingly important. This study aims to examine the development of green farming practices research through a bibliometric analysis of global scientific publications published between 2010 and 2024. Data were collected from the Scopus database and analyzed using bibliometric techniques and VOSviewer to explore publication trends, influential literature, collaboration networks, and thematic developments within the field. The findings reveal a significant growth in research output over the study period, reflecting increasing academic and practical interest in sustainable agriculture. Citation analysis identifies soil health, integrated soil fertility management, agroecology, conservation farming, and food security as the most influential research themes. Co-authorship and country collaboration analyses indicate active international cooperation, with China, India, the Russian Federation, the United States, and several European countries serving as major contributors to the field. Keyword co-occurrence, overlay, and density analyses demonstrate a transition from traditional sustainability-oriented agricultural studies toward technology-driven approaches characterized by artificial intelligence, machine learning, precision agriculture, smart agriculture, Internet of Things (IoT), blockchain, digital transformation, and Agriculture 4.0. The results suggest that future advancements in green farming practices will increasingly rely on the integration of digital technologies and sustainable agricultural principles to enhance productivity, resource efficiency, climate resilience, and food security.

Corresponding Author:

Name: Loso Judijanto
Institution: IPOSS Jakarta
Email: losojudijantobumn@gmail.com

1. INTRODUCTION

The agriculture sector has played a major role in maintaining food security in the world, economic growth, and the livelihoods of people in the rural areas. The intensification of agriculture within the last few decades has

resulted in numerous environmental problems such as degradation of soils, loss of biodiversity, pollution of water bodies, and production of greenhouse gases [1]. The conventional agriculture approach based on the use of chemical fertilizers, pesticides, and extensive use of land has been blamed for ecological imbalance and climate risks. As the world population keeps growing and climate change keeps becoming a problem in most parts of the world, there is an increasing need for sustainable food production systems in the coming years [2].

Green farming entails environmental-friendly methods that help reduce harm to the environment and ensure the efficient use of natural resources. Green farming methods include organic farming, conservation agriculture, agroforestry, integrated pest management, climate smart agriculture, precision agriculture, and regenerative farming methods. The main objective of green farming is to ensure reduced carbon emissions, improved soil health, conserving water resources, and increasing biodiversity [3]. The need for sustainability has led to increased efforts by governments, international bodies, and scientists to advocate for green agriculture. Sustainability goals such as climate change action, responsible consumption and production, and zero hunger have led to increased focus by scientists on sustainable agriculture.

The rising international focus on green farming has resulted in a considerable number of scientific publications in diverse fields such as environmental science, agronomy, agricultural economics, and sustainability. Scientists have analyzed various aspects of green agriculture such as innovation, policies, carbon footprint reduction, digital agriculture, and adoption behavior of farmers. In addition, the application of innovative technology like artificial intelligence, remote sensing, and Internet of Things (IoT) has made sustainable agriculture a multidisciplinary area of study [4]. The growing body of scholarly work indicates that sustainable agriculture is not only important for the environment but also a vital economic and social need for the coming generation. Studies based on bibliometrics reveal that the production of scientific articles concerning sustainable agriculture has witnessed a significant rise since the early 2010s, with prominent contributions from countries like China, the US, India, and some European countries [5].

Despite the extensive proliferation of research works on green farming, the current state of literature in this field is still rather fragmented in terms of its thematic orientation, methodology, and geographical coverage. Most researchers tend to narrow their scope down to individual aspects of sustainable agriculture such as organic agriculture and climate-smart agriculture; therefore, there is no overall view of the current state of research in this area. Besides, the differences in terminologies, scopes, and approaches used to examine the issue complicate the identification of the major tendencies, leading researchers, collaboration networks, and emerging topics in this field. In this regard, bibliometric analysis appears to be a promising scientific technique that allows for conducting an objective assessment of the progress of scientific investigations and building the intellectual structures of a certain field of study.

A bibliometric study focused on the topic of green farming practices between 2010 and 2024 is especially appropriate since this time period marks an important era of transition within the field of agricultural sustainability studies. Within these years, there was an increasing amount of attention placed on topics including climate change mitigation, regenerative agriculture, renewable energy sources, carbon-neutral farms, and sustainable food systems. There was also a growing emphasis on the significance of green agriculture in minimizing environmental impacts while promoting resilience against climate risks. Furthermore, the emergence of policies such as the Paris Agreement and the United Nations Sustainable Development Goals facilitated further interest and funding opportunities within sustainable agriculture. There was also a noticeable rise in collaborative efforts between multiple

disciplines and advancements within digital technology for agricultural purposes during this time period. Thus, carrying out a global bibliometric study of green farming practices within these years will be crucial to gain a better understanding of its historical development, present state, and future trajectory.

Even though the body of literature on green farming strategies has considerably increased in the last decade, a relatively poor awareness exists about the development, knowledge structure, and themes in this domain of scientific research. Previous studies have been confined to discussing green farming methods in particular or conducting a regional case study analysis, which makes the body of knowledge about trends in publications, key players in this area, collaboration networks in green farming research, and emerging topics relatively poor. Moreover, the rapid growth in the number of scientific publications in the period between 2010 and 2024 has complicated the task of researchers in defining prominent themes in the research on green farming. Conducting a bibliometric study can help address this problem. The objective of this research is to undertake bibliometric analysis of international research studies related to green farming technologies within agriculture from 2010 to 2024.

2. METHODS

The study adopted a bibliometric research methodology for the systematic examination of the development of the world scientific literature concerning the theme of sustainable farming in agriculture between the years 2010 and 2024. Bibliometric analysis is a quantitative research methodology that is often utilized by researchers to examine publication trends, research performance, scientific collaboration, and the development of themes within an area of study. Through the use of bibliometric analysis, researchers can pinpoint influential publications, prolific authors, prominent institutions, and developing research themes. This particular study adopted the bibliometric methodology since it gives a complete understanding of developments in research within an area of study.

In this research, the source of the data gathered is internationally accepted scientific databases such as Scopus and Web of Science since they provide a wide range of scientific publications. These articles could be located based on keywords regarding green agricultural practices, such as “green agriculture,” “sustainable farming,” “organic farming,” “climate-smart agriculture,” “regenerative agriculture,” and others. It is important to note that the selected articles were published from 2010 until 2024 and were written in English. At this stage, the sources include only journal articles, conference papers, and review articles. Next, the data gathered underwent a process of screening to eliminate irrelevant records and duplicates.

The bibliometric study was carried out by means of VOSviewer for creating network graphs and theme maps. Various methods of bibliometric analysis have been utilized, which include publication trends analysis, citation analysis, co-authorship analysis, co-citation analysis, and keyword co-occurrence analysis. For instance, the publication trend analysis method was employed in order to assess the dynamics of publication activity, citation analysis helped to discover key publications, authors, and journals in this sphere of science. Meanwhile, co-authorship analysis was implemented to reveal the patterns of international cooperation in the field under discussion, and keyword co-occurrence analysis helped to detect the most popular themes and new trends in the area of green farming studies.

3. RESULT AND DISCUSSION

3.1 Co-Author Analysis

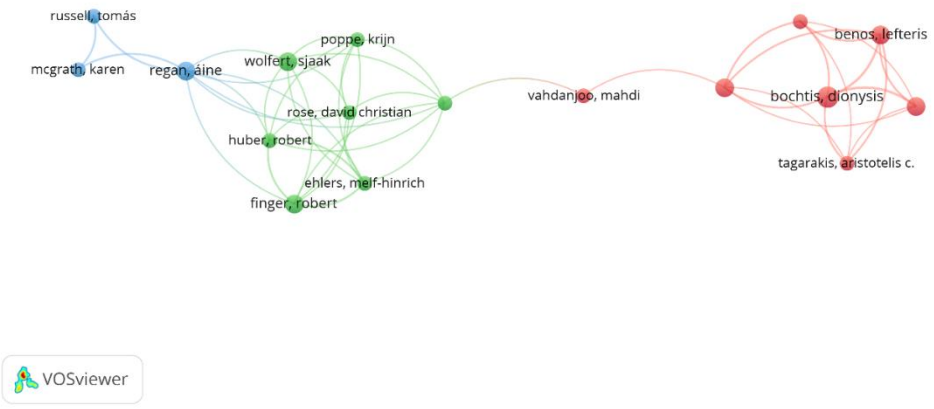

Figure 1. Author Visualization
Source: Data Analysis

The visualization of the co-authorship network shows three author collaboration clusters in the scientific domain of green farming practices, which shows that scholars tend to be connected with certain researchers' groups. The first cluster (colored green) is represented by David Christian Rose, Sjaak Wolfert, Robert Huber, Robert Finger, Mel-Hinrich Ehlers, and Poppe Krijn. It suggests that there is a well-developed collaboration circle of researchers involved in the investigation of digital agriculture and sustainable farming systems. In turn, the second cluster (colored red) includes Dionysis Bochtis, Aristotelis C. Tagarakis, and Lefteris Benos, who represent an influential research stream that probably explores topics related to precision agriculture and smart farming. The third collaboration cluster (colored blue) includes Aine Regan, Karen McGrath, and Russell Tomás. At the same time, it should be noted that Mahdi Vahdani Joo plays the role of the bridging author connecting two groups.

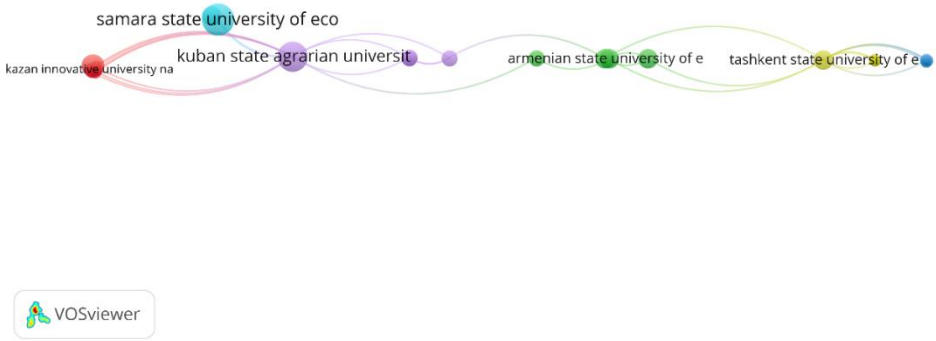

Figure 2. Institution Visualization
Source: Data Analysis

Based on the institutional collaboration network, the research on the implementation of green farming methods is characterized by a small group of universities that are well-connected with each other and function as key nodes in terms of spreading knowledge. Kuban State Agrarian University acts as one of the most significant institutions in the network, which is determined by its large-sized node and numerous connections with other universities. In addition, collaboration between Kuban State Agrarian University and Samara State University of Economics can be considered active since both universities make a significant contribution to research. Moreover, the network includes collaboration with various other institutions such as Armenian State University of Economics and Tashkent State University of Economics, thus forming a chain of connections with research communities of different countries. At the same time, smaller institutions such as Kazan Innovative University and several other affiliated universities, although located at the periphery of the network, are connected to the main network due to the development of their collaboration. Several clusters of universities, linked by only a few bridges of institutions, indicate the regional nature of cooperation in research of the topic, especially for Eurasian universities.

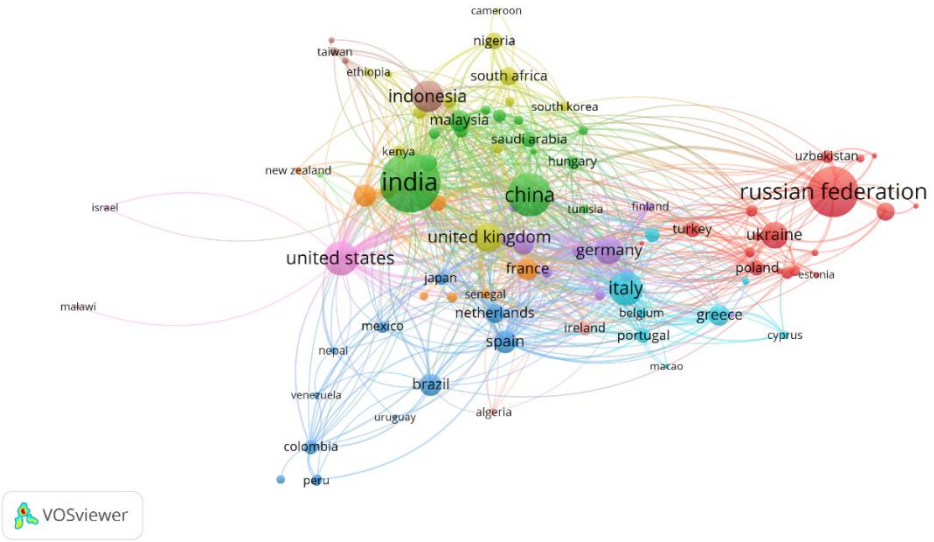

Figure 3. Country Visualization
Source: Data Analysis

The country collaboration network shows how research into green farming methods is highly internationalized through various countries acting as collaboration centers for science in the area. Countries such as China, India, and Russia prove to be very influential in the area through having big nodes as well as being collaboratively linked to many other countries. China emerges as one of the key nodes in the center where there are many connections with both developing and developed countries, demonstrating how it is increasingly assuming a lead role in sustainable agriculture research. Similarly, India plays an important role in collaboration networks, having many links to countries around the world in areas of Asia, Europe, Africa, and America. Another prominent collaboration cluster is that of the Russian Federation which has many links with countries from Eastern Europe and Central Asia such as Ukraine, Poland, and Uzbekistan. Besides, countries such as the United States, United Kingdom, Germany, Italy, France, and the Netherlands act as bridging countries facilitating linkages between different clusters in the network. In addition, emerging economies are

increasingly participating in sustainable agriculture practices, as demonstrated by countries such as Indonesia, Malaysia, Nigeria, South Africa, Saudi Arabia, and Ethiopia.

3.2 Citation Analysis

Table 1. Top Cited Literature

Citations	Authors and Year	Title
732	[6]	Soil enzyme activities, microbial communities, and carbon and nitrogen availability in organic agroecosystems across an intensively-managed agricultural landscape
505	[7]	Integrated soil fertility management: Operational definition and consequences for implementation and dissemination
394	[8]	Urban gardens, Agriculture, And water management: Sources of resilience for long-term food security in cities
350	[9]	Agroecological responses of heavy metal pollution with special emphasis on soil health and plant performances
334	[10]	The impact of farm size on agricultural sustainability
303	[11]	The fate of nitrogen in grain cropping systems: A meta-analysis of 15N field experiments
241	[12]	Food security for Africa: An urgent global challenge
236	[13]	Sustainable Agro-Food Systems for Addressing Climate Change and Food Security
231	[14]	Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research
230	[15]	An innovation systems approach to institutional change: Smallholder development in West Africa

Source: Scopus 2026

The most significant literature in the field of green farming practices appears to be mostly composed of papers concerned with soil quality and sustainable soil fertility, agroecology, food security, and innovative institutions, as illustrated in Table 1. The highest cited paper by [6], having 732 citations, proves that enzyme activity in soil, microbial population, and nutrient availability are critical concerns of research in this area. The high citation count for [7] and [11] again highlights the significance of integrated soil fertility and nitrogen management in sustainable farming. Other papers contribute significantly to research by broadening the scope of the field towards urban agriculture, heavy metals, farm sizes, conservation agriculture, and food security.

3.3 Keyword Co-Occurrence

Based on the keyword co-occurrence network, the research on green farming focuses heavily on incorporating concepts of sustainability with digital technology within agriculture. "Agriculture" represents the node with the highest centrality in the network, meaning that it acts as the core element that connects various areas of research. Keywords such as sustainable development, sustainability, food security, and agricultural sector show that the primary motivation behind green farming research is achieving a balance between agricultural production and preservation of nature and society.

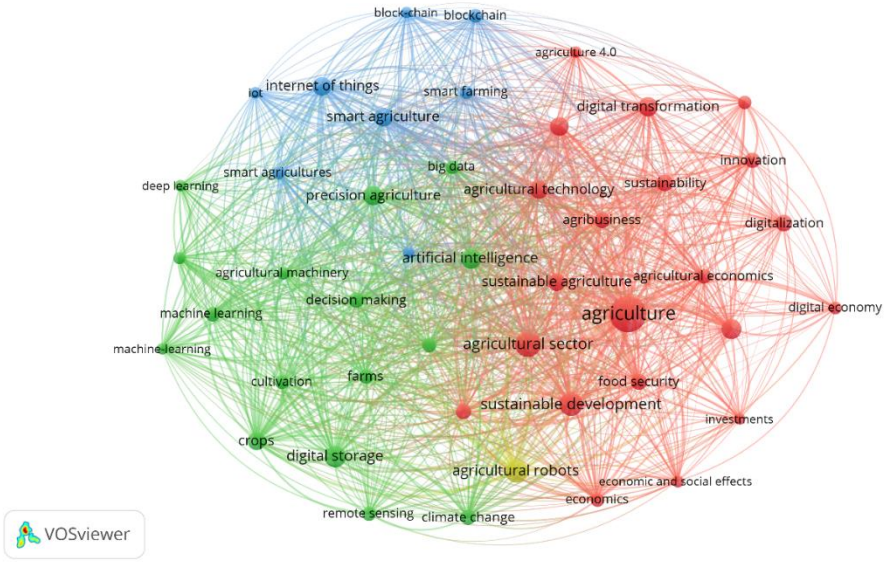

Figure 4. Network Visualization
Source: Data Analysis

The red cluster consists of studies concentrating on topics related to agricultural transformation and innovation as well as sustainability. The keywords include concepts like digital transformation, innovation, digitalization, agricultural economics, agribusiness, and digital economy. Such terms suggest the rising trend in academia of exploring the ways in which technological innovations can improve the efficiency of agriculture and contribute to sustainable development. Green farming appears to be seen not just as an environmental issue but also an economic and organizational one.

The green cluster includes the papers that deal with technology and farm management practices. Such terms like artificial intelligence, precision agriculture, machine learning, decision making, remote sensing, crops, and agricultural machinery show that there is a significant number of studies dedicated to data-based techniques in farming. These methods help to maximize the efficiency of farms, minimize their impact on nature, and provide farmers with tools for improving sustainable agriculture techniques.

Keywords relating to smart farming technology and digital infrastructure have been placed in the blue category. Some of these keywords include the Internet of Things (IoT), smart agriculture, smart farming, blockchain, big data, and Agriculture 4.0, all of which emphasize the increasing use of digital networks and connectivity in the agricultural industry. The strong correlation between these words implies that there is a growing interest in studying how digital connectivity, monitoring, traceability, and automation can aid in developing sustainable and efficient farming practices.

This shows that green agriculture research has progressed from being focused on sustainable agricultural methods to adopting a technology-based framework for achieving sustainable agriculture. The tight connections of sustainability principles to artificial intelligence, precision farming, IoT, and digital transformation point to the fact that future research will revolve around a synergy of environmental sustainability and digitalization trends. From this perspective, the realization of sustainable agriculture will depend more on the use of advanced technologies that can enhance output and ensure food security.

The overlay map allows for an understanding of how the topic areas of research within green farming have progressed through time based on how keywords have evolved. The color scheme includes blue and purple keywords (representing earlier topic areas dating back to

2022), while more recent topic areas are represented using green and yellow colors (approximately 2023 to 2024). Important terms like agriculture, agricultural industry, sustainable development, and sustainable agriculture are located centrally within the visualization and are connected to both early and recent topic areas, meaning that sustainability has been an important aspect from the beginning of the discipline's development.

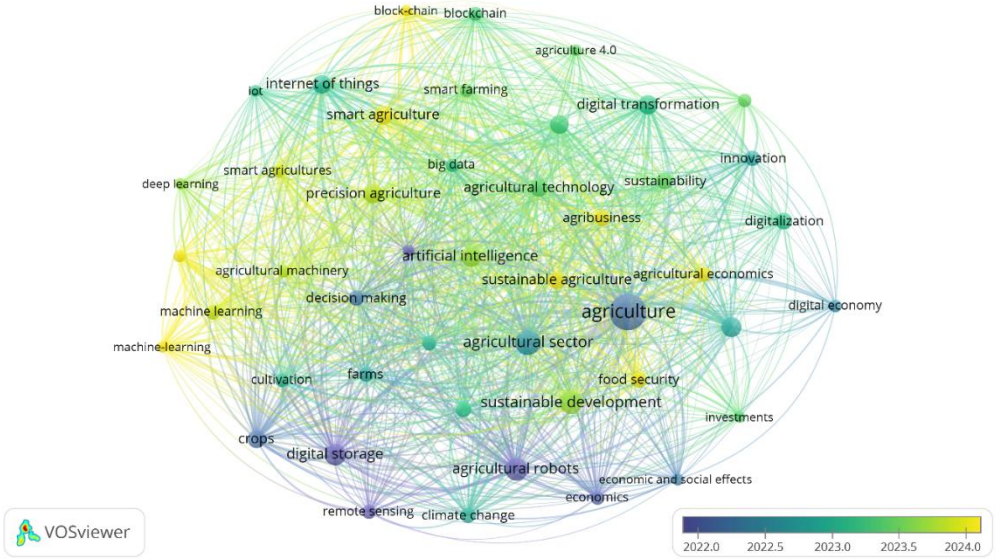

Figure 5. Overlay Visualization

Source: Data Analysis

As shown in the visualization below, previous studies were mainly related to issues like computer memory, agricultural robots, remote sensing, climate change, and economics, colored in dark blue and dark purple tones. Such aspects relate to the early stage of using digitalization and environmental issues in agriculture. Over time, research interests became oriented to artificial intelligence, precision agriculture, smart agriculture, IoT, big data, and even blockchain, indicated in green-colored nodes. In other words, there is an increase in the number of studies on technologies capable of making agricultural processes more efficient and sustainable.

The more recent trends, marked by yellow colors, have to do with machine learning, machine learning uses, agricultural machinery, and new techniques used for precision agriculture. The fact that these areas are now being regarded as new topics implies that modern research tends to rely more and more on intelligent automation and predictive analytics for improving agricultural productivity without harming the environment. The move from sustainable agricultural management approaches to advanced digital technologies, such as artificial intelligence, implies that future research in sustainable agriculture will be concerned with the integration of these tools into sustainable agriculture techniques.

Density visualization is a tool for identifying the main topics that are covered extensively in the literature of green farming practices. Yellow regions denote hotspots of high keyword association and frequency while green and blue denote topics of low frequency. "Agriculture" turns out to be the most important keyword that has been used extensively and centrally in the literature as denoted by its bright color. Some of the other closely located hotspots to this keyword include agricultural sector, sustainable development, sustainable agriculture, agricultural economics, food security, and artificial intelligence, suggesting that the focus

of the literature is on developing sustainable agriculture via technological and economic means.

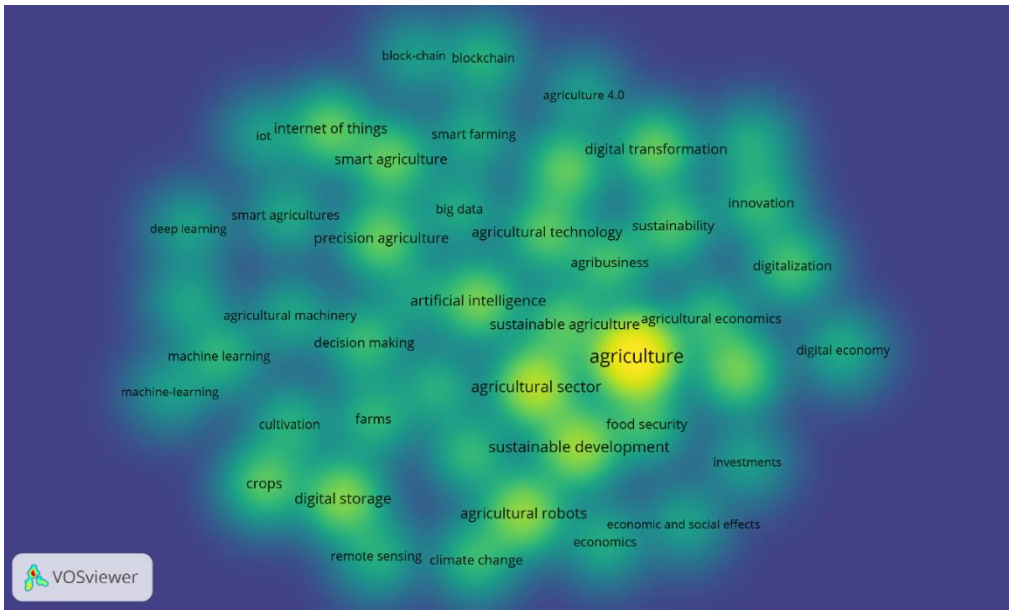

Figure 6. Density Visualization

Source: Data Analysis

However, the figure shows various emerging research topics that complement each other and exist around the main cluster. Areas such as precision agriculture, smart agriculture, Internet of Things, digital transformation, big data, blockchain, machine learning, agricultural robots, and remote sensing represent clusters of medium density, as researchers become interested in digital solutions and intelligent farming techniques. In addition, it is worth noting the emergence of clusters of keywords associated with such topics as climate change, economics, investments, and digital economy. However, their density is much lower than that of the most common sustainable technology-oriented clusters.

4. CONCLUSION

This bibliometric study provides an exhaustive insight into the evolution of research on sustainable practices in agriculture globally during the period of 2010 to 2024. The results show that there has been a considerable rise in the interest in sustainable agricultural practices owing to the issues related to food security, environmental problems, climate change, and resource efficiency. The results of citation analysis suggest that the most cited papers are largely those concerning the topics of soil health, integrated soil fertility management, agroecology, conservation agriculture, and sustainable food production. In addition, the analyses of collaboration networks also point to the high involvement of international collaborations within the scope of sustainable agricultural practices with China, India, the Russian Federation, the USA, and several European countries being the primary sources for collaboration.

The analysis based on the use of keywords, overlay maps, and density plots demonstrates that research in green farming has been progressing from the adoption of sustainable agriculture practices to a technology-based model. Sustainability, food security, and agricultural development are important issues; however, more recent concepts such as artificial intelligence, machine learning, precision agriculture, smart agriculture, IoT, blockchain, digital transformation, and Agriculture 4.0 have become popular topics in academic studies. It

can be assumed that future agricultural sustainability would involve the combination of modern technologies with sustainable agricultural practices. Thus, future research should promote interdisciplinary research and cooperation between countries regarding the practical applications of intelligent farming technologies.

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