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Exploring Trends and Challenges in Technological Innovation: A Bibliometric Analysis in Agriculture

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Abstract

This research aims to analyze the trends in research topics related to the use of technological innovation in the agricultural sector. The data for this study comes from the Scopus database (2024), comprising 277 documents analyzed. The analysis method used in this research is bibliometrics, facilitated by Bibliometrix and Vosviewer software. The findings indicate that research on technological innovation began to rise in 2016, with a focus on various sectors, including agriculture and digital agriculture, since 2020. The primary emphasis has been on improving efficiency, productivity, and sustainability in the agricultural sector. However, challenges such as technology adoption, data management, and workforce training still remain.

The use of innovative technologies is critical for addressing global challenges like climate change, food scarcity, and social inequality. Collaboration between government, research institutions, and industry is essential to explore the potential of these technologies. This research also highlights the importance of prioritizing and developing technology-related topics, identifying areas that require more research and development, and understanding the dynamics on the ground. The analysis results of this research provide insights into the developments in agricultural technology innovation that have been carried out by previous studies. Future research could improve methodologies and encourage innovation in environmental issues, including smart agriculture, by focusing on farmers' adaptability to applying such technologies.

Keywords: *Bibliometric, Innovation, Agriculture, Technology, Trend*

Introduction

Current research developments have provided a lot of knowledge about the use of innovative technology not only increasing agricultural yields, but also playing an important role in maintaining environmental sustainability (Molina-Maturano et al.

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2021). Technological innovation has been a key driver in the transformation of the agricultural sector worldwide, helping the agricultural industry overcome challenges such as increased productivity, more efficient resource management and environmental sustainability. Technological innovation is also critical for rural areas to adapt to a knowledge-based economy, enabling the expansion of innovative businesses and opening up new value chains at national and global levels (Rivza, Vasilevska, and Rivza 2019). There are still many debates about the use of technological innovation in agriculture, making this topic interesting to study.

The application of agricultural innovation technology plays an important role in increasing the productivity of agricultural businesses, so that it has the opportunity to improve the welfare of life, and improve food security, especially farming households (Heredia-R et al., 2021). Agricultural technology is the science and technology in agricultural practices in increasing productivity, efficiency and sustainability in the agricultural sector. Agricultural technology experienced rapid development, starting from the green revolution and modern agriculture that began in the 1940s to the 1960s. The beginning of the agricultural technology revolution due to hunger in various countries in the world (Birner et al., 2021). In the long run, there are efforts to increase the yield of staples so as to change nutritional outcomes in various countries. This concept is in the form of the use of superior seeds, intensive fertilization, efficient irrigation, and science-based agricultural practices (Calderan Gregolin et al., 2023).

Technological innovations can increase agricultural productivity around the world. The development of agricultural technology based on IoT (Internet of Things) which refers to a network of devices that are connected wirelessly via the internet. Agriculture that uses IoT is also called Precision Agriculture (PA) (Wang et al., 2020). PA is considered to be a solution to increase the production of the agricultural sector and can provide stable results every time it produces. PA itself aims to provide improvement and optimization of existing processes to ensure productivity can reach the best amount (Machii et al., 2020). This can be achieved by the existence of a system that can measure quickly, reliably and can be read easily by farmers as an overview of the situation that is happening in their agricultural area.

In agriculture, IoT is used to monitor environmental conditions in organizing automatic irrigation and collect agricultural data in real-time, and is used to control water, energy and fertilizer use (Anderson et al., 2022). PA also enables interconnected communication between automated operating machines to optimize energy consumption, such as water and electricity usage. Pests that have always been a problem for farmers can also be overcome quickly and precisely with a pest control system that can be on standby at any time. The accuracy of the system to eradicate pests can also continue to be improved as the longer the system is used.

Today's technological innovations are based on the internet (Internet of Things-IoT). The use of Internet of Things Technology, GIS, artificial intelligence, ultra-broadband networks, blockchain, and virtual reality enables environmentally friendly and sustainable development in agriculture, precision agriculture, food chain traceability, and market-based initiatives (Ciruela-Lorenzo et al., 2020; Scuderi et al., 2022). The Big Data-based Internet of Things (IoT) is revolutionizing organizations by collecting massive amounts of data for strategic decision making in a variety of business applications. The application of IoT technologies provides a sustainable competitive advantage, but also presents challenges such as privacy, security, standardization, and architecture concerns.

The development of current research has studied a lot about the application of renewable technology used in the agricultural sector. The use of innovative technology can provide convenience, risk analysis, increased production, and environmentally friendly (Stepanova et al., 2021). However, the current application still has difficulties with the use of these technologies. The adaptability of farmers tends to be low in responding to the challenges of current change. Therefore, this research aims to analyze research trends that discuss topics about the application of modern technological innovations in the agricultural sector.

Literature Review:

A. Agricultural technology

Agricultural technology is a term used to describe equipment, genetic material, agricultural techniques, and agricultural inputs that have been developed to improve agricultural effectiveness (Ruzzante et al., 2021). More further, according to Ruzzante et al (2021) Effectiveness here refers to the results of productivity, well-being, health, and sustainability that have a wide range. Agricultural technology also known as 'Agtech' which refers to the application of technology in agriculture to increase crop yields, reduce costs, and improve sustainability which includes the use of precision technologies, such as irrigation and crop monitoring to optimize resource allocation and minimize waste (Dayıoğlu & Turker, 2021; Shukla et al., 2021).

The term agri-tech or "Ag-Tech" defines various applications of digital technology in agriculture, encompassing a wide array of new technologies applied to agricultural systems, increasing productivity, efficiency, and profitability (Pérez-Pons et al., 2020). The use of technology in the agricultural sector has a positive impact on the sustainability of the economy, this is because it helps develop more efficient solutions and has a lower environmental impact (Khan et al., 2021). Technology improves agricultural operations during plant growth stages, such as crop harvesting, transportation of foodstuffs, and storage conditions (Sisinni et al., 2018). Currently, several technologies or tools including harvesters, lawn weeding robots, unmanned vehicles, and other otmoatical machines are useful for farmers to monitor crops (Ayaz et al., 2019). So the integration of technology in agriculture has the potential to revolutionize the oetany of producing food, making it more sustainable, efficient, productive, while addressing global challenges such as food security and climate change (Adenle et al., 2019)

B. Effects of technological innovation on the agricultural sector

Over time and the development of the times, many agricultural product innovations are carried out for the sustainability of the agricultural sector. Agricultural technology innovation refers to the development and application of new technologies, methods and practices that increase agricultural productivity, efficiency and sustainability (Berthet et al., 2018). In each case, technological innovation in the agricultural sector is aligned with incremental productivity gains and transformational changes in the Agricultural Innovation System (AIS) (Fielke et al., 2019).

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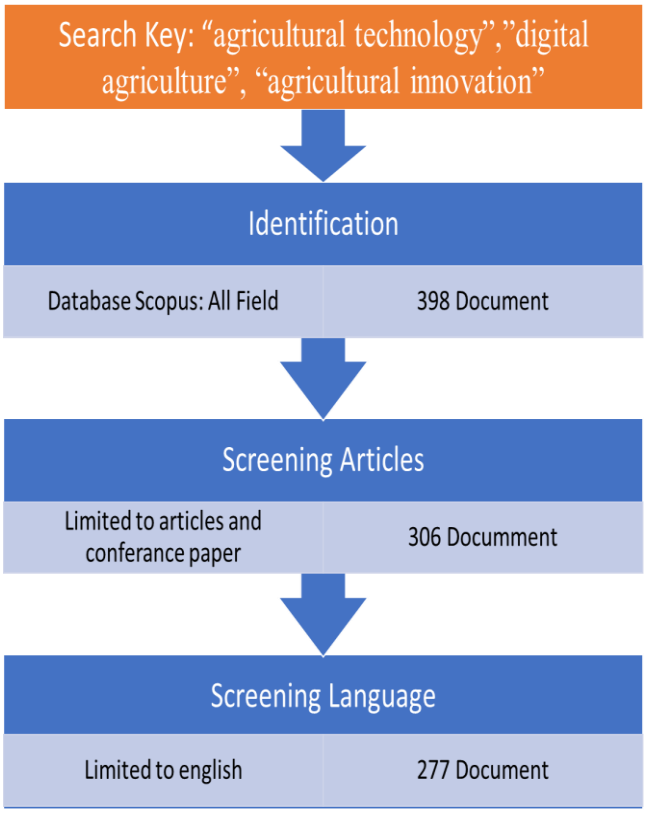
Technological innovations or so-called digitalization of agriculture that increase crop productivity and improve crop quality, protect the environment, provide efficient use of resources and reduce input costs can help us face economic, social and environmental challenges in agriculture today (Dayıoğlu & Turker, 2021). The impacts of agricultural innovation most frequently mentioned today tend to be those involving the widespread use of precision pertanin technologies that reduce costs associated with inputs or efforts to increase yields as well as productivity (Aiello et al., 2018; Fielke et al., 2019; Lindblom et al., 2017). For example, self-steering actors equipped with GPS units that utilize satellites to reduce driver fatigue and crop mapping (Man et al., 2015). This is the latest technological advancement applied independently by farmers who technically no longer need a long time to plow their fields and operate their tractors (Fielke et al., 2019).

Methodology

This research is a literature review. This research uses bibliometric methods as part of the research evaluation methodology, and bibliometric analysis can be performed using its own methods based on the available literature (Niknejad et al., 2021). Bibliometric analysis is also defined as a research strategy to understand research trends on a particular topic in academic paper production, using Scopus and WoS (Raparelli & Bajocco, 2019). Bibliometric analysis is a method for evaluating the usefulness and performance of academic publications and individual researchers by examining journal citations, authors, and other metadata. (Niknejad et al., 2021). Analyzing bibliometric data allows academics to analyze the effect and significance of scholarly publications, uncover emerging trends, and evaluate the productivity and impact of particular researchers, institutions, or study fields.

Figure 1. Research Analysis Flow



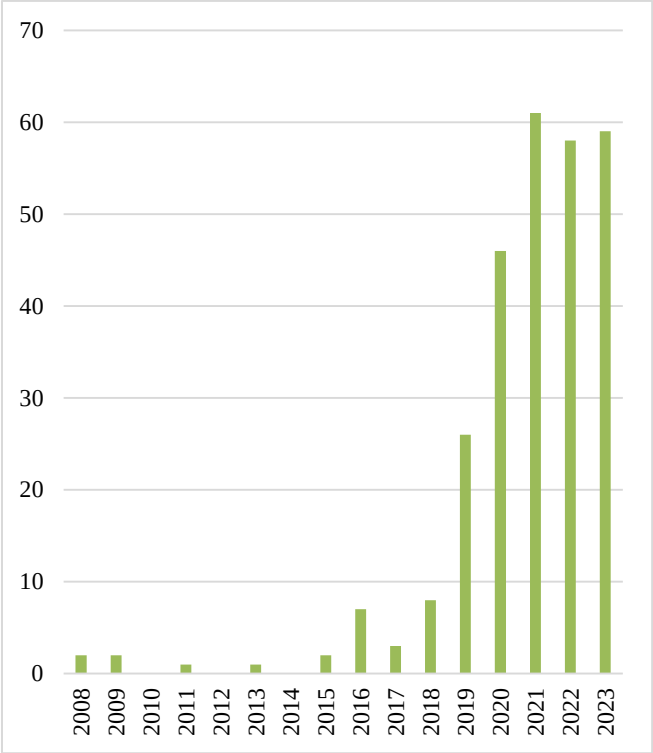
Source: Adopted From Mühl and de Oliveira (2022)

To ensure consistency in metadata, the study limited searches to full articles and conferences. This allows operationalization and analysis more easily using the software used in the study. A total of 277 documents were analyzed in this research. The analysis tools used are the Bibliometrix package on R-studio and VosViewer. The use of the Bibliometrix tool can make it easier for researchers to map collaboration networks between documents, authors, and countries, and also to carry out strategic mapping (Mühl & de Oliveira, 2022). Therefore, the use of both software can help reduce the ambiguity of the results of the research conducted.

Results

Research on technological innovations used in the agricultural sector has been started since 2008. In all publications about agricultural technology innovations until 2023, there have been 277 documents published in articles and conference papers in the Scopus database. Figure 2 shows the progress of articles published in the scopus database.

Figure 2. Growth Trends of Research Documents (2018-2023)



Source: Scopus Database, 2024

There are 2 articles in 2008 that have examined the development of technology used in the agricultural sector. The focus of both studies is to promote the use of digital technology to boost the performance of the agricultural sector. Research conducted based on the use of computer technology to facilitate understanding of the integration of the field of agricultural hydrology (Kuo et al., 2008), and provide designs on the application of agricultural technology that is right on target(Xu & Li, 2008). Both studies emphasize the importance of adopting digital technologies in the agricultural sector to increase efficiency and effectiveness. However, there were only a small number of articles on this topic for several years afterwards.

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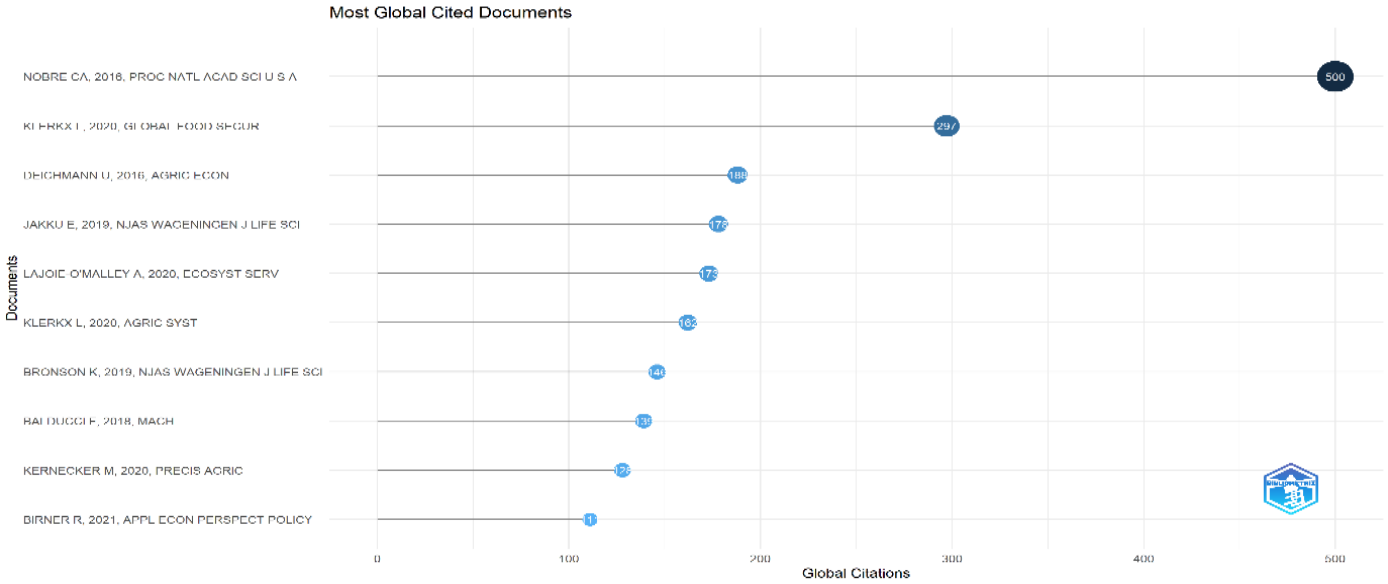
Figure 3. Most Citations



Source: Scopus Database, 2024

A major increase began in 2016, with gradual increases. This increase is indicated by the global number of citations beginning in 2016 (see Figure 3). There is a very influential document written by Nobre (2016), with the theme of technology innovation research in order to encourage sustainable development in the agricultural sector (Nobre et al., 2016). This new paradigm requires researching, creating, and scaling new solutions that combine digital, biological, and advanced materials technologies from technological innovation. Therefore, the article encourages the publication of articles on the topic of technological innovation and digitalization in the agricultural sector.

The year 2018 was the beginning of a strong upward trend, with the number of publications continuing to increase. The most significant growth was shown from 2019 onwards, with rapid increases peaking in 2021 and remaining high into 2023. The years 2020, 2021, and 2022 had the highest number of publications, each exceeding 60 publications. In 2020, there is also an article that has been widely cited, with a research topic on the concept of digital transformation in the agricultural sector (Laurens Klerkx & Begemann, 2020). This trend shows that there has been an increase in interest and research activity towards the topic over the past five years, which implies that the topic has become a focus of study within the academic community.

Tabel 1. Most Productive and Most Cited Author

No	Penulis	Jumlah Document	Penulis	Jumlah Sitasi
1	Jakku, E.	7	Nobre, C.A.	500
2	Fleming, A.	6	Klerkx, L.	301
3	Fielke, S.	5	Deichmann, U.,	190
4	Klerkx, L.	5	Jakku, E.,	179
5	Bronson, K.	4	Lajoie-O'Malley, A.	174
6	Turner, J.A.	4	Klerkx, L.,	164
7	Birner, R.	3	Bronson, K.	149
8	Daum, T.	3	Balducci, F.,	139
9	Knierim, A.	3	Kernecker, M.,	129
10	Kuznetsova, I.G.	3	Birner, R.,	115

Source: Scopus Database, 2024

Although Nobre, (2016) has the most cited documents, Nobre is not productive in writing articles on the topic of agricultural technology innovation (details, See Table 1). In the context of digital technologies in the agricultural sector, several authors stand out both in terms of their productivity and influence measured through citations. In this context, research shows that the author with the highest number of citations is Nobre, C.A. with a total of 500 citations (Nobre et al., 2016), followed by Klerkx, L. with 301 citations (L Klerkx & Rose, 2020). Jakku, E. and Bronson, K. were also identified as important contributors, with 179 and 149 citations, respectively (Bronson, 2019; Jakku et al., 2019). Interestingly, although Jakku, E identified as the most prolific writer, the number of citations is still below Nobre, C.A. this can also be

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interpreted because the article written by Nobre has a developmental influence on research with the theme of technological innovation in the agricultural sector.

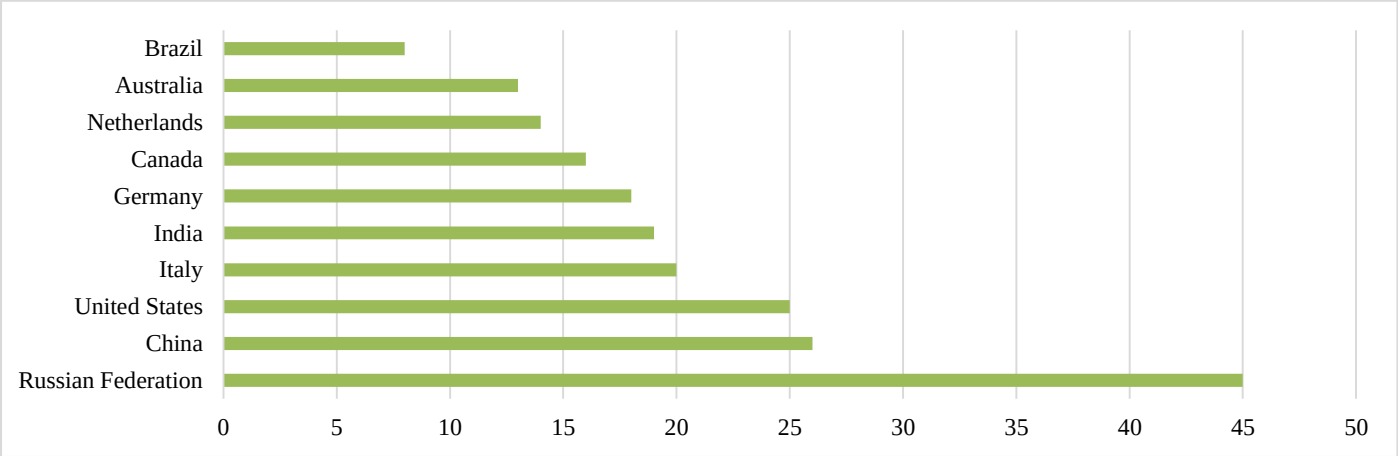
The first article of the most citations, investigating the effects of environmental damage that occurs due to climate change and land use change. Advances in precision agriculture and digital technologies can help farmers optimize resource use, increase crop yields, and reduce agricultural environmental impact. The use of technological innovations (e.g. satellite photography, drones, and sensors, etc.) can provide farmers with important data on soil health, moisture levels, and crop growth, helping them make better decisions and manage their land (Nobre et al., 2016). Therefore, Agriculture can contribute to regional economic growth and environmental preservation by utilizing technical advances, supporting sustainable practices, and using the potential of indigenous knowledge.

The second article of the most citations, themed on the development of agricultural technology. Agriculture 4.0, which is a combination of technologies such as robotics, nanotechnology, and artificial intelligence, has great potential in transformative changes to future agricultural and food systems. However, more attention is needed to understand the impact of inclusion and exclusion and their relationship to sustainable transition pathways. Responsible innovation, inclusive processes, and responsiveness are needed to adapt to emerging impacts (L Klerkx & Rose, 2020). Special attention needs to be given, so that the technology used can be used effectively and pay attention to environmental sustainability.

The third most cited article, discusses many of the benefits of new information and communication technologies in agriculture, focusing on their role in driving inclusion, increasing efficiency, and encouraging innovation. This article reviews the impact of these technologies on small-scale farmers in developing countries, and highlights that although some positive impacts have been observed, they may not be fully realized due to technological limitations. Technology-enabled interventions require complementary investments in infrastructure, electricity, and literacy. The flexibility of digital technologies can distract from focusing on the needs of beneficiaries and resource-constrained environments, causing interventions to be oversimplified. Thus, environmental aspects are often overlooked in technological innovations carried out (Deichmann et al., 2016).

This analysis illustrates a broad recognition of the intellectual contributions of researchers in building a foundation of knowledge about the development of agricultural technology. In addition, it highlights a research focus that is receiving greater attention within the scientific community, as well as reinforcing the urgency to continue unearthing new insights and findings through further research. This suggests that their research is often referenced and recognized as important by the academic community (Mühl & de Oliveira, 2022). Thus, these data identify the main authors who contribute significantly to the literature and the development of digital technologies in the agricultural sector. Apart from the author's contribution, the author's country of origin is also a fundamental concern in the analysis carried out.

Figure 4. Top 10 Coutry Contribution



Source: Scopus Database, 2024

Figure 4 shows the country's most productive contribution to the topic of agricultural technology innovation. Russia, with the most documents, is 45. The author with the most citations from Russia is Kuznetsova, I.G., with 2 documents and 18 citations (Kuznetsova, Goloshchapova, et al., 2019; Kuznetsova, Voronkova, et al., 2019). The research topics carried out are themed on food security issues that can be reduced by the effective application of technology in domestic and global agriculture, as well as the use of correct scientific-technical implementation. Interestingly, Brazil has the last order, having the most citation contributions (Nobre et al., 2016). This suggests that while Brazil is widely cited in the literature, its own research contribution in terms of the number of documents is not proportional to its citation level.

Discussion

An explanation of current research developments on agricultural technology innovations, described using VosViewer software features to create a network of events along with keywords. The keywords used by the author are nodes, the size of the nodes shows the appearance of keywords and the relationship between nodes is proportional to the occurrence of concurrent words (Oktaviani et al., 2021). In this research, only

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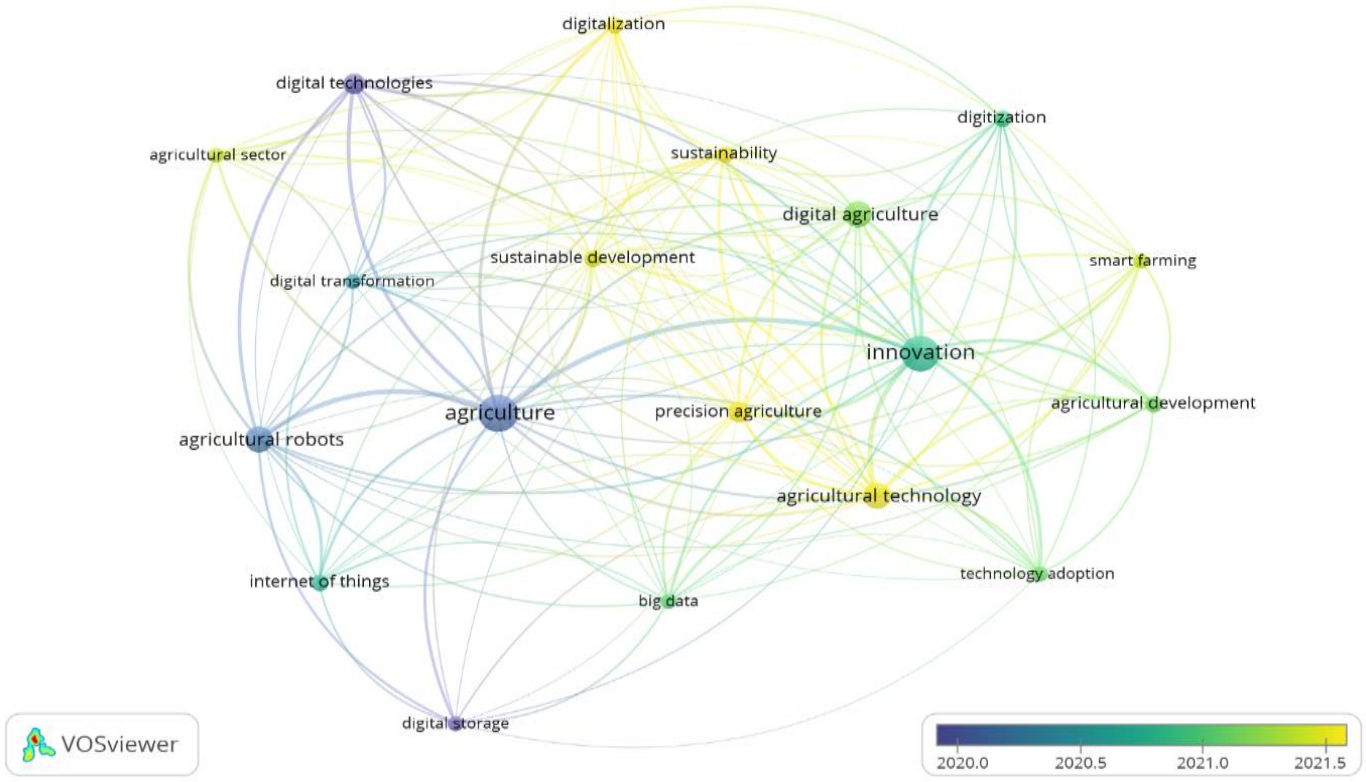
considered at least 15 keywords that often appear. This is used to reinforce the findings of this research. More clearly, can be seen in Figure, about the development of keywords on this research topic.

Figure 5. Keyword Co-occurrence Networks



Source: Data processed by Vosviewer, 2024

Searches with agricultural keywords have been growing since 2020. Starting with the keyword "Agriculture" with a occurence value of 90. This is the beginning of the development of research on agricultural technology innovation. This was initiated by the search keyword "digital agriculture" which occurred in 2020-2021. The variety of themes continues to grow until in 2021-2023 leading to the keywords "smart farming" and "sustainability". This happens because many technological innovations used often have an effect on the environment, which has an impact on the sustainability of the existing environment (D'Oronzio & Sica, 2021; Scuderi et al., 2022). Transition paths in agricultural innovation systems can be partially controlled but can be influenced by different approaches. Often, these systems develop specific technologies but it is still unclear their value and contribution to sustainability (L Klerkx & Rose, 2020). Despite embracing issues of sustainable development and policy, the dominant group in the system focuses on increasing agricultural productivity and growth through modernization, which is now increasingly in the spotlight.

Digitalization of agriculture is one of the steps to strengthen agricultural production through the use of renewable technology. In general, agricultural digitalization involves the use of information and communication technology (ICT), sensors, data analytics, artificial intelligence (AI), and other technological innovations in various stages of the agricultural cycle, starting from planning, monitoring, management, to marketing results (Andreev & Makarova, 2021; Garske et al., 2021). Digitalization creates new management principles for innovative activities (Sozaeva et al., 2021). The importance of geographic positioning systems, management of complex fleets of machinery, and application of technology in the context of modern agriculture. In addition, we present a comparison of technological efficiencies between sectors, including studies of aeroponics, hydroponics, and traditional methods.

Agricultural technology innovation, one of which is transforming digital agriculture into precision agriculture, requires great efforts from farmers, including the use of sensors and mapping agricultural land. One of the research developments that has not yet been carried out is Smart farming, which is also part of one of the discussions on agricultural digitalization. The keyword "smart farming" is a keyword that has novelty that can now be done. This keyword, only has occurrenceences of 17 points. This is because there is still not much research that discusses the use of smart farming in agricultural technology innovation. In practice, smart farming has obstacles, namely limited access to information (Visser et al., 2021). So it is necessary to integrate information technology systems that have the ability to map the entire series of agricultural activities (Risdawati et al., 2021). Transforming digital farming into a smart farm requires hard work from farmers (for example: adjusting sensors, checking crop maps, and corroborating algorithmic suggestions) and deep knowledge of the use of the technology (Relf-Eckstein et al., 2019). For farmers who have low knowledge, this creates difficulties in its implementation. Thus, integration between the government and farmers is needed to produce an appropriate technology.

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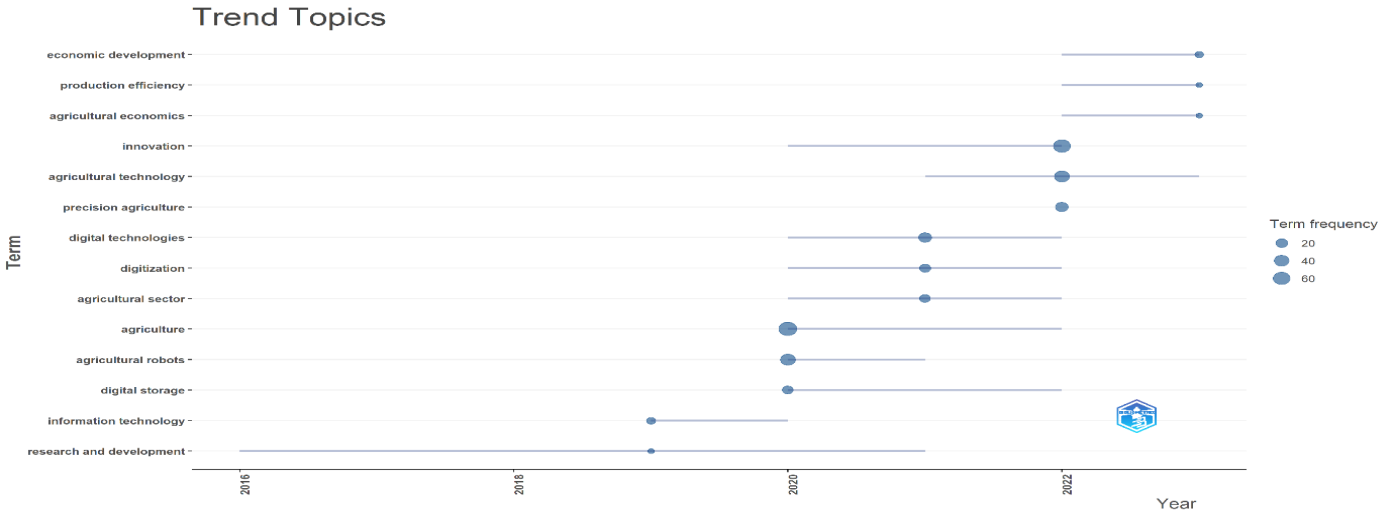
Figure 6. Trend Topic

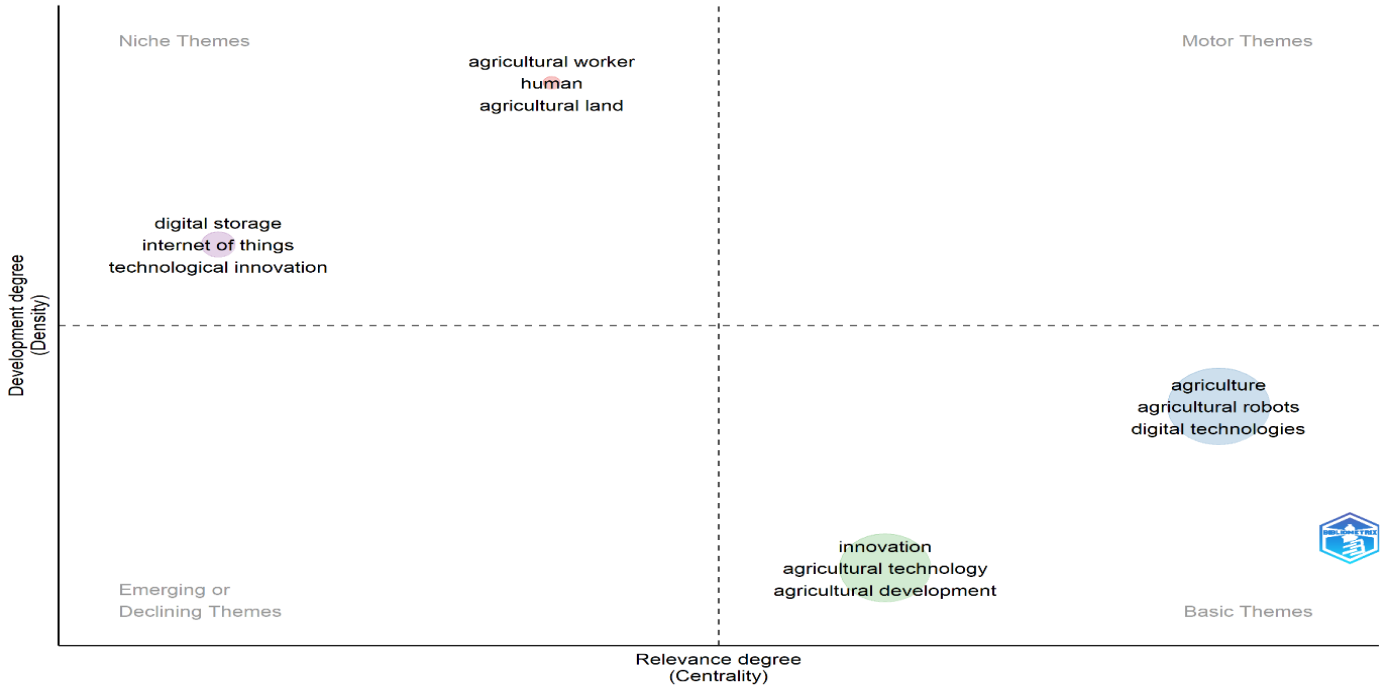


Source: Data Processed by Bibliometix, 2024

The current trend topic is also themed agricultural technology innovation, which leads to economic development (see Figure 6). The evolution of popularity of various topics related to agriculture and economics from 2016 to 2023. There has been a significant increase in attention to topics such as economic development, production efficiency, agricultural economics, innovation, and agricultural biotechnology in recent years. For example, the topic of 'Economic Development' began to become very relevant since 2020, showing increased attention to the impact of the agricultural sector on overall economic growth. The adoption of technologies such as the Internet of Things, big data analytics, and blockchain in agriculture is gaining momentum in the framework of economic development (Scuderi et al., 2022).

Topics such as 'Precision Agriculture' and 'Digital Technologies' that have emerged and increased in frequency since 2019 reflect the adoption of advanced technologies to improve efficiency and productivity within the agricultural sector. The increasing trend in frequency of topics such as 'Agricultural Robots' and 'Digital Storage' since 2021 also shows a growing interest in automation and digitization in this field. The use of technological innovation can encourage agricultural productivity, because it prioritizes production efficiency and effectiveness (Mishra & Sharma, 2023). This indicates that the agricultural sector is increasingly adopting technology-based approaches to address global challenges and increase productivity.

Figure 7. Thematic Map



Source: Data Processed by Bibliometix, 2024

Figure 7 classifies various topics related to agriculture and technology based on two main parameters: the degree of development (density) on the vertical axis, and the degree of relevance (centrality) on the horizontal axis. The graph is divided into four quadrants, each depicting different characteristics of the topics. As for the characteristics of the quadrant (Figure 7):

1. Niche Themes (Top Left Quadrant)

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There are 2 topics in this quadrant. The first topic includes agricultural workers, human, and agricultural land. When viewed from the point of view of the discussion in this quadrant, the topic leads to the drivers of the agricultural sector. In addition, there are also problems faced, so that it develops towards more in-depth research. Agricultural workers (farmers) when faced with technological changes, become a challenge in itself against the adoption of these technologies. Technological innovation must provide economic added value, easy to understand, and easy to use, especially for small-scale farmers (Dixit et al., 2023).

In the implementation of technology adoption, there needs to be efforts to form human resources in the digital economy, and the need for transition efforts (Kuznetsova, Goloshchapova, et al., 2019). In addition, the problem of land use change also underlies the development of research on technological innovation in the agricultural sector. Land use change results in environmental damage which results in decreased productivity in the agricultural sector (Nobre et al., 2016). Therefore, technological innovation needs to be directed towards achieving sustainable development.

The second topic covers digital storage, internet of things, and technological innovation. Judging from its development, this topic leads to the solutions needed to support interrelated agricultural technology innovation. Initiation of technological innovation using digital storage and the Internet of Things (IoT). The use of IoT-based information technology can make it easier for farmers to monitor the development of their agriculture (Bello-Bravo et al., 2020). IoT technology connects objects on the internet, enabling information sharing and transmission through sensors. It aims to create safety, convenience, and cost efficiency in sectors such as smart energy, healthcare, household, and automotive. IoT applications can have an effect on smart cities, energy, and RFID (Machii et al., 2020; Udalov et al., 2023). Big data analytics helps manage risk, improve customer service, and optimize resources. But the challenges include technical, privacy, security, business, architecture, and cost.

2. Basic Themes (Bottom Right Quadrant)

Topics covered here include: agriculture, agricultural robots, digital technologies, innovation, agricultural technology, agricultural development. These topics have high relevance but lower levels of development. They are important basic topics and are widely discussed in wider discussions, but may not indicate innovation or rapid development at this time.

The development of this topic is the basis for the emergence of new topics about technological innovations used in the agricultural sector. This is the trigger for research on Agriculture 5.0, which is the next phase of agricultural development (Balaska et al., 2023). The ultimate goal is to transform the industry into a smarter, more effective, and ecologically conscious sector. Innovations made to digital technologies such as big data, AI, robotics, IoT, as well as virtual and augmented reality are improving agricultural processes (Machii et al., 2020). In addition, to make the food system fair, healthy, and environmentally friendly in the framework of sustainable development. Robotic systems can help address threats to agriculture such as climate change, invasive pests, diseases, and costs (Hurst & Spiegal, 2023).

Overall, the current research provides insight into how various agriculture and technology-related topics are prioritized and evolving, helping in identifying areas that need more research and development, as well as understanding the dynamics within these fields. Agriculture must adopt technological innovations for several key reasons that contribute to the sustainability, efficiency, and productivity of the agricultural sector. Technological innovation can boost productivity, and increase efficiency (e.g., the use of IoT and sensors makes it easier to monitor agricultural conditions). This allows farmers to be in a faster process and can anticipate when there is a problem with the production that is being carried out.

There are several more advantages that can be the reason farmers today in using agricultural technology. Based on the findings of previous studies, the use of technology also has an impact on increasing environmental sustainability (Hackfort, 2023), addressing the challenges of climate change (Nobre et al., 2016), food safety (Kuznetsova, Voronkova, et al., 2019), Failure risk reduction (L Klerkx & Rose, 2020), and marketing innovation (Lioutas & Charatsari, 2020). This is interesting because currently, there are many platforms that utilize internet technology (IoT). This internet platform enables horizontal business integration, allowing customers to solve complex business problems more efficiently and agilely (Wang et al., 2020). Therefore, the use of renewable technology will have a significant impact on future development and have an impact on people's lives.

This research also found the topic of smart farming which is currently a new topic that can be developed. Smart farming, or Agriculture 4.0, is a development of the discussion of renewable technology in the agricultural sector (Giua et al., 2022). This presents various challenges despite offering many benefits. Key challenges include access to and adoption of technology, where the digital divide and high costs are barriers, especially for farmers in rural areas or developing countries (Jakku et al., 2019). Data management and privacy are also important issues, given the need for effective systems and high data security. Skills and education are other crucial factors, as farmers and the workforce must be trained to use new technologies and have in-depth technical knowledge (Kernecker et al., 2020). Therefore, the need for the integration of various technologies in existing systems often becomes complex and requires major changes in work practices.

Environmental conditions and reliance on weather add to the challenge of ensuring technology can help address weather variability and the impacts of climate change. Less supportive regulations and policies, as well as lack of government support, can hinder the adoption of smart farming technology (Martens & Zscheischler, 2022). Social and economic impacts, such as changes in social structures in rural areas and the risk of exacerbating inequality, also need attention. Addressing these challenges requires an in-depth study, including investments in digital infrastructure, training, policy support, and ongoing research and

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development to ensure that smart farming not only increases efficiency and productivity, but also contributes to environmental sustainability and social well-being (Shulgina et al., 2019).

Technological innovation and digitalization are transforming the agri-food sector, offering opportunities for sustainable and resilient systems. It also presents challenges, costs, and risks in economic, social, and ethical dimensions (Yu Gusev, 2021). Policy recommendations are needed to explore opportunities and avoid risks, and future research in agricultural economics will also be discussed. Current agricultural policy prioritizes technical and technological reforms for food independence and security. However, the outdated material and technical base of the industry is deteriorating, making it difficult to meet world standards. To increase profitability, the industry must turn to innovation, digital technology, and robotization. Modern methods are needed for assessing the efficiency of fixed assets, innovation and investment.

Conclusion

The development of research themes on agricultural technology innovation began in 2016, which was initiated by Nobre, C. A. Research on agricultural technology innovation shows significant development since 2020, focusing on various relevant keywords in this field. The keywords "Agriculture" and "Digital Agriculture" led the way from the start, with the emergence of themes such as "Smart Farming" and "Sustainability" from 2021 to 2023. This reflects increasing attention to the environmental impact and sustainability of agricultural technology. Bibliometric analysis shows the evolution in popularity of topics such as "Economic Development," "Production Efficiency," and "Agricultural Biotechnology," which have gained increasing attention in recent years.

The limitations of the study are due to its focus on statistically relevant issues and a single database, which may not cover all aspects of the research field. The database used in this research was only sourced from the scopus database, without compromising research in other journal databases. Future research could improve methodological methods and encourage innovation in agriculture to reduce environmental problems. In addition, the addition of technology adaptability studies (smart farming) is also a topic that can be done at this time. That's because there are still few researchers who raise the adaptability of technology used in the agricultural. Overall, the research provides insight into the priorities and developments of agricultural technology-related topics, helping to identify areas that need more research and development, as well as understanding the dynamics within these fields. Agriculture must continue to adopt technological innovations to achieve better sustainability, efficiency, and productivity, while paying attention to social and environmental impacts.

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