

Artificial Intelligence Technology in Japanese Agriculture

Yip Kang Qin¹, Alias Abdullah¹, Asmadi Hassan¹, Fathiah Mohamed Zuki², Md Imtiaz Uddin³

¹Department of East Asian Studies Faculty of Arts and Social Sciences, University of Malaya

²Department of Chemical Engineering, Faculty of Engineering, University of Malaya

³UM Agroforestry, Glami Lemi Biotechnology Research Centre, University of Malaya

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ABSTRACT

Nowadays, Japan's agriculture is facing a ton of serious issues which is rapid aging farming population, labor shortages, and declining of interest among youth in the regarding sector. In order to address these issues, Japan promote artificial intelligence (AI) technologies in their agricultural industry. Firstly, AI agriculture refers to the use of smart technologies such as drones, sensors, machine learning and robotics to monitor crops, harvest prediction, pests and diseases detection and others automatic farming tasks. This technology can help farmers to reduce their workload, provide more accurate decisions and further improve the quality and quantity of their harvests. For example, Japan's farmer uses AI for crop monitoring and harvest prediction. Farmers will use drones that equipped with high-resolution and infrared cameras which can scan fields, assess plant health and even determine the best time for harvesting without any physical inspection. In the other hand, the affordable robotic harvesters are designed to pick fruits and vegetables with minimal human input. These robots equipped with camera and soft robotic hands for them to pick crops like strawberries and tomatoes without any damages. Moreover, AI systems can also control temperature, humidity and lighting in a greenhouse automatically. These technologies grow crops throughout a year with minimal resource needed. In addition, precision agriculture that uses AI to apply the right amount of water, fertilizer and pesticides to specific areas can also help reduce waste and environmental impact. One of the biggest issues is the average age of farmers, many of them are unfamiliar with new technology and hesitant to change traditional farming methods. Besides that, the high cost of AI equipment is also a big issue because majorities of the small-scale farmers cannot afford the initial investment. Moreover, the lack of strong digital infrastructure in rural areas also limits the effectiveness of AI systems. It is because the AI rely on fast internet connections and cloud computing. To overcome these issues, Japanese government plans to offer training programs, financial support and providing better internet infrastructure for rural communities. Although it is difficult to widespread adoption, but Japan government is creating a strong foundation for future growth of AI technologies. This approach not only benefits Japan but also play as a role model for other countries like Malaysia, which plan to collaborate with Japan in AI agricultural development.

Keywords: Artificial Intelligence (AI), Aging Population, Smart Farming / Precision Agriculture, Agricultural Modernization, Labor Shortage

BACKGROUND OF AI AGRICULTURE DEVELOPMENT IN JAPAN

Artificial intelligence agriculture refers to the use of technologies like computer vision and machine learning to enhance efficiency, increase yields, and enable precision farming. It helps monitor crops, detect pests, predict yields, and automate machinery, reducing labor and enhancing productivity. Japan is accelerating the development of AI agriculture, partly to address the challenges posed by labor shortages and an aging population and partly to align with the trends of agricultural informatization and trade liberalization. The active promotion of national agricultural policies also drives this development.

With the development of industrialization and urbanization, the reduction of the agricultural population has become an inevitable trend. After the war, Japan's rapid economic growth drove a large number of workers into

manufacturing and service industries, causing a sharp decline in agricultural employment. In 2001, there were still 236.4 million people employed in agriculture in Japan, but by 2014 this number had decreased to 167.9 million and further dropped to 140.4 million in 2019. (MAFF & Livestock Statistics Division, 2002) Below is the statistic of Japan's agricultural employment population:

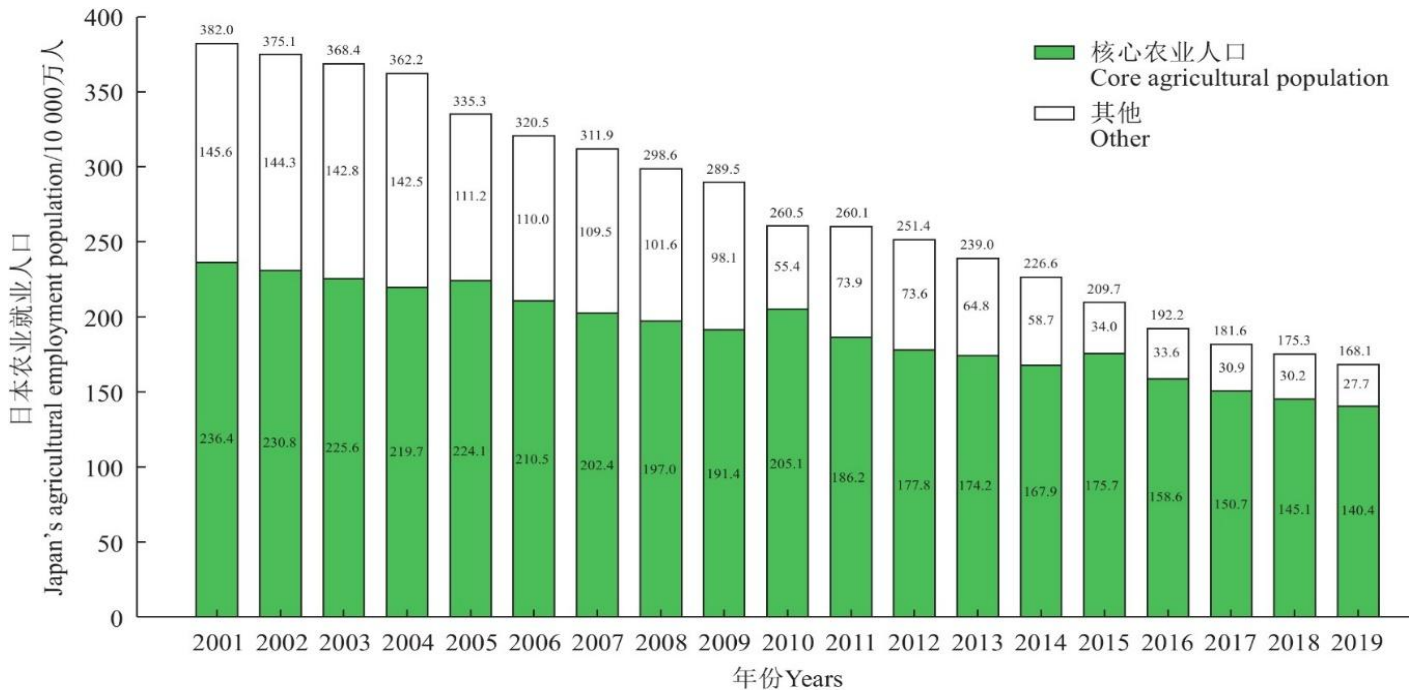


Figure 1: Statistic of Japan's agricultural employment population (2001-2019)

At the same time, influenced by population aging and a low birth rate, labor shortages and aging in the agricultural workforce have become increasingly serious, with the average age of agricultural workers reaching as high as 69.(MAFF & Livestock Statistics Division, 2002) Due to the relatively low income from agricultural work, young people are generally unwilling to continue their parents' farming, resulting in a serious shortage of successors in Japanese agriculture. Despite government efforts to attract youth, changing agriculture's traditional image remains challenging. Aging farmers continue production, causing reduced efficiency and land abandonment. Additionally, Japan's agriculture is highly specialized, making it a real challenge to transfer cultivation techniques and proprietary knowledge to newly recruited young workers. So, to tackle these issues, the government is promoting AI agriculture to accelerate informatization and smart farming. AI reduces labor burdens, attracts younger and female workers, and boosts production of high-value, quality products to enhance Japan's agricultural competitiveness.

With the acceleration of global trade liberalization, Japanese agriculture faces increasing international competition pressure. Although traditional protectionist policies have safeguarded domestic agriculture, they have also resulted in low production efficiency, placing Japanese agriculture at a disadvantage in free trade negotiations. Particularly under agreements such as the Trans-Pacific Partnership (TPP), the agricultural market is required to be fully opened, significantly increasing the pressure of trade liberalization. (Honma, 2015) To address this challenge and promote agricultural modernization and competitiveness, the Japanese government has actively promoted the informatization and intelligent transformation of agriculture, vigorously introducing artificial intelligence technologies. As early as 2004, the Ministry of Internal Affairs and Communications proposed the U-Japan Plan, including the development of agricultural Internet of Things (IoT) as a national strategy to advance the application of information technology in seeding, pest and disease control, quality and safety monitoring, and cost management. (He, Zhang, & Nie, 2021) Agricultural IoT technology has not only effectively alleviated labor shortages but also significantly improved agricultural production capacity and efficiency, achieving notable economic and ecological benefits. The development of AI agriculture has not only enhanced the international competitiveness of Japanese agriculture but also transformed the long-standing defense-oriented agricultural policy model, opening new opportunities and possibilities for flexible policy adjustment and sustainable development.

Lastly, the proactive promotion of agricultural policies by the Japanese government facilitated the development of AI agriculture. The government gradually shifted away from its long-standing protective and defensive agricultural policies, moving toward an aggressive strategy aimed at enhancing agricultural competitiveness. Within this policy transition, artificial intelligence emerged as a key technological pillar driving agricultural modernization. To realize the transformation from experience-based to smart farming, the Japanese government actively promoted the integration of advanced technologies, such as big data, AI, and agricultural robotics, into all stages of agricultural production, enhancing the sector's digitalization and automation. (Li, Nanseki, Chomei, & Kuang, 2023) In addition, to accelerate technological integration, the Japanese government encourages enterprises from all walks of life to participate in AI agriculture, use their own technological advantages, and develop professional agricultural solutions. In this context, electronic companies such as Toshiba and Panasonic have transformed into providers of agricultural AI technology. For example, Panasonic has developed a UV-B irradiation system that combines image recognition and data analysis technology to induce plant self-resistance (Kanto et al., 2016). This innovation can reduce pesticides, control pests and diseases, protect the environment and promote green agriculture.

In summary, Japan's development of agricultural AI is not only a practical measure to cope with labor shortages and an aging population but also an inevitable choice to comply with the global trend of agricultural modernization and trade liberalization. With strong support from the government, Japanese agriculture is developing rapidly. Through the use of advanced information technology and smart equipment, agriculture is becoming more digital, intelligent, and efficient. This transformation makes agriculture more competitive and sustainable while helping to solve many problems in traditional agriculture. In the future, as technology continues to advance, artificial intelligence will play an increasingly important role in Japanese agriculture and help achieve the goal of agricultural modernization.

AI TECHNOLOGIES AND THEIR APPLICATIONS IN JAPANESE AGRICULTURE

AI-Driven Harvest Prediction and Crop Monitoring

As we know, one of the most impactful AI applications in Japanese agriculture was harvest prediction. Farmers can estimate the right time to harvest without physically visiting their fields when they use AI and high-resolution drone images. Therefore, these drones can analyze the agriculture images to count the number of fruits or vegetables, measure their sizes, and assess growth stages. They can save their time and labor and improve accuracy in yield prediction (Nikkei, 2023).

In addition to predicting harvests, AI helps in early detection of problems in the field. AI systems can identify potential pest infestations or diseases early on with the ability to detect leaf color changes and spot weed growth. When more data is collected over time, farmers can compare their current crops with past seasons which makes agriculture more data-driven rather than relying on experience alone. A leading example of AI use in Japanese agriculture is the Izumibashi Brewery in Kanagawa Prefecture. Since 2020, the company has partnered with the Kanagawa Institute of Advanced Industrial Science and Technology to apply drone technology in sake rice farming. Previously, the company relied on visual inspection to assess rice growth and fertilizer needs. However, as their farming area expanded to 46 hectares, traditional methods became inefficient.

To solve this, the company adopted drones equipped with 4K and near-infrared cameras. These drones capture wide-area images to assess plant photosynthesis strength and determine fertilizer needs more accurately. The brewery is also researching how photosynthesis levels relate to protein content in sake rice, aiming to brew higher-quality sake by improving rice quality from the planting stage itself. Beyond crop monitoring, drones are also being used for remote agricultural guidance. Since 2022, East Nippon Telegraph and Telephone Co., Ltd. (NTT East) and the Tokyo Metropolitan Agricultural and Forestry Research Center have experimented with drone-guided greenhouse management. Using a local 5G network, drones transmit real-time images to experts who provide remote guidance to farmers (Nikkei, 2023).

This technology is especially useful for beginners and small-scale farmers who lack experience. By combining AI and remote systems, even inexperienced individuals can perform farming tasks efficiently. Furthermore,

drones have shown potential in crop transportation. For example, a company in Chiba City tested drone delivery of green onions and strawberries over a distance of one kilometer, easing the burden on elderly farmers who find transporting produce challenging (Kanto et al., 2016).

To support this transformation, Japan had invested in training programs. In 2022, the Kusakabe Green Park agricultural research facility which opened in Saitama Prefecture (Li, Nanseki, Chomei, & Kuang, 2023). The drone company Sekido had offered monthly training sessions for the small and medium sized farmers. There are also some programs aimed to equip farmers with knowledge. There are also skills which are needed to adopt drone technology in their daily agricultural work. Despite challenges like limited drone flight ranges and high operational costs, there are also some research and experimentation that are pushing Japanese agriculture toward high-precision, sustainable practices. This goal is admin to eventually use drones for field management and delivering produce directly to retail stores.

Affordable Robotic Harvesters in Japan

Japan's agriculture has faced major challenges like a shrinking workforce and the need for efficient food production. Many Japanese companies will develop affordable robotic harvesters in order to overcome these problems. These robots which were designed to give direction for farmers in harvesting fruits and vegetables had saved their time and labor. This section has discussed how these robotic systems work. They got the benefits and the technologies behind their development. Also, some companies in Japan have developed simple. The rail-based robots move around greenhouses to harvest crops like bell peppers and cucumbers. These robots are built in order to navigate uneven terrain. They also can handle obstacles which make them reliable in real-life farm situations.. These robots are more affordable than traditional harvesting machines. They are accessible even for small-scale farmers as they focus on essential functions(Roshanianfard, Kamata, & Noguchi, 2018).

Apart from that, these robots can be fitted with cameras that take images of the crops to harvest. These images had helped farmers to monitor plant health, recognize fruits and vegetables, and decide the best time to harvest. But there is the challenge to detect the right fruit for harvesting. For example, some of the agriculture products like leaves, stems, and unripe fruits often block the view of ripe produce, making it harder for the robot to know exactly where to cut. To solve this problem, Japan uses a strategy called "slope planting", which simplifies the robot's working environment. This method involves arranging the crops in a way that reduces overlapping. For example, farmers use flower and fruit thinning or apply growth control chemicals to keep ripe and unripe strawberries at different heights in strawberry farming. It had made it easier for the robot in order to identify the ripe fruit (Hou et al., 2021).

Advanced AI systems like deep convolutional neural networks also had helped robots to detect and identify ripe fruits. RGBD camera is a useful tool which produces 3D point cloud images to show the fruit's position in space. These technologies had worked together to upgrade the robot's decision-making in complex environments. The tool used to pick the fruit is also another important part of a harvesting robot is the end effector. If the robot uses

hard materials, it might damage the delicate skin of fruits like tomatoes or strawberries. To prevent this, engineers design soft or flexible end effectors that can gently pick fruits without causing harm. There are several solutions already in use. For example, soft robotic hands, pressure sensors that give the robot force feedback, and bionic designs that copy the human hand have all been tested (Hayashi, Ganno, & Ishii, 2001; Hou et al., 2021). These technologies allow the robot to pick a variety of fruits and vegetables without damaging them.

These robotic harvesters provide many benefits to Japanese farmers. First, they help decide the best time to harvest, increasing efficiency. Second, they allow more land to be harvested without the need for extra workers or larger fields. Most importantly, they solve the problem of labor shortages in rural areas, where fewer young people are willing to work on farms. These machines also lower personnel costs, making farming more sustainable by reducing the need for human labors. Affordable robotic harvesters had helped to modernize Japanese agriculture and improved their quality of lifestyle. They are improving efficiency, saving labor and reducing costs of agriculture.

AI and the Green Society: Sustainability and Environmental Impact

One of the key ways AI promotes sustainability in Japanese agriculture is through precision farming. AI assists farmers in making extremely accurate decisions and tracking crop conditions in real time by evaluating data gathered from sensors, satellites, and drones. By applying precisely, the right amount of water, fertilizer, and pesticides to each section of the field, this technology helps farmers minimize waste and prevent overuse. As a result, precision agriculture minimizes environmental pollution, saves precious resources, and enhances more sustainable forms of agriculture.

Artificial intelligence (AI) systems automatically regulate lighting, humidity, and temperature to provide ideal growing conditions all year long. This makes it possible to grow crops more effectively in any season. Spread Co., a Kyoto-based business that runs AI-powered indoor vertical farms, is a noteworthy example. These cutting-edge facilities maximize yield while consuming the least amount of land and resources. As a result, smart greenhouses improve food security, save water and energy, and lessen the need to expand agricultural land.

Different technologies are being used to improve agricultural practices in a small greenhouse. One noteworthy advancement is robotic harvesting, where crops like bell peppers and tomatoes are now being picked by AI-powered robots. Productivity is raised and labour costs are decreased thanks to this innovation. Improvements have also been made in disease detection and crop monitoring. Real-time crop image analysis by drones with AI-based computer vision can detect problems like pests or diseases. This enables farmers to react promptly to any issues that may come up. AI is also useful in predictive analytics. AI can forecast crop yields and optimise planting schedules by evaluating sensor data and historical trends, which helps farmers make better decisions. Regarding climate control, artificial intelligence (AI) systems automatically adjust greenhouse parameters like humidity and temperature to produce optimal growing conditions for particular crops. Additionally, AI is used by smart irrigation systems to create accurate watering schedules, which ensures healthy crop growth while conserving water.

AI is also playing a key role in improving labor productivity and reducing the carbon footprint of Japanese agriculture, especially as the country faces an aging population and a serious shortage of farm workers. By replacing labor-intensive jobs like planting, harvesting, and crop monitoring with little human oversight, robotics and autonomous machines are assisting in reducing this strain. In addition to lowering labor costs, this also lowers fuel consumption, greenhouse gas emissions, and human error, all of which contribute to a more sustainable agricultural system. AI systems also increase productivity by making precise, data-driven decisions that maximize crop yields and optimise resource use. Through policy initiatives and training programs, the Japanese government is actively promoting this technological transformation by encouraging farmers to integrate AI and robotics into their operations.

Beyond fieldwork, these technologies have a wide range of uses. Robots are being used for precision irrigation, crop disease detection, animal health monitoring, and even automated milking in dairy farms. AI and robotics are essential to the efficient, controlled, year-round food production in Japan's highly advanced greenhouses. For instance, drones with AI provide aerial crop monitoring, fruit-picking robots manage delicate crops like apples and peaches, autonomous tractors carry out seeding and harvesting, and milking robots simplify dairy farming. When combined, these technologies are helping Japan overcome its labor shortage while simultaneously improving the productivity, efficiency, and environmental sustainability of its agriculture.

Furthermore, AI is transforming pest and disease management in agriculture. Using AI technology for image recognition, typically via smartphones or drones with advanced cameras, farmers can identify early signs of pest infestations or crop disease. In order to spot problems before they get worse, these systems evaluate visual data in real time and compare it with large databases of plant health indicators. Farmers can take prompt, targeted action thanks to this early detection, such as treating only the impacted areas rather than spraying entire fields. They can thus drastically cut back on the use of chemical treatments and pesticides, which benefits the environment and the economy.

By minimizing the application of chemicals, AI-driven approaches help protect local ecosystems and maintain

biodiversity by avoiding harm to non-target organisms, such as pollinators and beneficial insects. It stops dangerous chemical runoff into adjacent water and soil systems. By enhancing soil health, conserving water, and advancing food safety, they also support the objectives of sustainable agriculture. Furthermore, farmers can continuously improve their pest and disease management techniques by using AI systems to monitor the efficacy of interventions over time. In addition to improving crop yield and quality, this data-driven strategy aids in the shift to more sustainable and environmentally friendly farming methods.

Challenges of AI Use in Japanese Agriculture

In order to cope with agricultural problems such as labor shortage and low productivity, the Japanese government encourages farmers to integrate AI technology into traditional agriculture. According to statistics, Japan's investment in AI in the agricultural market is expected to reach US\$651 million in 2033, which is much higher than the US\$213 million in 2023 (Shinde, 2025). Although the integration of AI technology can help Japanese agriculture improve farming sales and sustainability. But overall, the application of AI in Japanese agriculture also faces three major challenges.

First, integrating AI technology into traditional farming models requires sufficient learning time. As mentioned above, the aging population is one of the biggest challenges for Japanese agriculture. Since young Japanese people lack interest in agricultural-related jobs, most of Japan's farming industry is supported by the elderly. The average age of migrant workers in Japan is about 69 years old, which is one of the countries with the oldest farmers in the world (The Associated Press, 2024). Older farmers are usually unfamiliar with AI technology, and it takes a long time for AI to effectively use these technologies. In addition, some elderly farmers are reluctant to learn new technologies and are skeptical of AI technology (Oi, 2024). This reluctance to try new technologies has hindered the development of smart agriculture.

Second, high cost is one of the obstacles to widespread application in AI agriculture. Japan's AI agriculture relies on technologies such as automated irrigation, climate control, and real-time data monitoring software. The application of these AI technologies can bring long-term cost-effectiveness, but it requires high costs in the initial introduction. Since smart agricultural machines are expensive, large-scale or larger agricultural operations can use AI technology. However, Japan's agricultural characteristics are mainly small-scale operations (Fuhrmann-Aoyagi et al., 2024). This also means that most Japanese farms cannot reach the level where smart agricultural technology can be introduced. Although the Japanese government has actively promoted the development of smart agriculture through various subsidies and fiscal policies (Yamaguchi, 2025). But this is still a heavy financial burden for small-scale farmers in Japan.

Third, the effective application of artificial intelligence must be based on a strong digital infrastructure, such as cloud computing and Internet connectivity. In addition, various automatic control systems, such as irrigation, temperature control, and fertilization, require high-quality Internet connections to be effective (Dhanaraju et al., 2022). Farmers in Japanese cities have better digital infrastructure to use smart agricultural technologies. Farmers in rural or remote areas face weak or unstable digital infrastructure. The Japanese government has been underinvesting in information and communications technology (ICT). More than 80% of ICT investment before the 2020s was used to repair legacy systems rather than develop new systems (Daisuke, 2023). The weak digital infrastructure limits the coverage and effectiveness of AI technology applications in Japanese agriculture.

In general, AI technology has helped the development of Japanese agriculture, but it has been hindered in its actual application. The aging agricultural population and the lack of young practitioners limit people's ability to use AI technology. High input costs limit the investment of small-scale farmers. And the weak digital infrastructure in rural and remote areas limits the effective application of AI. In order to overcome these challenges and better promote the development of artificial intelligence technology in agriculture. The Japanese government and local communities need to pay attention to the technical education of farmers, financial support and the improvement of digital infrastructure. Only by solving these problems can we help the comprehensive development of artificial intelligence in Japanese agriculture.

CONCLUSION AND FURTHER OUTLOOK

In summary, the main reason for the emergence of AI agriculture in Japan is to cope with the aging of the agricultural population and labor shortage in Japan. In the Japanese agricultural industry, where fewer and fewer young people are willing to join, AI agriculture replaces the workload of ten people with one machine, which does not affect agricultural output when there are few farmers. Secondly, the precision of AI agriculture can enhance Japan's global competitiveness in the context of trade liberalization. For example, Japanese fruits can improve their quality through AI planting, making them more popular internationally. As a developed country, Japan attaches great importance to scientific and technological progress. Therefore, the popularization of AI agriculture is also one of the results promoted by the Japanese government's policies.

Japan's AI agriculture is very important in Japanese agriculture. It has two main functions: intelligent and accurate prediction and robot assistance. First, AI agriculture uses artificial intelligence to achieve real-time monitoring (sensors, drones) and precise resource application (water, fertilizers, pesticides), reduce waste in agricultural planting, improve efficiency and reduce the cost of planting losses. Secondly, the intelligent robots in AI agriculture can realize automatic picking of fruits and vegetables in greenhouses, and can also detect pests and diseases and control the climate. This means that the agricultural industry can cope with less labor and produce more stable output.

Although Japan's AI agriculture has its advantages, it also has disadvantages. Its advantage is that it can realize precision agriculture and achieve precise control of production through data analysis. Secondly, it can also realize smart greenhouses, so that fruits can be produced all year round. Not only that, robot picking and greenhouse innovation can solve the problem of labor shortage while increasing agricultural production. Finally, AI agriculture can solve the problem of pests and diseases, reduce farmers' losses and increase production.

In the popularization of Japan's AI agriculture, it has also been hindered by many reasons. The first is the technical complexity of AI agriculture. As Japan's agricultural labor force is aging (average age 69 years old), the elderly are generally not proficient in using AI machines, and their learning ability is also poor. It is difficult for them to believe in AI and introduce AI technology to help them plant. Secondly, due to the high difficulty in the research and development of AI agricultural equipment, it is costly, and small-scale agriculture cannot bear the high equipment costs and maintenance costs. Finally, there are rural infrastructure limitations. AI agricultural machinery is actually very dependent on strong digital infrastructure, but rural areas still face the problem of unstable digital connections.

From Japan's AI agriculture, it is not difficult to see that AI has made great contributions to the development of the agricultural industry. Therefore, as a developing country, Malaysia should also introduce advanced technology from Japan to realize agricultural modernization. In order to realize the artificial intelligence of Malaysian agriculture, Minister of Agriculture and Food Security Mohammad bin Sabu held formal face-to-face talks with representatives of Fukui Prefecture in Japan. The talks aimed to promote technical exchanges, provide youth training and promote artificial intelligence agriculture, thereby improving Malaysia's food security and agricultural productivity. In fact, in order for Malaysian agriculture to overcome transformation obstacles, it needs strong support from the government to achieve high-yield, low-loss, and low-cost agricultural output, thereby improving the international competitiveness of Malaysian agriculture.

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