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The Role of Agricurtural Technology in Achieving Sustainable Food Security

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Abstract

Sustainable food security is a critical challenge facing the agricultural sector amidst population growth, climate change, and limited natural resources. Agricultural technology presents a strategic solution to increase the productivity, efficiency, and sustainability of agricultural systems. This study aims to analyze the role of agricultural technology in achieving sustainable food security and identify various barriers to its implementation. The research method used was qualitative with a descriptive approach, utilizing secondary data obtained through literature review of relevant scientific journals, books, and research reports. The results indicate that agricultural technology plays a crucial role in increasing productivity and efficiency through precision agriculture, assisting adaptation to climate change through superior varieties, supporting modern, land-saving agriculture such as hydroponics and aeroponics, reducing yield losses through storage and drying technologies, and supporting environmentally friendly agriculture through the use of biopesticides and organic fertilizers. However, the implementation of agricultural technology still faces various obstacles, such as limited capital and infrastructure, low quality human resources, and social and institutional constraints. Therefore, support from the government and relevant parties through the provision of facilities, training, and mentoring is needed to increase the adoption of agricultural technology. With optimal technology implementation, sustainable food security can be achieved more effectively.

Keywords : Agricultural Technology, Food Security, Sustainable Agriculture, Productivity, Agricultural Innovation.

INTRODUCTION

Food security is a strategic issue of primary concern for many countries, including Indonesia. Food security is not only related to the availability of sufficient food but also encompasses aspects of accessibility, quality, safety, and sustainability (Arif et al., 2020). As the population increases, the need for food also increases significantly. This situation demands systematic and sustainable efforts to ensure food availability for all, both now and in the future (Saliem & Ariani, 2002).

However, the agricultural sector, as the primary food provider, faces various complex challenges. These challenges include the conversion of agricultural land to non-agricultural use, climate change affecting cropping patterns and yields, limited water resources, and low

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agricultural productivity in some regions (Sarjana et al., 2015). Furthermore, the continued dominance of traditional agricultural methods is also a factor hindering optimal production increases. This situation has the potential to threaten food security if not addressed with appropriate solutions (Prihartini et al., 2025).

To address these challenges, innovative efforts are needed to increase the efficiency and productivity of the agricultural sector. One possible solution is through the use of agricultural technology. Agricultural technology is the application of science and technology in agricultural activities to increase production yields, work efficiency, and the quality of agricultural products (Sarjana et al., 2015). This technology encompasses various aspects, such as the use of modern agricultural tools and machinery, irrigation technology, superior seeds, and the use of information technology in agricultural management (Maulida et al., 2023).

The use of technology in agriculture encompasses various aspects, from agricultural tools and machinery to information systems that support better decision-making (Siregar, 2023). Technologies such as precision farming and smart irrigation systems not only increase productivity but also assist in more efficient land management, reduce environmental impact, and promote sustainable agriculture (Mamat & Sukarman, 2020). By implementing this technology, farmers can manage land more effectively, reduce waste, and increase yields.

The use of agricultural technology plays a crucial role in increasing the productivity and efficiency of the agricultural sector. With technology, farmers can cultivate land more effectively, save time and energy, and increase yields (Ali, 2017). Furthermore, technology also allows farmers to obtain more accurate information on weather conditions, cultivation techniques, and market price developments. This will certainly help farmers make more informed decisions and reduce the risk of loss (Alfidyah, 2025). The use of appropriate technology can also help reduce excessive resource use, maintain soil fertility, and minimize negative impacts on the environment (Azhari et al., 2025). Thus, agricultural technology not only contributes to increased food production but also supports the creation of a sustainable and environmentally friendly agricultural system.

Although agricultural technology offers numerous benefits, its implementation in the field still faces a number of significant obstacles. One major obstacle is farmers' limited access to modern technology, both due to relatively high costs and limited availability of supporting facilities and infrastructure (Wanda et al., 2024). Furthermore, farmers' knowledge and understanding of new technologies remains relatively low, resulting in many farmers being unable to utilize them optimally. The lack of training, extension services, and technical assistance also slows down the adoption of technology in the agricultural sector. This situation

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causes some farmers to still rely on conventional methods that have lower levels of efficiency and productivity (Wulandari & Kurniati, 2025).

The purpose of this research is to analyze the role of agricultural technology in achieving sustainable food security and to identify various obstacles faced in implementing agricultural technology among farmers. The benefits of this research are expected to provide theoretical contributions as a scientific reference and study material for future researchers related to agricultural technology and sustainable food security. In practice, this research is expected to be a source of information for farmers, the government, and related parties in formulating policies, strategies, and programs that support the development and application of agricultural technology to increase productivity and strengthen food security in a sustainable manner.

METHOD

This research uses a qualitative method with a descriptive approach. This approach was chosen because it aims to understand and describe in depth the role of agricultural technology in achieving sustainable food security. Descriptive qualitative research allows researchers to examine phenomena systematically, factually, and accurately based on the data obtained (Fiantika et al., 2022). The research focuses on the use of agricultural technology, its benefits, and the obstacles encountered in its implementation. This approach is expected to provide a comprehensive picture of the importance of agricultural technology in supporting sustainable food security.

The type of data used in this research is secondary data obtained through literature review. Data were collected from various sources such as scientific journals, books, research reports, scientific articles, and other documents relevant to the research topic. Data analysis techniques are carried out through several stages: data reduction, data presentation, and drawing conclusions. Data reduction is carried out by selecting and focusing data that aligns with the research objectives. Then, the data is presented systematically in the form of descriptive descriptions. The final stage is drawing conclusions based on the results of the analysis. Through these stages, this research is expected to produce valid conclusions that align with the research problem.

RESULTS AND DISCUSSION

The Role of Agricultural Technology in Achieving Sustainable Food Security

Modern agricultural technologies, such as precision agriculture (IoT, drones), hydroponics, and biotechnology, are crucial for sustainable food security by increasing productivity, optimizing resources (water, fertilizer), and reducing environmental impact. These

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innovations accelerate growth, strengthen crop resilience to pests/climate change, and minimize food loss. The following are the key roles of agricultural technology in achieving food security:

- **Increased Productivity & Efficiency**

Increased productivity and efficiency are key roles of agricultural technology in supporting sustainable food security. Through the use of modern technology, cultivation processes can be carried out in a more planned, measurable, and targeted manner. Technology enables farmers to manage various aspects of production, from land preparation and planting to fertilization and harvesting, more effectively. This results in increased yields and reduced excessive resource use, resulting in more efficient and sustainable agricultural activities.

Figure 1 Drone technology for agriculture

One technology that plays a crucial role is the use of drones and Internet of Things (IoT)-based sensors. Drones can be used to monitor the overall condition of agricultural land, such as plant health, soil conditions, and areas experiencing drought or pest infestation. Meanwhile, IoT sensors can provide real-time data on soil moisture, air temperature, and crop water requirements. This information helps farmers make more informed decisions, such as determining the timing of watering, fertilizing, and pest control, thus optimizing the use of agricultural inputs and avoiding waste.

With this technology, agricultural productivity can significantly increase because crops receive treatment tailored to their needs. Furthermore, efficiency is also enhanced by more precise control of water, fertilizer, and pesticide use. This not only increases yields but also reduces production costs and minimizes negative impacts on the environment. Therefore, the implementation of modern agricultural technology is a crucial step in increasing the productivity and efficiency of the agricultural sector to support sustainable food security.

- **Climate Change Adaptation**

Adapting to climate change is a major challenge in the agricultural sector, as shifting rainfall patterns, rising temperatures, and the increasing frequency of natural disasters can

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impact crop productivity. These conditions can lead to crop failure, decreased agricultural quality, and increased risk of pest and disease attacks. Therefore, innovative agricultural technologies are needed to help plants adapt to constantly changing environmental conditions to ensure sustainable food production.

Figure 2. Superior rice varieties developed through genetic engineering.

One form of this innovation is the use of superior varieties developed through genetic engineering and modern breeding techniques, including genome editing. Through this technology, plants can be engineered to possess certain superior traits, such as drought resistance, resistance to pests and diseases, and the ability to grow in less fertile soil conditions. Furthermore, superior varieties can also have faster harvest times and higher yields compared to conventional varieties. This benefits farmers by reducing the risk of losses due to uncertain environmental conditions.

With plant varieties that are more resistant to abiotic stressors such as drought, extreme temperatures, and flooding, as well as disease, food production stability can be more assured. This technology helps farmers maintain optimal harvests even when facing the impacts of climate change. Furthermore, the use of superior varieties can also reduce dependence on pesticides and other chemical inputs, making them more environmentally friendly. Therefore, the development and application of modern plant breeding technology is a strategic step in increasing the resilience of the agricultural sector and supporting the realization of sustainable food security.

- **Modern & Land-Saving Agriculture**

Modern and land-saving agriculture is a crucial solution to addressing the dwindling availability of agricultural land due to land conversion and population growth. This situation demands innovation in cultivation systems that no longer rely solely on large plots of land.

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Modern agricultural technology allows food production to be carried out optimally even on limited land, even in urban environments. This ensures food availability remains secure without having to rely on large-scale agricultural land expansion.

Figure 3 Hydroponic Method

One widely developed method is hydroponics, a technique for cultivating plants without soil, but instead using nutrient solutions as a growing medium. This system allows for more controlled plant growth because nutrients are supplied directly to the plant's needs. Furthermore, hydroponics allows for more efficient water use compared to conventional methods. This system is ideal for applications in limited spaces, such as yards, greenhouses, and urban environments, and produces cleaner, higher-quality products.

Figure 4 Aeroponic Method with AFK

Besides hydroponics, aeroponics is also a significant innovation in modern agriculture. Aeroponics is a plant cultivation technique that suspends plant roots in the air and provides nutrients through mist or spray. This method allows for optimal nutrient absorption, allowing plants to grow faster and produce higher yields. Aeroponics also offers advantages in efficient

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use of water and nutrients as well as reducing the risk of disease attacks that typically originate in soil-borne media.

Figure 5 Tissue Culture

Another technology supporting modern agriculture is tissue culture, a plant propagation technique using small plant parts, such as cells or tissue, under sterile conditions in a laboratory. This technique allows for the production of large quantities of seedlings in a relatively short time with uniform quality. Furthermore, the resulting seedlings are more resistant to disease and have better productivity. With hydroponic, aeroponic, and tissue culture methods, agricultural activities can be carried out more efficiently, conserve land, and produce optimal production, thus contributing to sustainable food security.

- Reducing Food Loss & Food Safety

Reducing food loss and improving food safety are crucial aspects of achieving sustainable food security. Food loss often occurs during the post-harvest stage due to improper handling, inadequate storage, and limited storage facilities. This condition causes some agricultural products to spoil before reaching consumers, reducing food availability and causing losses for farmers. Therefore, technological support is needed to maintain the quality and extend the shelf life of agricultural products.

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Figure 6 Cold Storage, a place for storing agricultural products

One technology that plays a crucial role is the use of cold storage, or low-temperature storage. This technology allows agricultural commodities such as fruit, vegetables, meat, and other products to be stored at controlled temperatures, thereby slowing the decay process and the growth of microorganisms. With cold storage, product freshness and quality can be maintained for longer, thus maintaining their safety and increasing their selling value. Furthermore, this technology also helps maintain a stable food supply, especially during times of abundant production.

Gambar 7 Teknologi pengering dengan panel solar

In addition to cold storage, the use of drying technology is also an effective solution for reducing post-harvest losses. This technology is used to reduce the water content of agricultural

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commodities such as rice, corn, and other crops, allowing them to be stored longer without deterioration. The drying process using modern technology is faster, more hygienic, and does not rely entirely on sunlight like traditional methods. Therefore, the use of cold storage and drying technology not only helps reduce agricultural losses but also improves the quality, safety, and economic value of products, thus supporting sustainable food security.

- **Environmentally Friendly Agriculture**

Environmentally friendly agriculture is an important approach to realizing a sustainable agricultural system. The excessive use of chemicals, such as pesticides and synthetic fertilizers, can have negative impacts on the environment, including soil and water pollution, and decreased soil fertility in the long term. Therefore, safer and more sustainable alternatives are needed through the use of technologies that support the use of biopesticides and organic fertilizers. This approach aims to maintain ecosystem balance while maintaining agricultural productivity..

Figure 8 Use of Biopesticides from durian skin

Biopesticides are pesticides derived from natural materials, such as microorganisms, plants, or other organic materials, that function to control pests and plant diseases. With technological support, biopesticides can be produced and applied more effectively and precisely. The use of biopesticides does not leave harmful residues in the soil or agricultural products, making them safer for the environment and human health. Furthermore, biopesticides also help maintain the presence of other beneficial organisms, such as natural enemies of pests and soil microorganisms.

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Figure 9 Organic fertilizer

Furthermore, the use of technology-enhanced organic fertilizers also plays a crucial role in maintaining soil fertility. Organic fertilizers can improve soil structure, increase nutrient content, and enhance the soil's ability to retain water. Modern technology allows for faster and more efficient organic fertilizer production, resulting in better quality fertilizer. By implementing biopesticides and organic fertilizers, agriculture can be conducted in a more environmentally friendly manner, preserving natural resources, and supporting the long-term sustainability of food production.

Barriers to the Application of Agricultural Technology to Achieve Food Security

- **Economic and Infrastructure Constraints**

High costs are one of the main obstacles to the implementation of modern agricultural technology. The use of technologies such as smart farming, hydroponics, automated greenhouses, and Internet of Things (IoT)-based sensors requires significant initial investment. Smallholder farmers generally have limited capital due to relatively low and unstable incomes, making it difficult for them to purchase, operate, and maintain such equipment. Furthermore, farmers must bear additional costs such as equipment maintenance, spare parts purchases, and other operational expenses. This situation means that not all farmers are able to adopt technology, resulting in uneven use of agricultural technology.

In addition to cost constraints, limited infrastructure is also a significant inhibiting factor. Many agricultural areas, particularly in rural and remote areas, still have limited access to adequate internet networks, electricity, and transportation. Yet, most modern agricultural technologies, especially digital-based ones, rely heavily on stable internet connections and electricity supplies. Limited road access also complicates the distribution of agricultural

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equipment and products. This situation prevents optimal technology implementation and hampers agricultural modernization efforts to support sustainable food security.

- **Human Resource Constraints**

Low digital literacy among farmers is one of the obstacles to the implementation of modern agricultural technology. Many farmers, especially older generations, are unfamiliar with using digital devices such as agricultural applications, sensors, and technology-based automated tools. This lack of ability to understand and operate technology makes it difficult and less confident for farmers to use it. As a result, farmers tend to stick to traditional methods, which they consider easier and more suited to their habits.

Furthermore, the lack of training, extension services, and mentoring exacerbates this situation. Not all farmers have the opportunity to participate in training related to the use of agricultural technology. Yet, training is crucial for improving farmers' knowledge and skills in operating, maintaining, and optimally utilizing technology. Without ongoing mentoring, existing technology is at risk of not being utilized optimally or even being damaged due to misuse.

- **Technical and Environmental Constraints**

Climate change is one of the technical constraints affecting the effectiveness of agricultural technology implementation. Unpredictable weather conditions, such as changing rainfall patterns, extreme temperatures, and natural disasters, can impact the performance of precision agriculture technology. For example, automated irrigation systems and agricultural sensors require stable environmental data to operate optimally. Uncertain environmental conditions can lead to inaccurate decision-making, thus reducing agricultural productivity.

Furthermore, land degradation is also a serious problem in the application of agricultural technology. Inappropriate use of technology, such as excessive use of chemical fertilizers, can damage soil structure and reduce fertility. Degraded soil will struggle to support optimal plant growth, which can actually reduce agricultural productivity in the long term. Therefore, the use of technology must be balanced with the principles of sustainable agriculture to maintain environmental sustainability.

- **Social and Institutional Barriers**

The relatively small scale of farming is one of the obstacles to the adoption of modern agricultural technology. Many farmers have small and fragmented plots of land, making the use of modern agricultural tools and machinery less efficient. Certain technologies are more effective on larger plots of land, leading smallholder farmers to feel that using technology does not provide significant benefits. This situation slows technology adoption, especially among smallholder farmers.

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Furthermore, reluctance to change also hinders technology adoption. Some farmers remain comfortable with traditional farming methods that have been used for generations. They tend to be hesitant about new technologies due to fear of failure or loss. A lack of understanding of the benefits of technology and a lack of successful examples in their local environment also reinforce this resistance. Therefore, appropriate approaches, such as outreach, education, and mentoring, are needed to increase farmers' openness to accepting and implementing agricultural technology.

CONCLUSION

Agricultural technology plays a crucial role in achieving sustainable food security, particularly in increasing the productivity and efficiency of the agricultural sector. Through the use of modern technologies such as precision agriculture, smart irrigation systems, superior varieties, hydroponics, aeroponics, and post-harvest technologies like cold storage and dryers, farmers can increase yields, reduce yield losses, and maintain food quality and safety. Furthermore, technology supports the implementation of more environmentally friendly agricultural systems through the use of biopesticides and organic fertilizers, thereby preserving natural resources. In addition to increasing production, agricultural technology plays a crucial role in helping the agricultural sector adapt to climate change and land constraints. Innovations such as stress-resistant varieties and land-saving cultivation methods enable agricultural activities to continue operating optimally despite various constraints.

However, the implementation of agricultural technology still faces various obstacles, including economic, infrastructure, human resources, technical, and social barriers. Limited capital, low technological literacy, lack of training, limited infrastructure, and small-scale farming are key factors hindering technology adoption. Furthermore, persistent farmer resistance to change also poses a challenge in the process of modernizing the agricultural sector. Therefore, comprehensive support is needed from various parties, particularly the government, educational institutions, and the private sector, in the form of technological assistance, training, mentoring, and adequate infrastructure development. With this support, it is hoped that agricultural technology will be adopted more widely and optimally by farmers. Thus, agricultural technology can be a strategic solution for increasing productivity, maintaining environmental sustainability, and achieving sustainable food security.

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