Advanced and Sustainable Technologies (ASET) eISSN 2976-2294
Volume 2, No 2, December 2023 [30-40]

Technological Applications in Smart Farming: A Bibliometric Analysis

Jonitha Anand[1], Dr. Nooraini Yusoff[1], Ts. Dr. Hadhrami Ab Ghani[1], Dr. Kiran Kumar Thoti[2*]

[1]Faculty of Data Science & Computing, Universiti Malaysia Kelantan, Malaysia.
[2]Faculty of Entrepreneurship & Business, Universiti Malaysia Kelantan, Malaysia.

Received 4 July 2023, Revised 23 August 2023, Accepted 4 September 2023

ABSTRACT

Precision agriculture, often known as smart farming, employs cutting-edge technology to change farming processes. This paper covers smart farming's history, important advancements, and possible impacts on agriculture. The essay begins with the history of "smart farming," or precision agriculture, and how GPS technology improved fertilization, pest control, and irrigation. Since then, automation and sensor technology have enabled continuous crop vitality, moisture, and environmental monitoring, enabling empirical decision-making. Networking technologies, especially the Internet of Things, have transformed smart farming. Farmers may gather, analyze, and apply real-time data using connected drones, satellite images, and farm management software. Big data analytics and AI allow farmers to leverage enormous datasets for crop health monitoring, production forecasts, and resource management. Smart farming improves accuracy and sustainability. By using resources efficiently, farmers may reduce their environmental impact. Due to remote monitoring and control, farmers can adapt to changing conditions and manage their operations from anywhere. Smart farming has numerous benefits, but various barriers limit its broad implementation. Due to expensive startup costs, specialized training, and limited Internet connection, some farmers are unwilling to use these technologies. Governments, NGOs, and industry actors must collaborate to provide financing, training, and improved connections to address these difficulties. This review and study of smart farming's growth highlights its revolutionary potential in agriculture. Smart farming may enhance output, optimize input returns, and ensure long-term viability, making it an exciting new route for agriculture.

Keywords: Agricultural, Industrial 4.0, Smart Farming, Techno agriculture

1. INTRODUCTION

In 2017, a historic first in digital agriculture — often called "smart farming" or "e-agriculture"- occurred: harvesting a crop that had been sowed and tended entirely by machines. Internet, mobile devices, data analytics, AI, and apps and services supplied online are only some of the digital technologies influencing the agricultural and food sectors. Traceability technologies and digital logistics services offer the potential to streamline agri-food supply chains and provide trusted information for consumers; farm machinery automation allows fine-tuning of inputs and reduces demand for manual labor; remote satellite data and in-situ sensors improve the accuracy and reduce the cost of monitoring crop growth and the quality of land or water; and so on. Governments can also benefit from digital technologies in terms of enhancing the efficacy of current policies and programs and developing new ones. For instance, the expense of monitoring numerous agricultural activities is greatly reduced because of freely available and high-quality satellite photography. As a result, governments may be able to implement laws that reward (or punish) farmers in accordance with the environmental results they provide. Automation of agricultural administrative operations and the development of new government services, such as

*Corresponding author: kiran.kt@umk.edu.my

extension and advising programs, are both made possible by digital technologies, which are also used to monitor compliance with environmental rules. Digital technologies can facilitate agricultural and food product trade by linking private sector suppliers to new markets, allowing for improved government oversight of standards compliance and streamlining border processes, which are crucial for transporting perishable goods [1]. More resilient, productive, and sustainable agriculture and food systems that better fulfil consumer requirements can be achieved with the help of these technological advancements. These advantages arise in two ways: first, when private participants in the sector (such as service providers) adopt new technologies; second, when governments employ new technologies to implement more effective policies.

2. REVIEW OF LITERATURE ON SMART AGRICULTURE

One of the main goals of "smart agriculture" is to increase agricultural output and productivity. The effectiveness of smart agriculture approaches is assessed by contrasting their results with those of conventional farming practices. Field trials, in which various technologies are put to the test in operational agricultural environments, are one method of accomplishing this goal. Researchers keep tabs on things like crop development, production, and quality to evaluate the efficacy of smart agriculture techniques versus conventional farming methods. It is possible to learn a lot about the efficacy of smart agriculture technologies by analyzing crop production and productivity [2].

Smart farming practices strive to reduce the wasteful consumption of resources, including water, fertilizer, and power. Evaluating resource efficiency entails comparing the resource savings produced by using smart agriculture techniques to those of more conventional methods. Water, fertilizer, and energy consumption rates can be compared between conventional farming and smart agriculture systems to reach this conclusion. Precision irrigation and variable rate fertilization are only two examples of smart agriculture technologies that have been found to drastically increase yield per unit of input [3].

Impact on the Environment: Evaluating the ecological footprint of smart farming is essential for maintaining environmentally responsible agricultural methods. Indicators like greenhouse gas emissions, water pollution, and soil health are measured for evaluation in this field. Precision farming and sensor-based crop monitoring are two examples of smart agriculture systems that help farmers use less harmful chemicals while protecting the environment. Smart agricultural practices have been shown to lessen the environmental strain and conserve valuable materials [4].

The economic viability of smart agriculture can be determined by calculating the expected return on investment (ROI) and determining whether the implementation of smart agricultural technologies is cost-effective. The costs of implementation, maintaining operations, and the potential savings from greater efficiency and productivity are all considered. To determine if smart agriculture approaches are worth the investment, researchers use cost-benefit assessments and economic modeling. Evidence suggests smart agriculture can increase farm income and reduce costs [5].

For smart agriculture technologies to be widely adopted, it is essential to assess how well they are received by end users. To complete this evaluation, we must first understand how farmers feel about and interact with smart agriculture systems. Quantitative data can be gained by analyzing adoption rates and usage trends, while qualitative data can be collected through surveys, interviews, and focus groups. Barriers and drivers to the widespread use of smart agriculture technologies can be identified through research into user acceptance and adoption [6].

3. OBJECTIVE OF THE RESEARCH

• The purpose of this research would be to identify the various technical applications employed in smart farming by conducting a comprehensive literature study and bibliometric analysis. The utilization of data analytics, Internet of Things (IoT) gadgets, drones, precision farming methods, and other cutting-edge tools could be examined.

• The goal of this study is to evaluate the research trends and publication patterns in smart farming by looking at factors like the growth of research output, the top journals and conferences, the ways in which scientists work together, and the distribution of publications across different countries. Such an examination would provide light on the present research landscape and point to areas where more investigation is needed.

• The purpose of this study is to evaluate the influence of smart farming research by examining the citation habits of academic papers in the field. The first step would be to compile a list of the most-cited works, most-cited authors, and most important study topics. The most impactful studies can be better understood, and new study fields can be found by evaluating the influence of previous studies.

4. EVOLUTION OF TECHNOLOGY IN AGRICULTURE

Low-tech mechanization may be packed with many clever components based on very clever engineering, but it can only replace or assist a human being or human activity in relatively simple tasks and has limited adaptability in terms of the task at hand, the objects it must handle, and the working environment in which it operates. This type of technology typically relies heavily on mechanical engineering solutions and has nothing in the way of electronics, sensors, software, or "intelligence."

The tractor has effectively replaced the horse, the ox, and even the human in terms of movement and muscle force on and off the field, but it has no idea what operation to execute, where to perform it, or how to perform it. A human operator (the farmer or one of her staff) is still responsible for overseeing the operation and keeping everyone safe. Obviously, a variety of implements have been developed to attach to the tractor and carry out the activities necessary for agricultural production [7]. Again, the implements' limited adaptability means they have always been operated with a full field "one size fits all" strategy in mind. In the precision agriculture paradigm, sensors that use recent developments in artificial intelligence map fields, arable crops, or fruit tree crops show the inherent diversity of these areas and aid farmers in making informed decisions [6].

The development of automated farming systems: When it comes to farming, the milking robot is the first practical application of robotic technology. The robotic milking parlor, which began as a research challenge in the early 1980s and is now widely employed in agriculture, has come a long way from its inception [8]. Autonomous barn cleaning robots and feed dispensers are two further pieces of cutting-edge technology that have recently become accessible in livestock farming. When moving from cage systems to loose housing systems for laying hens, the issue of floor eggs has been studied in the context of robotic floor egg collection in poultry production. Self-driving tractors: It is currently difficult to fully replace human capabilities in all areas of arable farming [9]. However, cutting-edge tools to aid the farmer are already available. Autosteer systems based on global positioning satellite data assist human drivers in one aspect of tractor operation. This innovation has been widely used in agriculture over the past two decades due to its ability to cut down on operational costs and fuel use. While plans for fully autonomous tractors or robots have been in the works in academia and industry for some time, worries about liability have slowed their development. It is anticipated that advances in autonomous driving will pave the way for similar advances in agricultural robotics. One semi-autonomous option is a tractor-pulled tool that uses computer vision for precise weeding. The recent advancement in camera vision and AI, particularly Deep Learning approaches, shows promise for weed identification in cash crops [10]. Harvesting: Autonomous fruit picking has received a lot of focus in greenhouse horticulture. Still, this is a major obstacle because of the greenhouse's subpar illumination, the disorganized layout, the fact that fruits are sometimes hidden by leaves and stems, and the substantial natural variety among plants and fruits. While the 'Hands-free hectare' is still in its infancy, AI capabilities are being successfully tested in the autonomous greenhouse challenge, and a robot to remove leaves from tomatoes in a high-wire cultivation growing system is close to the market right now. Adopting new technologies: Creating new robotic technology is one thing, but using it in farming is another. First, there seems to be a shift in the ecology-supporting technology. A new type of company is entering the agricultural technology sector, one that specializes in robots and artificial intelligence. Second, essential success criteria for the adoption of robotic technology include tailoring technology to farmers' needs and teaching farmers to operate increasingly high-tech equipment. Thirdly, being data-intensive technology, incorporating robotics into the future farm's digital infrastructure presents its own unique set of difficulties. Robots are a clear addition to the Internet of Things infrastructure in agriculture. The issues of data ownership and confidentiality must be resolved. It's the same with concerns like risk and responsibility. Several European initiatives, like the Internet of Farming (IoF) and AgRoboFood, are working to incorporate this cutting-edge technology into the food production process. However, the adoption of technology is not just a problem for farmers. Consumers have mixed feelings about the intersection of food and technology. There are moral questions we must answer about this type of cutting-edge technology.

5. TECHNOLOGY ADOPTED IN AGRICULTURE

Today, more than ever, agricultural progress depends on novel approaches. Rising material and labor costs, as well as shifting customer priorities toward greater openness and ecological responsibility, pose serious threats to the entire business. Companies in the agricultural sector are coming to realize the urgency with which these problems must be addressed. Thankfully, agtech (tech used in agriculture) has arrived. To boost efficiency, productivity, and sustainability in food production, a new concept has emerged: precision agriculture. Precision agriculture incorporates a wide range of technologies, such as smart irrigation, biotechnology, and automation. In addition, there have been substantial technological developments that we will delve into more in this essay, including indoor vertical farming, livestock technology, contemporary greenhouse methods, artificial intelligence, and blockchain.

Indoor Vertical Farming: Grow more crops on less land using indoor vertical farming and lessen farming's environmental effect by shortening the supply chain. Fruits and vegetables are piled vertically in a controlled setting to maximize growing space. Its primary benefit is that it requires far less land for plant cultivation than conventional methods. One advantage of vertical farming is that in some configurations, dirt is not necessary for plant growth. The majority are either hydroponic, where plants are grown in a nutrient-rich bowl of water, or aeroponic, where water and nutrients are sprayed consistently onto the roots of the plants. Up to 70% less water is needed for vertical farms compared to conventional farms. The benefits of indoor vertical farming are obvious, ranging from sustainable urban growth to increased food yields with decreased labor expenses. Increased food production with consistent harvests is made possible by innovative agricultural technology that allows for the exact management of light, humidity, and water. By automating tasks like harvesting, planting, and logistics, farms can overcome the labor deficit now plaguing their business.

Farm automation: Farm automation, sometimes known as "smart farming," is a type of agricultural technology that streamlines the entire process of growing crops or raising livestock.

Drones, autonomous tractors, robotic harvesters, automatic watering, and seeding robots are just some of the innovations in robotics that a growing number of AgTech firms are working on. Although these technologies are still relatively new, more and more conventional agricultural businesses are incorporating farm automation into their operations.

Livestock farming technology: Providing much-needed renewable natural resources that we rely on daily, the traditional livestock business is undoubtedly the most vital yet largely disregarded sector. Livestock management, more often known as the administration of farms, cattle ranches, and other similar agribusinesses, entails keeping correct financial records, overseeing employees, and guaranteeing the proper care and feeding of animals. But new agricultural technologies are changing animal husbandry forever. These innovations have considerably benefited the business by making livestock tracking and management much simpler and more efficient. Animal and livestock production, care, and administration can all benefit from technological advancements in the livestock industry. Equipping herds with sensors to monitor health and boost productivity gave rise to the "connected cow" concept. Producers can keep better tabs on daily activities and health issues with the use of wearable sensors attached to individual cows. Understanding the complete gene landscape of a living animal and how it interacts with other genes to affect growth and development is the focus of animal genomics, a relatively new agricultural technique. The genetic risk of their herds and the potential profitability of their cattle can be better assessed using genomic information. Thus, farmers can maximize profits and outputs from livestock herds through strategic animal selection and breeding decisions. The advantages of agtech to the sector are substantial. The productivity of cattle herds can be increased using data-driven decision-making.

Modern greenhouses: larger greenhouses now compete head-on with traditional farming on the ground, a shift that has occurred over the past few decades. Historically, greenhouses were employed largely for research and aesthetic purposes (such as in botanic gardens). The United States accounts for less than one percent of the world's greenhouse vegetable production, which totals around $350 billion per year. The sector is flourishing like never before, and a big reason for it is the recent enormous breakthroughs in growing technologies. Large-scale, capital-intensive, and city-based greenhouses are proliferating. Nearly US$350 billion worth of vegetables are now grown in greenhouses throughout the world every year. The market has expanded significantly, and there have been discernible patterns in it during the past few years. LED lighting and automated control systems are two examples of the increasing technological sophistication of today's greenhouses. To meet the rising demand for locally grown food, successful greenhouse businesses are expanding rapidly and positioning their greenhouses near major cities. The greenhouse business is becoming more capital-infused to achieve these goals, leveraging venture finance and other means to expand the infrastructure necessary to compete in the present market.

Figure 1: Indoor Precision Farming.

Precision agriculture technology: Technology is rapidly becoming an integral part of every industrial farm, marking a significant shift in the agricultural industry. To help farmers increase their profits, cutting-edge precision agriculture firms are creating tools to monitor and adjust factors such as soil moisture, sunlight exposure, and microclimates. Precision agriculture helps farmers save time and money by giving them more precise methods of planting and cultivating crops. There is a massive market for precision agriculture businesses to expand into. The precision agricultural market is expected to grow to $43.4 billion by 2025, according to a new analysis from Grand View Research, Inc. A new breed of farmers is on the rise, and they're drawn to the agility and efficiency of businesses that systematically increase harvests.

Blockchain and food traceability: Food fraud, safety recalls, supply chain inefficiencies, and food traceability are just some of the problems the blockchain's record-keeping and security features could help fix. Its distributed nature assures that only tried-and-true goods and procedures make it onto the market. New developments in blockchain applications have brought food traceability to the forefront of discussions about food safety. The food business is particularly at risk of catastrophic failure because of the perishable nature of the products they handle. Immediate problems in the present food system that blockchain technology can address include food fraud, safety recalls, supply chain inefficiency, and food traceability. The food supply chain cannot function without traceability. Since some participants in the food ecosystem are keeping track of information on paper, the present communication framework makes traceability a time-consuming effort. A responsible and traceable system, the blockchain design permits data points to be generated and shared safely by all participants in the food value chain. Massive data sets with custom labels can be captured instantly and unaltered. This means that the entire process of food distribution may be tracked in real-time. Blockchain's potential applications in the food industry extend far beyond the realm of safeguarding the security of food supplies. It's an improvement on the present market since it creates a distributed ledger and helps keep prices stable. The traditional market price discovery technique is based on the opinions of the participants rather than the data available from the complete value chain. By making information available, a more complete picture of the market's supply and demand can be painted.

Agriculture and artificial intelligence: The health of plants, soil, temperature, humidity, and other environmental factors may all be tracked with these [11, 12]. The purpose of this cutting-edge technology is to provide farmers with more information about their fields than the human eye can detect. It's quicker and more efficient, and it is also more precise. Algorithms derived from distant sensors read field boundaries as statistical information that farmers can use. When given new information, algorithms can adjust and improve their performance. The better the algorithm can anticipate various outcomes, the more inputs and information it collects. The hope is that this AI would help farmers make more informed decisions in the field and lead to increased crop yields [13, 14].

Figure 2: Drown agriculture process.

6. BIBLIOMETRIC ANALYSIS

The total number of research articles that appear on the Scopus database is 56,327 documents based on the keyword search as technology in Agriculture.

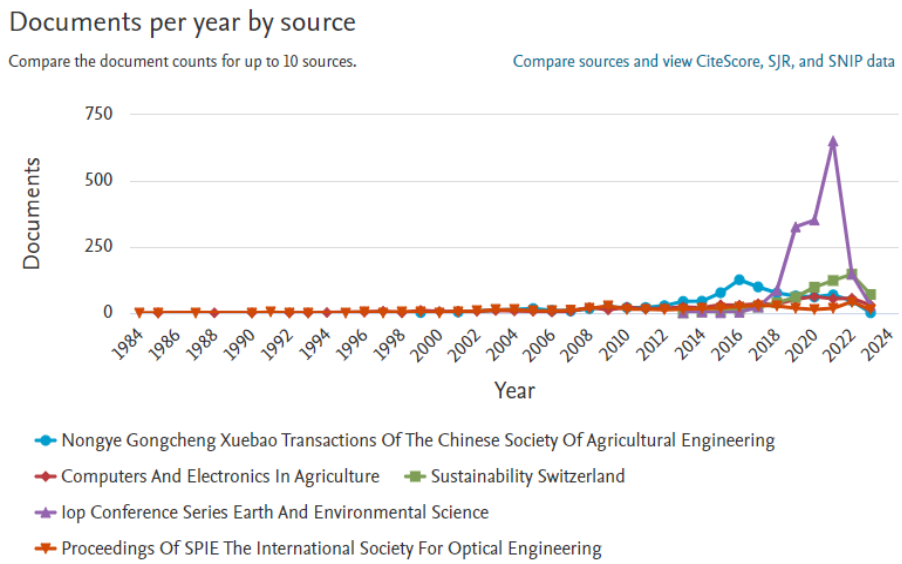

Figure 3: Documents Published in Scopus (Source: Scopus Database).

According to the above graph (Figure 3), most of the documents contribute to technological agriculture, and most of the articles are developed and discussed in the Iop conference series Earth and Environmental Science.

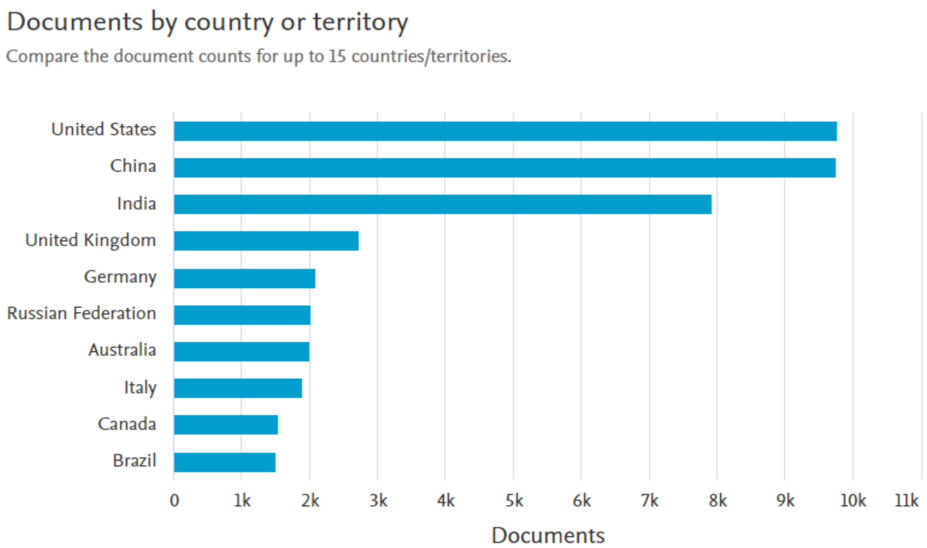

Figure 4: Documents contributed by Territory (Source: Scopus Database).

According to the above graph (Figure 4), most of the documents that contribute to technological agriculture are generated by United States followed by China, India, United Kingdom, Germany, Russian Federation and many more countries focusing on agriculture research.

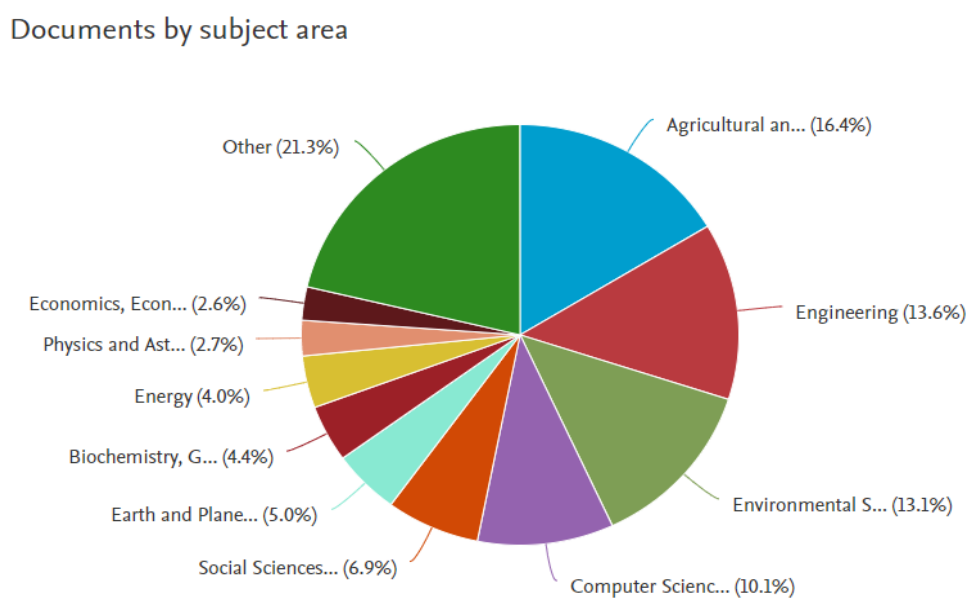

Figure 5: Documents contributed by Subject area (Source: Scopus Database).

According to the above graph (Figure 5), most of the documents contribute to the development of technology through agriculture, engineering, environment, computer sciences, social science, earth and planetary, Biochemistry, Energy, Physics, and Economics.

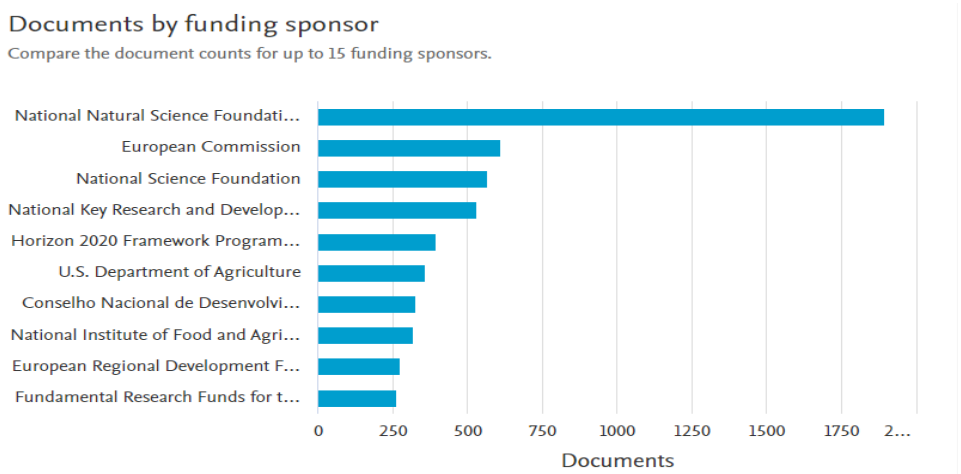

Figure 6: Documents Contribute by Funding Sponsor (Source: Scopus Database).

According to the above graph (Figure 6), most of the documents are funded by the National Natural Sciences Foundation, and the rest of the funders are the European Commission, National Science Foundation, National Key Research and Development, Horizon 2020 framework, U.S. Department of Agriculture and most of the organizations are supporting individuals to contribute the innovation of work in agriculture.

7. RESULTS & DISCUSSION

Several important technology applications in smart farming were uncovered by bibliometric study. According to the literature review, IoT devices are becoming increasingly important in smart farming. Data-driven decision-making is aided by IoT devices' constant monitoring of conditions, including soil moisture, temperature, and crop health. Aerial imaging, crop monitoring, and pesticide spraying are just some of the many uses that drones were found to have in smart farming [15]. It has been determined that variable rate technology, remote sensing, and GPS-based guiding systems are essential instruments for optimizing resource allocation and increasing crop yields using precision agriculture techniques. In addition, farmers were able to gain useful insights from massive amounts of agricultural data thanks to the widespread use of data analytics and machine learning. Analysis of publication patterns in smart farming revealed a sharp increase in research output over the previous decade. There has been a consistent rise in the number of smart farming-related publications, suggesting a growing interest in the topic. The investigation also uncovered the top academic conferences and publications in the field, such as the "Journal of Agricultural Informatics" and the "International Conference on Precision Agriculture [16][17][18]." The researchers observed that there were interdisciplinary patterns of collaboration, including input from agronomy, computer science, engineering, environmental science, and other disciplines [19]. The investigation showed that publications came from around the world, with major contributions from Asia, Europe, and the Americas. Insights on the influence of smart farming research were gleaned from an examination of citation trends. Several highly cited articles were found, which likely represent seminal research. These pieces discussed several facets of smart farming, such as the creation of cutting-edge technologies, the introduction of precision agriculture methods, and the use of data analytics to assist with managerial decisions. In addition, the investigation singled out prominent researchers who have made important contributions to the field of smart farming. Their research has shaped what comes next and the overall trajectory of the field. Smart farming research has been found to be very interdisciplinary, as shown by the analysis. Expertise in agriculture, technology, and data science is converging, as seen by patterns of collaboration among academics from different scientific fields. The agriculture industry has complicated issues, and utilizing technical advances for sustainable and effective farming techniques requires an interdisciplinary approach [20]. For creative solutions to be developed and technology integrated into farming processes, it is essential that professionals in agronomy, computer science, engineering, and environmental science work together.

8. CONCLUSION

The bibliometric study revealed various new lines of inquiry and promising fields for further study in the field of smart farming. Artificial intelligence (AI) and machine learning integration for sophisticated decision support systems is one such topic. Models powered by artificial intelligence can improve forecasting accuracy and pave the way for preventative measures in crop management, disease diagnosis, and yield maximization. Using blockchain technology to increase traceability and transparency in the food supply chain is another encouraging development. Using blockchain technology, we can check the legitimacy of food goods and guarantee honest dealings amongst all parties involved. The study also underlined the importance of studying the socioeconomic effects of smart farming, such as evaluating its benefits for small-scale farmers and the rural community. Finally, the multidisciplinary character, important technologies, and research trends of smart farming were all uncovered through the bibliometric examination of technical applications. The research found that Internet of Things gadgets, drones, precision agriculture methods, and data analytics are all very useful. Smart farming has been receiving more and more attention recently, as seen by the rising levels of research production and interdisciplinary collaboration. The analysis of citation trends sheds light on seminal research and authors. The study also highlighted promising future research avenues, such as blockchain applications in agriculture and AI-driven decision support systems. Sustainable agriculture techniques can be improved with the help of these results, which can be used by researchers, practitioners, and policymakers in the field of smart farming.

REFERENCES

[1] Trendov, M., Varas, S., & Zeng, M. Digital technologies in agriculture and rural areas: status report. Digital technologies in agriculture and rural areas: status report, (2019).

[2] Tian, H., Wang, T., Liu, Y., Qiao, X., & Li, Y. Computer vision technology in agricultural automation—A review. Information Processing in Agriculture, vol 7, issue 1 (2020) pp. 1-19.

[3] Farooq, M. S., Riaz, S., Abid, A., Umer, T., & Zikria, Y. B. Role of IoT technology in agriculture: A systematic literature review. Electronics, vol 9, issue 2 (2020) p. 319.

[4] Takahashi, K., Muraoka, R., & Otsuka, K. Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. Agricultural Economics, vol 51, issue 1 (2020) pp. 31-45.

[5] Lu, B., Dao, P. D., Liu, J., He, Y., & Shang, J. Recent advances of hyperspectral imaging technology and applications in agriculture. Remote Sensing, vol 12, issue 16 (2020) p. 2659.

[6] Tao, W., Zhao, L., Wang, G., & Liang, R. Review of the internet of things communication technologies in smart agriculture and challenges. Computers and Electronics in Agriculture, vol 189, (2021) p. 106352.

[7] Jung, J., Maeda, M., Chang, A., Bhandari, M., Ashapure, A., & Landivar-Bowles, J. The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. Current Opinion in Biotechnology, vol 70, (2021) pp. 15-22.

[8] Simões Filho, L. M., Lopes, M. A., Brito, S. C., Rossi, G., Conti, L., & Barbari, M. Robotic milking of dairy cows: a review. Semina: Ciências Agrárias, vol 41, issue 6 (2020) pp. 2833-2850.

[9] Barrile, V., Simonetti, S., Citroni, R., Fotia, A., & Bilotta, G. Experimenting agriculture 4.0 with sensors: A data fusion approach between remote sensing, UAVs and self-driving tractors. Sensors, vol 22, issue 20 (2022) p. 7910.

[10] Venice, J. A., Thoti, K. K., Henrietta, H. M., Elangovan, M., Anusha, D. J., & Zhakupova, A. Artificial Intelligence based Robotic System with Enhanced Information Technology. In 2022 Sixth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC). (2022, Novembe) pp. 705-714).

[11] Jha, K., Doshi, A., Patel, P., & Shah, M. A comprehensive review on automation in agriculture using artificial intelligence. Artificial Intelligence in Agriculture, vol 2, (2019) pp. 1-12.

[12] Ben Ayed, R., & Hanana, M. Artificial intelligence to improve the food and agriculture sector. Journal of Food Quality, vol 2021, (2021) pp. 1-7.

[13] Jung, J., Maeda, M., Chang, A., Bhandari, M., Ashapure, A., & Landivar-Bowles, J. The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. Current Opinion in Biotechnology, vol 70, (2021) pp. 15-22.

[14] Eli-Chukwu, N. C. Applications of artificial intelligence in agriculture: A review. Engineering, Technology & Applied Science Research, vol 9, issue 4 (2019).

[15] Chiu, M. T., Xu, X., Wei, Y., Huang, Z., Schwing, A. G., Brunner, R., ... & Shi, H. Agriculture-vision: A large aerial image database for agricultural pattern analysis. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. (2020) pp. 2828-2838.

[16] Daponte, P., De Vito, L., Glielmo, L., Iannelli, L., Liuzza, D., Picariello, F., & Silano, G. A review on the use of drones for precision agriculture. In IOP conference series: earth and environmental science. vol 275, issue 1 (2019, May) p. 012022.

[17] Lowenberg-DeBoer, J., & Erickson, B. Setting the record straight on precision agriculture adoption. Agronomy Journal, vol 111, issue 4 (2019) pp. 1552-1569.

[18] Fawakherji, M., Youssef, A., Bloisi, D., Pretto, A., & Nardi, D. Crop and weeds classification for precision agriculture using context-independent pixel-wise segmentation. In 2019 Third IEEE International Conference on Robotic Computing (IRC). (2019, February) pp. 146-152.

[19] Chebrolu, N., Lottes, P., Läbe, T., & Stachniss, C. Robot localization based on aerial images for precision agriculture tasks in crop fields. In 2019 International Conference on Robotics and Automation (ICRA). (2019, May) pp. 1787-1793.

[20] Liu, Y., Ma, X., Shu, L., Hancke, G. P., & Abu-Mahfouz, A. M. From Industry 4.0 to Agriculture 4.0: Current status, enabling technologies, and research challenges. IEEE Transactions on Industrial Informatics, vol 17, issue 6 (2020) pp. 4322-4334.