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CONTRIBUTION OF AI IN IMPROVING FOOD SECURITY: A LITERATURE STUDY

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ABSTRACT

Global food security is a major challenge due to population growth, climate change and limited natural resources. Artificial intelligence (AI) technologies offer innovative solutions to address these issues by improving efficiency and productivity in the agricultural sector. This article reviews the contribution of AI in supporting food security through applications such as yield prediction, crop health monitoring, water management, and food waste reduction. Several studies demonstrate the use of AI in precision agriculture, which optimizes resource use through real-time data analysis from IoT sensors, satellite imagery, and drones. Innovations such as AI-based automated irrigation systems and smart farming apps help farmers manage water use more efficiently, especially in areas at risk of drought. In addition, the application of AI in vertical farming enables precise environmental control, increasing productivity in urban areas with limited land. The study also highlights the role of AI in reducing reliance on chemical pesticides through early detection systems that enable timely intervention. Despite the potential, the adoption of AI technology in agriculture still faces challenges such as initial investment costs and training needs for farmers. Collaboration between the government, private sector, and research institutions is essential to ensure effective and sustainable implementation of AI in agriculture, so that global food security can be achieved

1. Introduction

Food security is an increasingly pressing global issue as the world's population grows and environmental challenges such as climate change. According to the Food and Agriculture Organization (FAO), food production must increase by 60% to meet the needs of a population predicted to reach 10 billion with food requirements increasing by 70-90% by 2050[1]. Meanwhile, climate change, land degradation, and limited water resources pose significant threats to agricultural productivity. Based on these data, it is necessary to immediately increase agricultural productivity to meet the gap that occurs. In addition, agriculture plays an important role in the economic development of every country. The use of artificial intelligence in modernization efforts is a demand and can also ensure efficient and effective food production [2].

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Facing these challenges, modern technologies, especially artificial intelligence (AI), offer innovative solutions to improve the efficiency of food production and ensure global food security. AI is a technology that allows computers and machines to simulate human learning processes, namely understanding, problem solving, decision making, creativity, and independence [3].

Digital computer capabilities associated with AI can apply a system with human intelligence processes, such as the ability to reason, interpret, generalize, or even learn from the past [4]. Currently, with these capabilities, AI technology can be applied in various fields, such as medical, security, agriculture, fisheries, and others. Technically, the computer system receives data from a sensor and then stored as a database to be processed with an intelligent algorithm, in this process the data is divided into training and testing data. Training data as input for intelligent network training based on criteria obtained from experts. Systems with trained intelligent algorithms then have the ability to process new data, for example classifying, detecting, predicting, making decisions, and others. The more data that is trained will make the system smarter. AI technology is able to process large amounts of data quickly and accurately, so AI can optimize various aspects of agriculture, from crop yield prediction, plant health monitoring, to water and soil management [5], [6].

AI technology enables precise performance, as data can be obtained from various valid sources, such as sensors from IoT systems, satellite images, and drones. The system can also work in real-time to provide accurate insights or information to farmers regarding soil, crop, and weather conditions, thereby increasing agricultural efficiency and productivity [7], [8]. This article will discuss about 17 national and international publication articles, starting from the introduction, AI-based agricultural production optimization, AI-based smart irrigation, food waste reduction through AI technology, Agriculture 4.0 and Agriculture 5.0 in food security, results, discussion and conclusions.

2. Method

2.1. Optimization of AI-Based Agricultural Production

The use of AI in agriculture has become a growing research topic in recent years. Previous studies have shown that AI technology can be used for a variety of applications, including crop yield prediction, plant health monitoring, water management, and fertilizer use optimization. AI has changed the way farmers manage their farms. In practice, AI enables precision farming, where real-time data from various sources (such as soil sensors, satellite images, and drones) are analyzed to provide accurate information regarding soil, crop, and weather conditions. Chu et al. applied several methods, including support vector machine (SVM), random forest, and eXtreme Gradient Boosting (XGBoost). The best results were shown in XGBoost, to overcome abnormal changes in rainfall and temperature due to climate change, which can lead to disasters [9]. Artificial neural network (ANN) with multilayer perceptron (MLP) model can effectively predict more accurate crop yields by considering various environmental factors, such as weather conditions, soil moisture, and crop growth patterns. Datasets were obtained from various regions in Saudi Arabia from 1994-2016, namely temperature, insects, rain, and yields of potatoes, rice, sorghum, and wheat [10]. Similarly, Zhao (2023) used AI technology in the form of mapping and navigation algorithms to optimize farmland monitoring [6]. In addition, a study conducted by Debnath & Basu (2023) mentioned that AI technology is able to improve the efficiency of agricultural resource use through real-time data analysis using IoT sensors and machine learning [5]. Another study by Lugonja et al. (2022) revealed how smart agriculture and digital transformation can drive efficiency in food production management. IoT-based smart agriculture enables end-user-oriented production monitoring and control, allowing smallholder farmers to actively collect farming data and process in real-time [7], [11].

The utilization of AI and IoT technologies can improve livestock management in the Agriculture 4.0 era, which can address the challenges of population growth and global food demand [8]. The integration of IoT, Big Data, AI, robotics, and automation technologies will change agriculture to be more efficient. This efficiency is obtained from the integration of AI and IoT technologies that allow real-time data collection, so that the data can be used as information for end-users (farmers) to make decisions that can increase production yields. Wahyudi Sumari (2020) shows how AI is being used in Indonesia to increase agricultural production as part of achieving Sustainable Development Goals (SDGs). In his article, it is stated that SGDs will be optimistically achieved if technology can be mastered well, with a national scale strategy AI can provide the best for society and the country [12].

On the other hand, it is also possible to increase farmers' income. Currently with social media, marketing can be done effectively and efficiently. The integration of mobile applications with AI technology can connect farmers with buyers as a means of marketing. In addition, this application can also embed some information related to sustainable agricultural practices and guidelines that can serve as a reference source [13].

2.2. AI-Based Smart Irrigation

Efficient water management is a critical element in agriculture, especially in drought- prone areas. AI-based smart irrigation systems enable automatic adjustment of the amount of water applied to crops based on real-time data from soil sensors and weather forecasts. This technology ensures that crops receive the optimal amount of water, reducing wastage and saving increasingly limited water resources [10], [14]. For example, automatic irrigation systems controlled by machine learning algorithms can predict crop water requirements and regulate watering according to the specific needs of plants in each phase of their growth [1]. Approaches with hyperspectral remote sensing (HRS), geographic information system (GIS), and AI can effectively improve sustainable agricultural productivity, as shown in Figure 1.

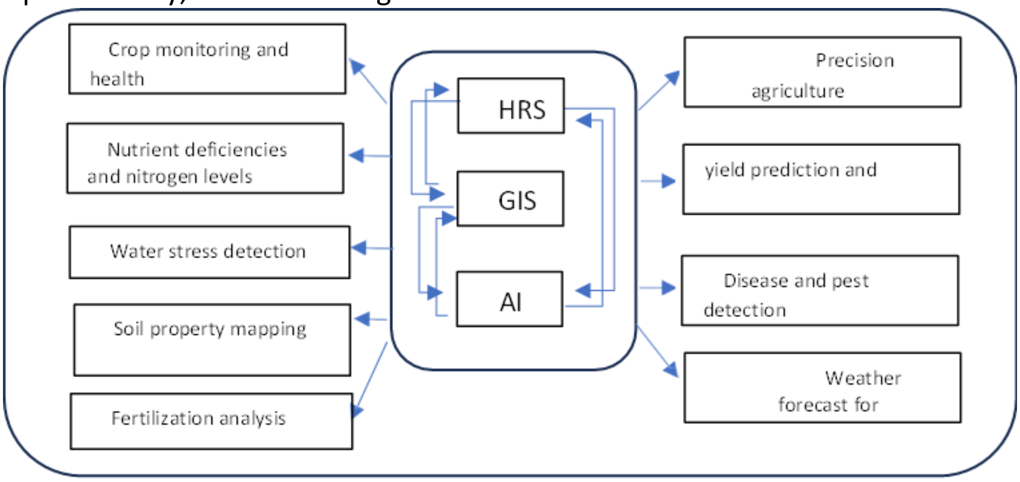

Fig. 1. HRS, GIS, and AI applications in agriculture

Chang et al. (2023) explained that AI in hydrological management can improve water resource management with more accurate predictions of irrigation needs, which is critical for food security, especially in areas with drought risk [10]. In addition, Agriculture 5.0 refers to the next phase of agricultural development, which builds on previous digital revolutions in the agrarian sector that aim to transform the agricultural industry to be smarter, more effective, and ecologically aware [10), more effective, and ecologically conscious [15]. Balaska et al. (2023) describe how robotics and AI in agricultural systems can reduce dependence on chemical pesticides, which helps in the production of healthier and more sustainable crops [15].

AI innovations in agriculture cover a wide range of aspects, from crop yield prediction to automation in crop management. AI helps farmers by providing timely recommendations for irrigation, fertilization, and pesticide use based on the analysis of data collected from sensors and IoT devices. Chanyal et al. (2024) discussed AI technologies that enable smart agriculture in water-stressed regions through automated irrigation systems integrated with IoT sensors for water savings [1]. In addition, research by Kumar et al. (2024) showed that AI can help reduce food waste through applications that enable better management of food waste in households, which also contributes to global food security [16].

AI has also been applied in the development of vertical farming, as described by Kabir et al.[17]. AI technology in vertical farming systems enables precise environmental control, which improves the productivity and quality of crop yields in urban areas with limited land [17]. Furthermore, Balaska et al. (2023) describe the use of drones and machine learning algorithms in identifying plant health and detecting diseases early, enabling faster intervention and reducing yield losses [15].

2.3. Food Waste Reduction through AI Technology

Food waste is one of the major challenges in the food supply chain that has a direct impact on global food security. AI has helped reduce this waste by developing applications that monitor consumption patterns and distribute excess food to those in need. AI-based applications can predict demand and supply trends, and provide recommendations to minimize food waste at the household and industrial level [13].

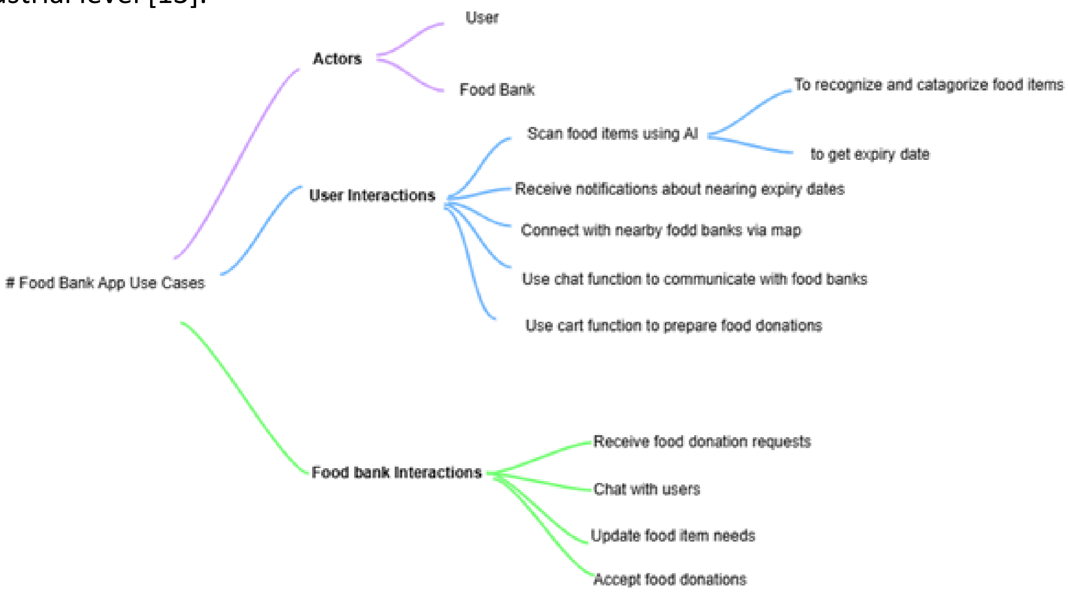

Fig. 2. Mind Map on Food bank Application [16]

In addition, this technology assists in more efficient distribution, ensuring that excess food can reach consumers before it spoils. The system develops an image classification model that can be automatically derived from images captured by application users. A Convolutional Neural Network (CNN) is used to train a dataset of food images of various categories, including fruits, vegetables, etc., shown in Figure 2. Optimization methods are applied to obtain optimal weights, resulting in optimal system performance [5].

2.4. Agriculture 4.0 and Agriculture 5.0 in Food Security

Agriculture 4.0 is an agricultural revolution that adopts digital technology to improve efficiency and precision in various agricultural processes. It includes the use of IoT, Big Data, AI, robotics, and automation to monitor and manage agricultural activities in real-time. Its implementation will contribute greatly to efficiency in increasing agricultural production, the use of resources will be more optimized, as well as enabling automation with the use of robots that can reduce manual workload.

Table 1. The role of Agriculture 4.0 and 5.0

Aspect	Agriculture 4.0	Agriculture 5.0
Focus	Process efficiency and automation	Sustainability, human-machine collaboration, efficiency and social welfare
Technology	IoT, Big Data, AI, robotics, automation	AI, IoT, ML, renewable energy, robotics, biopesticides
Pros	High efficiency, optimal use of resources	Holistic approach, e c o - f r i e n d l y , high connectivity
Disadvantag es	High cost, need for digital infrastructure	Complexity Implementation, cost of advanced technology

Agriculture 5.0 is a development of Agriculture 4.0 that emphasizes collaboration between humans and intelligent machines. In Agriculture 5.0, the focus is not only on efficiency but also on sustainability, social welfare, and the environment. The application of AI, IoT, machine learning (ML), and robotics technologies are utilized to create a more integrated and sustainable agricultural ecosystem. Agriculture 4.0 and 5.0 each have an important role in improving agricultural productivity, but the Agriculture 5.0 approach emphasizes sustainability and collaboration between humans and intelligent machines, as summarized in Table 1.

3. Results and Discussion

3.1. Results

Some other improvements are summarized in Table 2. The ANN network method has been proven effective in predicting crop yields with a high accuracy of 92% [9]. This method is able to achieve high accuracy with significant improvement when compared to traditional methods.

Table 2. Methods and Results of AI Application

No	Author & Year	Method	Result
1	Al-Adhaileh & Aldhyani (2022)[9]	ANN for crop yield prediction in Saudi Arabia	92% accuracy
2	Zhao (2023)[6]	Mapping and navigation algorithm for farmland monitoring	Able to map a land area of 100 hectares with accuracy 95%, reduced monitoring costs by 30%
3	Debnath & Basu (2023)[5]	Sensors IoT and Machine Learning for precision agriculture	Water and fertilizer use reduced by 25% compared to traditional methods methods, increasing production efficiency
4	Kumar et al. (2024)[16]	AI application for food waste reduction in households	Reduced food waste by 40% with consumption prediction system based algorithm machine learning
5	Balaska et al. (2023)[15]	Robotics and AI systems for pest management	Reduced pesticide use by 35% and increased crop yields by 20% compared to conventional methods

No	Author & Year	Method	Result
6	Chanyal et al. (2024)[1]	AI and IoT-based automated irrigation	Water use efficiency increased by up to 30%, especially in dry areas with smart irrigation systems
7	Sumari (2020)[12]	National strategy for the use of AI in agriculture for SDGs	Increased national agricultural productivity by 15% in three years with the implementation of AI technology
8	Ogubuike et al. (2021)[13]	AI-based mobile application for farmers	90% of users find it more helpful in marketing their produce
9	Willi Bianyosa Arif Wibiya et al. (2023) [11]	IoT for monitoring and controlling strawberry hydroponic farming.	Able to monitor and control strawberry hydroponic farming to keep it in ideal conditions.

In addition, the application of IoT and ML can save water and fertilizer usage up to 25%, which has an impact on increasing production efficiency [5]. The same thing was also found by Chanyal et al. (2024), with an AI-based automatic irrigation system can increase water use efficiency up to 30%, especially in areas with limited water [1].

3.2. Discussion

Overall, the integration of AI in various aspects of agriculture, from crop yield prediction to water management and waste reduction, shows significant results in improving food security. However, challenges in the adoption of these technologies, such as cost and training needs, remain to be addressed to ensure that the benefits of AI are accessible to all, including smallholder farmers in remote areas. Successful implementation requires cross-sector collaboration to overcome these barriers and drive further innovation in agriculture.

4. Conclusions

AI has opened up huge opportunities to improve global food security in a more efficient and sustainable way. Through yield prediction technology, smart irrigation, precision farming, and food waste reduction, AI contributes to creating a more efficient, resource-saving, and environmentally-friendly agricultural system. While there are still challenges in the application of these technologies, such as cost and infrastructure limitations, the potential for AI in agriculture is huge and growing. Continuous innovation and cross-sector collaboration are needed to ensure that these technologies can be used effectively to achieve better food security in the future.

Conflict of interest

The authors declare no conflict of interest.

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