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Bibliometric Analysis of Digital Agriculture Research in the Agricultural Sector

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ABSTRACT

The rapid advancement of digital technologies has significantly transformed the agricultural sector, giving rise to the concept of digital agriculture. This study aims to analyze the global development, thematic structure, and collaboration patterns of digital agriculture research through a comprehensive bibliometric approach. Data were retrieved from the Scopus database covering publications from 2010 to 2024 and analyzed using VOSviewer to examine co-authorship networks, country collaboration, keyword co-occurrence, overlay visualization, and density mapping. The results indicate a substantial growth in scholarly output, particularly in recent years, reflecting increasing global attention to agricultural digitalization. Core research themes revolve around digital transformation, artificial intelligence, Internet of Things (IoT), precision agriculture, and sustainable development. Emerging topics such as blockchain, digital platforms, and innovation ecosystems suggest a shift toward integrated and system-level approaches. Country collaboration analysis highlights China, India, and the United States as major contributors, supported by active European research networks. Digital agriculture research has evolved from a technology-centered perspective toward a broader ecosystem-oriented framework integrating sustainability, supply chain digitalization, and innovation. The findings provide a comprehensive overview of the intellectual structure of the field and identify potential directions for future research, particularly in governance, inclusivity, and long-term socio-economic impact

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1. INTRODUCTION

The agricultural sector is undergoing a significant transformation driven by technological advancements. Digital agriculture, which integrates information technology with farming practices, is at the heart of this revolution. This integration encompasses a range of technologies, such as Internet of Things (IoT), artificial intelligence (AI), data analytics, and satellite imagery, among others [1]. These innovations are enhancing productivity, improving resource management, and fostering sustainability in farming practices worldwide. As the global population continues to grow, the demand for food production is increasing, necessitating more efficient and sustainable agricultural practices [2]. Digital agriculture, by enabling real-time data collection and analysis, promises to meet these challenges and revolutionize traditional farming methods. In recent years, the agricultural sector has witnessed a surge in the adoption of digital technologies. These technologies have the potential to reduce costs, optimize crop yields, improve decision-making processes, and mitigate environmental impacts. The development of digital tools, including precision farming, autonomous tractors, and automated systems, is enabling farmers to make more informed decisions based on data-driven insights [3]. The rise of digital platforms has also democratized access to agricultural information, allowing small-scale farmers in developing regions to leverage cutting-edge technologies for increased productivity and profitability [3], [4].

The adoption of digital technologies is not limited to developed countries. Emerging economies, especially in Asia and Africa, are experiencing rapid growth in digital agriculture. For example, in India, mobile applications and e-commerce platforms have been implemented to provide farmers with access to market prices, weather forecasts, and expert advice [5]. Similarly, in Sub-Saharan Africa, satellite data and drones are being used to monitor crop health, assess soil quality, and guide precision irrigation. These developments suggest that digital agriculture has the potential to bridge the technological gap between developed and developing countries, ensuring that all farmers can benefit from the innovations driving the industry forward. Moreover, the impact of digital agriculture on the sustainability of farming practices cannot be overstated. By reducing the overuse of chemical inputs such as fertilizers and pesticides, digital tools are helping to minimize environmental harm and promote ecological balance [6]. Precision agriculture, in particular, enables farmers to apply inputs more efficiently, which not only boosts yields but also reduces waste and environmental degradation. Through better data management, digital agriculture is aligning with the global sustainability goals of reducing food waste, conserving water, and mitigating the effects of climate change [3].

As the digital agriculture field continues to evolve, a wealth of academic research is emerging, exploring the various facets of this technological transformation. These studies span multiple disciplines, including agricultural engineering, environmental science, economics, and social sciences, highlighting the multifaceted nature of digital agriculture. The growing body of research calls for a systematic exploration of the field to understand the current trends, challenges, and future directions of digital agriculture. Despite the increasing interest and investment in digital agriculture, there remains a lack of comprehensive understanding regarding the scope, trends, and key areas of research within this field. The academic community has yet to fully map out the intellectual structure of digital agriculture research, particularly in the context of the agricultural sector. While individual studies focus on specific technologies or applications, there is no holistic analysis that synthesizes these findings into a cohesive framework. This lack of a unified perspective hinders the ability to identify gaps, prioritize research, and make informed decisions about policy, investment, and further technological development. As digital agriculture continues to gain traction globally, understanding the academic landscape and research trajectories is critical for stakeholders across the agricultural ecosystem. The objective of this study is to conduct a bibliometric analysis of digital agriculture research in the agricultural sector.

2. METHOD

This study employs a bibliometric analysis to explore the landscape of digital agriculture research within the agricultural sector. The analysis is conducted using VOSviewer, a tool specifically designed for the visualization and analysis of bibliometric networks. VOSviewer enables the creation of co-authorship, co-citation, and keyword co-occurrence maps, which provide valuable insights into the intellectual structure of a field. By analyzing citation data, VOSviewer identifies key trends, clusters of related topics, and influential authors and journals in digital agriculture. This method helps reveal the relationships between research areas, track the evolution of digital agriculture, and identify emerging topics within the field.

The bibliometric data for this study is sourced from Scopus, one of the most comprehensive and reliable databases for academic publications. Scopus provides access to a vast repository of peer-reviewed journal articles, conference papers, and other scholarly works that are essential for understanding the breadth of research in digital agriculture. The study focuses on articles published in the past decade to ensure the inclusion of the most current and relevant research. Using VOSviewer, the data is analyzed to extract key patterns, such as, author collaborations, and the thematic evolution of digital agriculture technologies. This method provides a robust framework for mapping the growth and future trajectory of digital agriculture research.

3. RESULT AND DISCUSSION

Author Visualization

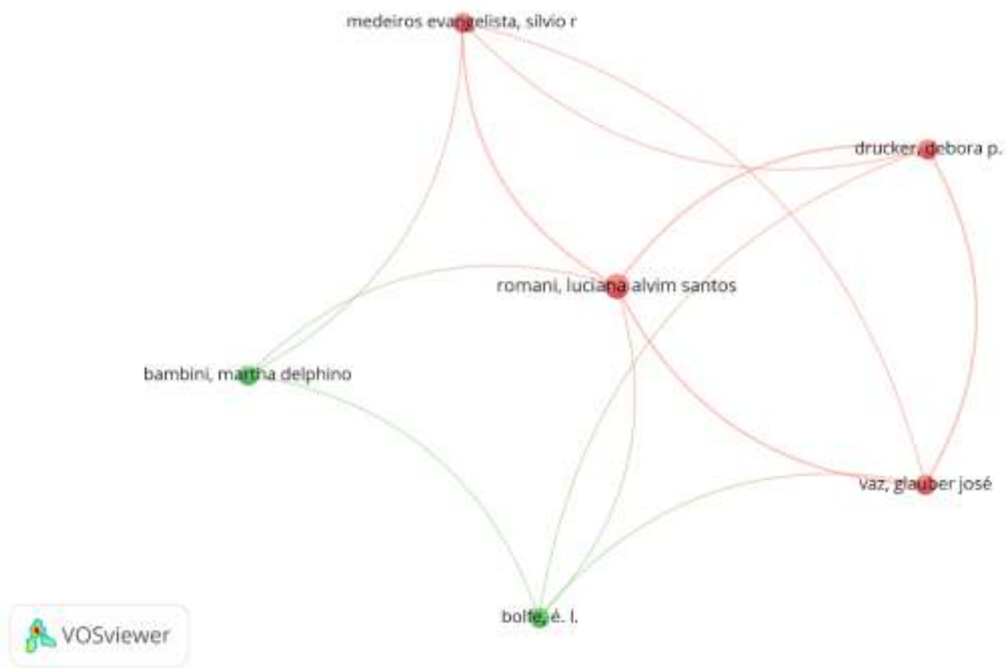

Figure 1. Author Visualization
Source: Data Analysis

Figure 1 illustrates a relatively small but interconnected group of researchers contributing to digital agriculture research. Two main clusters are visible: a red cluster and a green cluster. The red cluster appears to be centered around Romani, Luciana Aylin Santos, who acts as a key bridging author connecting with Medeiros Evangelista, Sílvio R., Drucker, Debora P., and Vaz, Glauber José, indicating strong collaborative ties within this subgroup. The density and thickness of the links among these authors suggest frequent co-publication and a closely related research agenda. Meanwhile, the green cluster consists of Bambini, Martha Delphino and Bolfe, É. L., who are connected both to each other and indirectly to the red cluster through Romani and Bolfe, indicating cross-cluster collaboration.

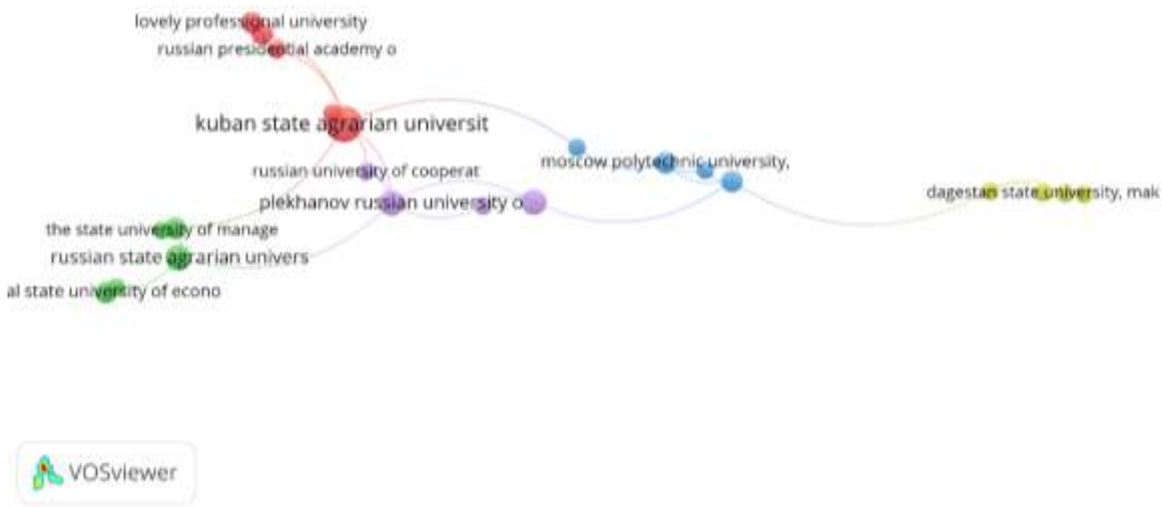

Figure 2. Institution Visualization
Source: Data Analysis

Figure 2 reveals several interconnected clusters dominated by Russian academic institutions, indicating a strong regional concentration in digital agriculture research within this dataset. Kuban State Agrarian University appears as a central hub in the red cluster, closely linked with institutions such as Lovely Professional University and the Russian Presidential Academy, suggesting active collaborative partnerships. Plekhanov Russian University of Economics also plays a bridging role, connecting with the Russian University of Cooperation and forming links toward Moscow Polytechnic University, which serves as another important connector in the blue cluster. On the periphery, institutions like Dagestan State University are connected through fewer but still visible collaborative ties, reflecting more limited participation in the broader network. Meanwhile, several green-cluster institutions (e.g., Russian State Agrarian University and related management/economics universities) form a smaller subgroup connected to the main structure via Plekhanov University.

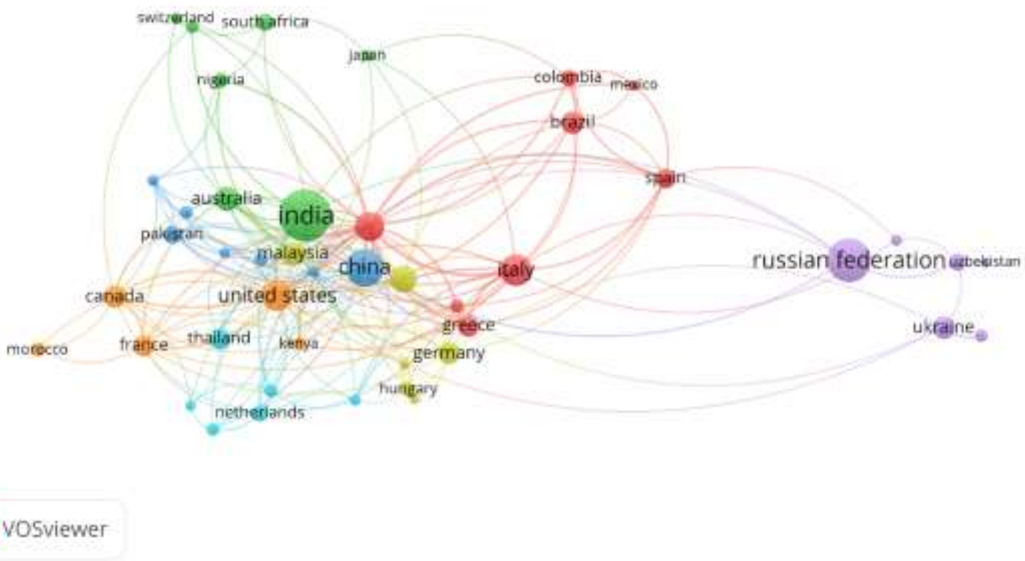

Figure 3. County Visualization
Source: Data Analysis

Figure 3 demonstrates a dense and globally interconnected structure in digital agriculture research, with China, India, and the United States emerging as the most central and influential contributors, as indicated by their larger node sizes and multiple cross-cluster linkages. China appears as a major hub connecting Asian, European, and American research networks, while India shows strong ties with countries such as Australia, Malaysia, and several African nations, reflecting South–South and transcontinental collaboration patterns. The United States is embedded within a broad collaborative web involving European countries like Germany, France, and the Netherlands, indicating strong transatlantic partnerships. A distinct cluster is formed around the Russian Federation, which is closely connected with neighboring countries such as Uzbekistan and Ukraine, suggesting regional collaboration concentration. Meanwhile, countries like Italy, Spain, and Brazil act as bridges between European and Latin American networks.

Keyword Co-Occurrence Analysis

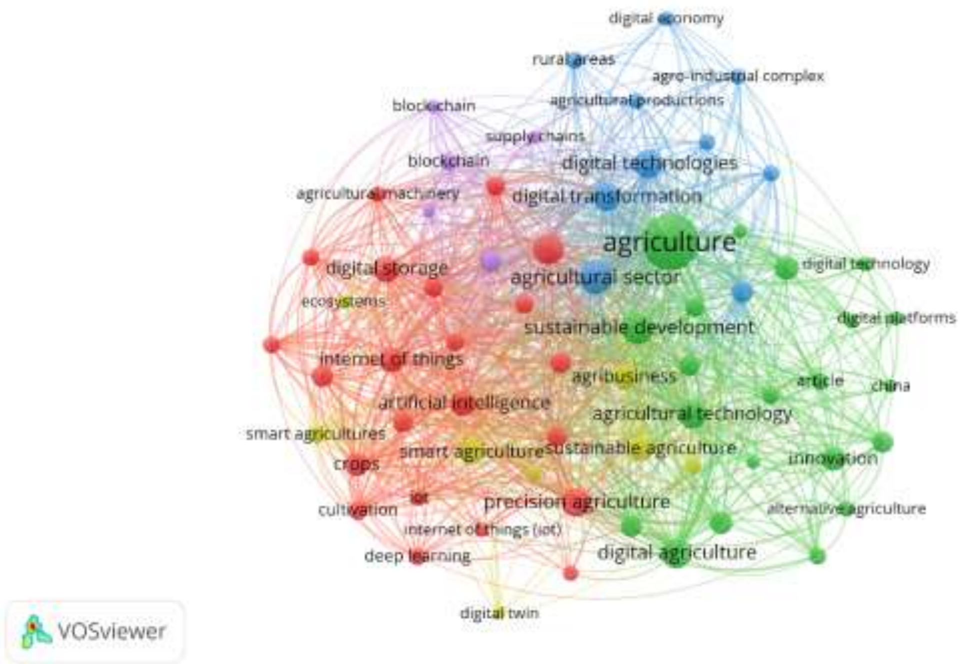

Figure 4. Network Visualization
Source: Data Analysis

Figure 4 reveals a highly interconnected and multidisciplinary structure of digital agriculture research. At the center of the map, "agriculture" and "agricultural sector" appear as dominant nodes, indicating that the technological discourse remains strongly grounded in core agricultural studies. These central terms are closely linked with "sustainable development" and "digital technologies," suggesting that digital transformation in agriculture is not merely technology-driven but is increasingly aligned with sustainability objectives and long-term development goals. The red cluster primarily reflects technology-intensive themes such as "artificial intelligence," "internet of things (IoT)," "precision agriculture," "deep learning," and "smart agriculture." This cluster represents the technical backbone of digital agriculture research, emphasizing automation, sensor integration, predictive analytics, and data-driven crop management. The strong interconnections among these terms indicate that AI and IoT are frequently studied together, forming the technological foundation for modern precision farming systems.

The green cluster focuses more on applied and innovation-oriented aspects, including "digital agriculture," "agricultural technology," "innovation," "digital platforms," and "agribusiness." This suggests that research is expanding beyond farm-level technologies to include digital ecosystems, value chain integration, and platform-based agricultural services. The presence of terms like "alternative agriculture" and "sustainable agriculture" within this cluster indicates a shift toward environmentally responsible and innovation-driven agricultural models supported by digital tools. The blue cluster highlights structural and macro-level perspectives, such as "digital transformation," "agro-industrial complex," "rural areas," "supply chains," and "digital economy." This suggests that digital agriculture research increasingly examines systemic changes, including rural digitalization, agri-food supply chain management, and integration into the broader digital economy. The connection between supply chains and digital technologies indicates growing attention to traceability, logistics optimization, and blockchain-based transparency systems. Emerging and bridging keywords such as "digital twin," "blockchain," and "ecosystems" indicate evolving research frontiers. These terms are positioned at the intersection of multiple clusters, suggesting their role as integrative technologies linking production, monitoring, and market systems.

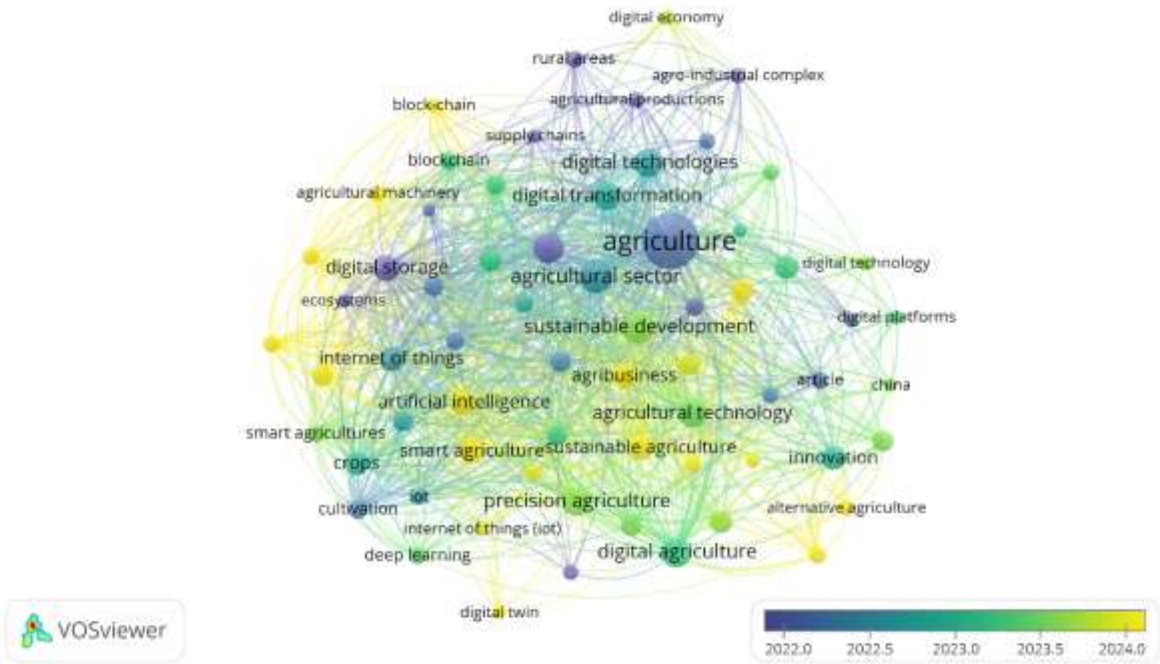

Figure 5. Overlay Visualization
Source: Data Analysis

Figure 5 illustrates the temporal evolution of digital agriculture research from 2022 to 2024, as indicated by the color gradient ranging from blue (earlier publications) to yellow (more recent publications). Core foundational terms such as "agriculture," "agricultural sector," "digital transformation," and "digital technologies" appear in darker blue tones, suggesting that these themes were more prominent in earlier years. This indicates that initial research efforts focused on conceptualizing digital transformation in agriculture and establishing its structural and technological foundations. As the timeline progresses toward green tones (around 2023), research attention appears to shift toward applied technological integration, with keywords such as "artificial intelligence," "internet of things," "precision agriculture," "sustainable development," and "agribusiness" becoming more central. This suggests a growing emphasis on practical implementation, sustainability alignment, and data-driven agricultural systems. The interconnections among these terms highlight the increasing maturity of the field, where technological innovation is closely linked with productivity enhancement and environmental objectives.

More recent topics, indicated by yellow shades (2024), include “innovation,” “digital storage,” “ecosystems,” “blockchain,” and certain aspects of “digital platforms.” These emerging keywords reflect a shift toward ecosystem-based approaches, digital infrastructure management, and value chain transparency. The appearance of blockchain and ecosystem concepts in the most recent period suggests that digital agriculture research is moving beyond farm-level applications toward integrated digital networks, supply chain traceability, and broader digital economy integration.

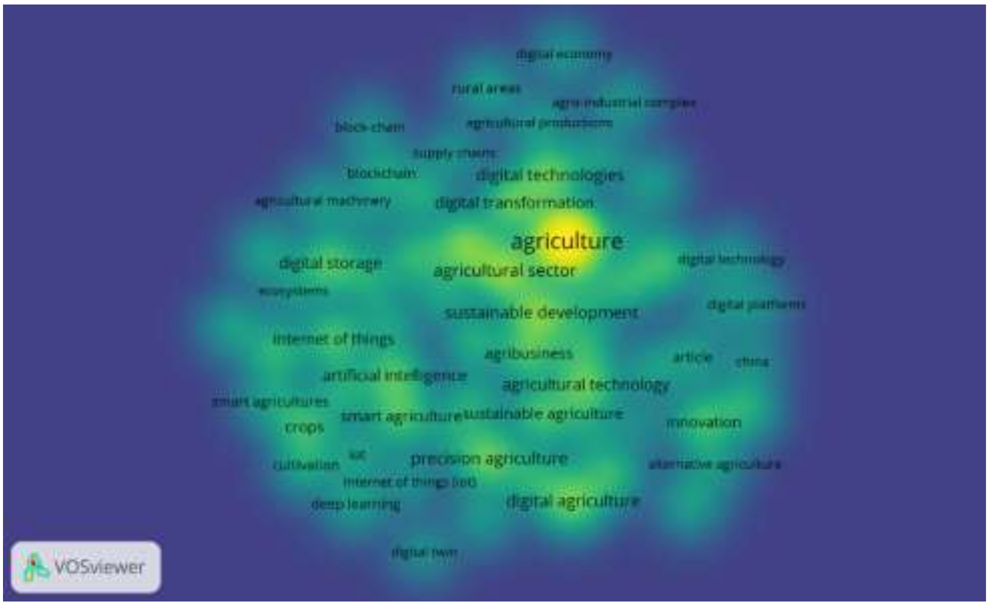

Figure 6. Density Visualization
Source: Data Analysis

Figure 6 highlights the most intensively researched themes in digital agriculture, with brighter yellow areas indicating higher frequency and stronger co-occurrence among keywords. The brightest concentration appears around “agriculture” and “agricultural sector,” confirming that these are the conceptual core of the research field. Closely surrounding this central hotspot are terms such as “digital technologies,” “digital transformation,” and “sustainable development,” suggesting that much of the scholarly discussion integrates technological advancement with sustainability objectives within the agricultural context. Moderate-density areas (green zones) include keywords such as “precision agriculture,” “artificial intelligence,” “internet of things,” “digital agriculture,” “innovation,” and “agribusiness.” These themes represent strong but slightly more specialized subfields within the broader domain. Peripheral and lower-density areas, such as “digital twin,” “blockchain,” “digital storage,” and certain rural or ecosystem-related terms, indicate emerging or less frequently studied topics.

Table 1. Top Cited Literature

Citations	Authors and Year	Title
888	[7]	A review on the practice of big data analysis in agriculture
393	[8]	The digitization of agricultural industry – a systematic literature review on agriculture 4.0
383	[9]	Automation and digitization of agriculture using artificial intelligence and internet of things
345	[10]	Big Data in food and agriculture

328	[11]	Cyber-Physical Power System (CPPS): A Review on Modeling, Simulation, and Analysis with Cyber Security Applications
311	[12]	The promise (and pitfalls) of ICT for agriculture initiatives
291	[13]	Pesticide-free agriculture as a new paradigm for research
217	[14]	Looking through a responsible innovation lens at uneven engagements with digital farming
202	[15]	Adoption of the Internet of Things (IoT) in agriculture and smart farming towards urban greening: A review
161	[16]	Digital innovations for sustainable and resilient agricultural systems

Discussion

This bibliometric analysis reveals that digital agriculture research has evolved into a highly interdisciplinary and globally interconnected field. The findings demonstrate a significant expansion of scholarly attention, particularly after 2018, reflecting the growing urgency to modernize agricultural systems in response to climate change, food security challenges, and digital transformation agendas. The dominance of keywords such as agriculture, digital technologies, and digital transformation confirms that the field remains firmly rooted in agricultural sciences while simultaneously integrating advanced computational and data-driven technologies. This convergence suggests that digital agriculture is no longer viewed as a technological add-on but as a structural transformation of agricultural systems.

The keyword co-occurrence analysis highlights three major thematic orientations. First, the technology-driven cluster—comprising artificial intelligence (AI), Internet of Things (IoT), deep learning, and precision agriculture—represents the technical backbone of digital agriculture research. These technologies are frequently studied in combination, emphasizing sensor integration, predictive modeling, and automated decision-making systems. This indicates that research has moved beyond conceptual discussions and now focuses on operationalizing smart farming solutions. The prominence of AI and IoT further reflects the global push toward real-time monitoring, data analytics, and automation to enhance productivity and optimize resource use.

Second, the sustainability-oriented cluster integrates digital innovation with environmental and socio-economic goals. The strong co-occurrence between sustainable development, sustainable agriculture, and agribusiness suggests that digital agriculture is increasingly framed within sustainability discourse. Rather than focusing solely on yield maximization, recent studies emphasize efficiency in water use, fertilizer management, emission reduction, and climate adaptation. This alignment with sustainability goals indicates that digital agriculture research contributes directly to broader global frameworks such as the Sustainable Development Goals (SDGs), particularly those related to food security, responsible production, and climate action.

Third, the systemic and ecosystem-based cluster reflects a macro-level shift in research orientation. Keywords such as digital economy, agro-industrial complex, supply chains, and digital platforms demonstrate growing interest in structural transformation beyond farm-level technologies. The emergence of blockchain, digital storage, and digital twin technologies in the overlay visualization further indicates a transition toward integrated digital ecosystems. These technologies support traceability, transparency, and value chain optimization, signaling that digital agriculture is expanding toward platform-based agricultural governance and supply chain digitalization.

4. CONCLUSION

This bibliometric analysis demonstrates that digital agriculture research in the agricultural sector has evolved into a dynamic, interdisciplinary, and globally interconnected field characterized by strong technological integration and sustainability orientation. The findings reveal that core themes such as digital transformation, artificial intelligence, Internet of Things, and precision agriculture form the technological foundation of the field, while more recent trends emphasize innovation ecosystems, blockchain integration, and digital platforms within agri-food supply chains. Country collaboration patterns highlight the leading roles of China, India, and the United States, supported by active European partnerships, indicating the global strategic importance of agricultural digitalization. The study confirms that digital agriculture is transitioning from isolated technological applications toward a comprehensive ecosystem-based model that integrates productivity, sustainability, and digital economy frameworks, while also opening opportunities for future research on governance, inclusivity, and long-term socio-economic impacts.

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