

# Analysis of the Applicability of Cutting-Edge Technologies to Enhance Sustainable Agriculture in ASEAN

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Economic Research Institute for ASEAN and East Asia (ERIA)  
Sentral Senayan II 5<sup>th</sup>, 6<sup>th</sup>, 15<sup>th</sup> Floors  
Jalan Asia Afrika No. 8, Gelora Bung Karno  
Senayan, Jakarta Pusat 10270  
Indonesia

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## List of Project Members

The report was prepared by the ERIA research team and a consultant. ERIA staff members directly involved in the study are Masanori Kozono (Senior Policy Fellow) and Ari Aji Cahyono (Research Associate, Project Officer), supported by Dr Ade Sumiahadi as the consultant.

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## List of Abbreviations

|         |                                                                       |
|---------|-----------------------------------------------------------------------|
| ABEMIS  | Agricultural and Biosystems Engineering Management Information System |
| AI      | artificial intelligence                                               |
| AIMS    | agricultural information management system                            |
| APEC    | Asia-Pacific Economic Cooperation                                     |
| APO     | Asian Productivity Organization                                       |
| ASEAN   | Association of Southeast Asian Nations                                |
| AWD     | alternate wetting and drying                                          |
| AWR     | Agriculture War Room                                                  |
| CEA     | Controlled Environment Agriculture                                    |
| CSA     | climate-smart agriculture                                             |
| DRS     | direct seeded rice                                                    |
| ERIA    | Economic Research Institute for ASEAN and East Asia                   |
| FAMA    | Federal Agricultural Marketing Authority                              |
| FAO     | Food and Agriculture Organization of the United Nations               |
| ICT     | information and communication technology                              |
| IFAD    | International Fund for Agricultural Development                       |
| IoT     | internet of things                                                    |
| LaCSA   | Laos Climate Services for Agriculture                                 |
| MAFF    | Ministry of Agriculture, Forestry and Fisheries                       |
| MARDI   | Malaysian Agricultural Research and Development Institute             |
| MD      | Malaysia Digital                                                      |
| NDC     | nationally determined contribution                                    |
| NIN     | National Information Network                                          |
| R&D     | research and development                                              |
| SISCrop | Standing Crop Information System                                      |
| TAM     | Technology Acceptance Model                                           |

## Executive Summary

The agricultural sector remains strategically important in the Association of Southeast Asian Nations (ASEAN), contributing significantly to employment, rural livelihoods, and regional food security. However, ASEAN agriculture faces diverse challenges, including increasing food demand, climate change, low productivity, ageing farmers, limited infrastructure, and the dominance of smallholder farming systems. At the same time, digitalisation and smart agriculture technologies have emerged as important solutions to improve agricultural productivity, efficiency, sustainability, and climate resilience. Technologies such as the internet of things (IoT), artificial intelligence (AI), drones, big data analytics, digital marketplaces, and precision agriculture are increasingly being introduced across ASEAN Member States (AMS).

This study examines the implementation of digital agricultural technologies in ASEAN and Japan, focusing on the opportunities and challenges of transferring Japanese technologies to AMS and supporting their adoption on the ground. The study employs a qualitative approach, including desk research and semi-structured interviews with government representatives, technology providers, agritech companies, universities, farmers, and agribusiness actors. Indonesia was selected as the primary case study to better understand technology adoption dynamics within the ASEAN context.

The findings show that the level of agricultural digitalisation in ASEAN varies significantly across countries. Japan and Singapore represent the most advanced digital agriculture ecosystems, with strong integration of AI, automation, robotics, and smart farming systems. Countries such as Indonesia, Malaysia, Thailand, and Viet Nam are entering the commercialisation and partial integration stage through the expansion of agritech start-ups, drones, IoT systems, and precision agriculture. Meanwhile, Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Timor-Leste, and to a lesser extent Brunei Darussalam and the Philippines, remain at the pilot or experimental stage due to infrastructure limitations, low digital literacy, and fragmented agricultural systems.

Japan has developed one of the most advanced smart agriculture ecosystems globally, supported by strong government co-ordination, extensive research and development (R&D) investment, and integrated innovation systems. Technologies such as autonomous tractors, AI-based crop monitoring, smart irrigation, agricultural robotics, and digital agricultural data platforms are widely implemented to address labour shortages and improve production efficiency. This technological maturity positions Japan as a strategic partner and creates

significant opportunities for ASEAN–Japan collaboration in accelerating agricultural digitalisation across the region. However, the study reveals that gaps exist between the digital technologies available in Japan and the actual needs of AMS. These gaps are not merely technological but also deeply rooted in differences in farming systems and institutional conditions. For instance, Japanese technologies are generally designed for more mechanised and capital-intensive agricultural systems, while ASEAN agriculture is predominantly smallholder-based, with varying levels of digital infrastructure, financial capacity, and digital literacy across the region. As a result, some advanced technologies may require adaptation to better suit local farming conditions and user capacities.

Several major barriers to technology adoption were identified in ASEAN, including high investment costs, limited digital infrastructure, low farmer digital literacy, weak technical support systems, and business models that are often economically unsustainable for smallholders. These findings indicate that successful agricultural digitalisation in ASEAN cannot rely solely on direct technology transfer. Instead, technology adaptation, localisation, and inclusive ecosystem development are essential.

At the country level, the Indonesia case study further confirms that digital agriculture adoption remains uneven and highly dependent on commodity type, business scale, infrastructure availability, and human resources capacity. Large agribusiness companies have begun implementing advanced digital technologies such as IoT systems, drones, automated greenhouses, and data-driven monitoring systems. In contrast, smallholder farmers generally adopt simpler, semi-automated technologies due to financial and technical constraints.

The study concludes that ASEAN offers substantial opportunities for digital agriculture development, particularly through collaboration with Japan. However, successful implementation requires differentiated approaches tailored to the readiness levels of each ASEAN market. Advanced and growing markets such as Indonesia, Malaysia, Singapore, Thailand, and Viet Nam offer significant opportunities for commercial smart agriculture technologies, while emerging markets require simpler, lower-cost, and more accessible digital solutions. Ultimately, the future of digital agriculture in ASEAN depends on the development of context-sensitive, affordable, and climate-smart technologies supported by stronger infrastructure, farmer capacity-building, multi-stakeholder collaboration, and sustainable business models. ASEAN–Japan cooperation, therefore, has strong potential not only to improve agricultural productivity and food security but also to build a more inclusive, resilient, and sustainable agri-food system across the region.

# Chapter 1

## Introduction

The global agricultural sector faces increasingly complex pressures from population growth, climate change, and limited natural resources. The global population is projected to reach about 9.7 billion by 2050, significantly increasing food demand (APO, 2023). This situation calls for a transformation of the agricultural system towards a more efficient, productive, and sustainable model. The Association of Southeast Asian Nations (ASEAN) Member States (AMS) have a strategic role in meeting this food demand. With a population of over 670 million, ASEAN is a region with dynamic economic growth and high food consumption (ASEAN, 2024). Agriculture remains a key sector in the region, particularly as a source of livelihood for rural communities. In some AMS, a large proportion of the population still relies on the agricultural sector, underscoring the importance of its sustainability for social and economic stability.

One important indicator demonstrating the strategic importance of agriculture in ASEAN is the relatively high contribution of the agricultural sector to gross domestic product (GDP) and employment in several Member States. Although ASEAN economies are increasingly diversifying towards manufacturing and services, agriculture still plays a substantial role, particularly in developing Member States. In countries such as Myanmar, the Lao People's Democratic Republic (Lao PDR), Cambodia, and Viet Nam, agriculture contributes significantly to GDP and absorbs a large share of the workforce. According to data from TheGlobalEconomy.com (2025) and *ASEAN Key Figures 2025* (ASEAN, 2025), in 2024, agriculture contributed 0.03%–20.83% of GDP across 10 AMS, while agricultural employment accounted for 0%–57.5% of total employment. At the regional level, agriculture contributes 10.58% of total ASEAN GDP while employing more than one-quarter of the region's labour force. These figures indicate that agriculture remains highly labour-intensive and socially significant, particularly for rural livelihoods, poverty reduction, and regional economic stability.

However, the agricultural structure in ASEAN is dominated by smallholder farmers<sup>1</sup> with limited access to technology, capital, and information. It is estimated that there are around 100 million smallholder farmers in the region (CropLife Asia, 2024). In addition, the agricultural sector faces demographic challenges, including

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<sup>1</sup> Smallholder farmers are small-scale farmers who manage areas typically ranging from less than 1 hectare to 10 hectares, and are often characterised by limited access to resources, information, technology, capital, and assets, although the degree to which each of these constraints applies varies considerably across contexts (FAO, 2013; IFAD and UNEP, 2013).

an ageing farmer population and low interest amongst younger generations in farming. This situation has the potential to reduce productivity and threaten long-term food security. Beyond demographic pressures, agricultural productivity in ASEAN remains suboptimal. Conventional agricultural practices often inefficiently use inputs such as water and fertilisers, contributing to environmental degradation. The impacts of climate change, such as unpredictable rainfall and increased disaster frequency, exacerbate these conditions (APO, 2023). Therefore, innovative approaches are needed to improve the efficiency and sustainability of agricultural systems in the region.

In this context, digitalisation and the application of cutting-edge technologies are potential solutions to transform the agricultural sector. Technologies such as the internet of things (IoT), artificial intelligence (AI), drones, and big data analytics are enabling precision agriculture, which can improve input efficiency and productivity while reducing environmental impacts (Getahun, Kefale, and Gelaye, 2024). Digitalisation also enables data-driven decision-making, which is crucial in addressing the uncertainty caused by climate change. More importantly, the dissemination of digital technology in agriculture is not merely an option but a strategic necessity for ASEAN.

ASEAN has prioritised digitalisation in regional development. This is reflected in its digitalisation strategy based on the Consolidated Strategy on the Fourth Industrial Revolution for ASEAN (ASEAN, 2021), which encourages the integration of technology across sectors, including education and agriculture. Digitalisation is seen as the foundation for building an adaptive and competitive society in the future. However, the success of digitalisation depends heavily on the level of digital literacy amongst its citizens. The average internet penetration rate in AMS is around 76.03%, but significant disparities exist between countries. For example, countries like Singapore and Brunei have internet penetration rates above 90%, while others, such as Myanmar and the Lao PDR, remain below 60% (Pascua-Valenzuela, 2025). This inequality indicates that access to digital technology is not evenly distributed across the region.

In the agricultural context, low digital literacy is a serious barrier to the adoption of cutting-edge technology. Farmers who lack adequate digital skills will struggle to use data-driven technologies, such as sensors, agricultural applications (apps), or AI-based prediction systems. Limited infrastructure, such as internet access and electricity, in rural areas worsens this situation (ERIA, 2025). Without technological transformation, the agricultural sector risks becoming increasingly vulnerable to climate change, labour shortages, and declining youth participation in farming. Moreover, the uneven productivity structure across ASEAN means that digital agriculture can play a major role in reducing regional development disparities and

strengthening long-term food security.

Nevertheless, the opportunity to develop digital agriculture in ASEAN remains significant, particularly through international collaboration. Japan, as one of the countries with the most advanced agricultural technology, has significant potential to contribute to this transformation. Japan has developed a smart agriculture system based on robotics, IoT, and AI to increase production efficiency and address labour shortages (Jie et al., 2023). Japan can also support the development of more adaptive and locally appropriate technologies tailored to the diverse needs of farmers in ASEAN.

This study is fully supported by the Ministry of Agriculture, Forestry and Fisheries of Japan. The study's primary goal is to analyse the applicability of Japanese digital agricultural technologies to agriculture in the ASEAN region and propose recommendations for supporting technology adoption.

## Chapter 2

### Method

This study used a qualitative approach to gain a deeper understanding of the application of digital technology in the agricultural sector in the ASEAN region, with Indonesia serving as a primary case study. Data were collected through two main methods: a desk study for the broader ASEAN analysis and semi-structured interviews for the Indonesia case study. The documents used as secondary data sources included country presentations at symposia on agriculture and digitalisation (the ASEAN–Japan Symposium on Accelerating the Digitalisation of the Agriculture and Food System in the ASEAN Region in 2024 and the ASEAN–Japan Symposium for Promoting Sustainable Agriculture Development in ASEAN: Focusing on Decarbonisation and Digitalisation in 2025), policy documents and official publications, scientific literature, and reports from international organisations. The desk study provided insights into policy frameworks, technological developments, and trends in agricultural digitalisation at the national and regional levels. For the Indonesia case study, interviews were conducted with 13 informants across three main stakeholder groups: the government, technology providers (companies and universities), and technology users (farmers and agribusinesses). The interviews were semi-structured, allowing the researcher to follow a structured guideline while maintaining flexibility to explore the issue in greater depth based on interviewees' responses. This method is effective for obtaining rich, in-depth data because it allows direct exploration of experiences, perceptions, and practices (Kallio et al., 2016).

The informants in the Indonesia case study were selected using purposive sampling, a method of selecting samples based on specific considerations relevant to the study objectives. In this context, informants were selected by considering their knowledge, experience, or direct involvement in the application of digital technology in the agricultural sector. The criteria for selecting informants in this study included (i) direct experience in the development or use of agricultural technology; (ii) involvement in decision-making, implementation, or use of technology; and (iii) representation of diverse stakeholder perspectives. This approach allows the study to capture comprehensive perspectives on the digital agricultural ecosystem. Ultimately, this study aims to provide a comprehensive overview of the opportunities and challenges of agricultural digitalisation in the ASEAN region, and to identify how Japanese technologies can support and accelerate this transformation.

## Chapter 3

### Analysis Results

#### 3.1 Digital Technology Implementation in ASEAN Member States and Japan

##### 3.1.1 Brunei Darussalam

Brunei has adopted advanced technologies, but implementation remains concentrated in selected government-supported farms and high-tech projects (Department of Agriculture and Agrifood of Brunei Darussalam, 2024). Thus, Brunei is best categorised as being at the pilot-to-selective commercialisation stage. This progress has been driven by the adoption of several key technologies across agricultural production and management systems. According to a national presentation at the ASEAN–Japan Symposium on Accelerating the Digitalisation of the Agriculture and Food System in the ASEAN Region in 2024, key technologies include IoT, drones, and an agricultural information management system (AIMS). The use of IoT in agriculture enables real-time monitoring of agroclimatic conditions, including temperature, humidity, rainfall, soil pH, and nutrient levels. These sensors help farmers optimise agricultural inputs and improve production efficiency. Drone technology is also used to monitor crop health through multispectral analysis and to spray fertilisers and pesticides more efficiently and safely. This technology enables early detection of plant stress up to 2 weeks before it is visually apparent (Department of Agriculture and Agrifood of Brunei Darussalam, 2024). Meanwhile, the AIMS serves as a web-based platform for collecting and analysing agricultural data, including crop production and livestock data, as well as market demand trends. This system supports data-driven decision-making in the management of the agri-food sector.

In addition to data-driven digitalisation, Brunei is also developing a climate-smart agriculture (CSA) approach to increase resilience to climate change. This approach combines sustainable agricultural practices with digital technologies such as IoT and aerial imagery-based monitoring (Hassan and Suhaili, 2024). The technologies have been shown to increase productivity while reducing environmental impact through efficient fertiliser and water use. The adoption of these technologies is driven by the younger generation's motivation, despite persistent gaps in technical knowledge and skills. Motivation alone, however, is not sufficient: limited exposure to CSA in agricultural education, together with the high cost of the technology and limited institutional support, continues to constrain uptake — pointing to a continuing need for training and awareness alongside subsidies and accessible

finance (Hassan et al., 2024). Beyond CSA, technological innovations such as hydroponics, aquaponics, fertigation systems, and closed-house poultry systems are increasingly implemented to improve resource efficiency and productivity (Mustafa et al., 2024).

### 3.1.2 Cambodia

Agricultural digitalisation in Cambodia does not stand alone but is integrated with the sustainable development and decarbonisation agenda. This is reflected in various national policies, such as the Rectangular Strategy Phase IV (2023–2028), which promotes green growth and resilient agriculture, and the Cambodia Digital Economy and Society Policy Framework (2021–2035), which supports digitalisation in the agriculture, logistics, and market sectors. Cambodia has adopted a long-term strategy towards carbon neutrality through the Long-Term Strategy for Carbon Neutrality and its nationally determined contribution (NDC) 3.0. These policies demonstrate that agricultural digitalisation in Cambodia aims not only to increase productivity but also to reduce greenhouse gas emissions and enhance resilience to climate change. Some relevant practices that have integrated digital technology include alternate wetting and drying (AWD), direct seeded rice (DSR), and CSA (Ministry of Industry, Science, Technology, and Innovation of Cambodia, 2025).

The application of digital technology in Cambodia is still in the development and pilot project stages, with a focus on three main aspects: data collection, knowledge dissemination, and market connectivity. This includes agricultural data collection through the CAO Farmbook app (created for Commune Agricultural Officers in Cambodia), knowledge dissemination through platforms such as AgriLibrary, and market connectivity through applications such as Chamkar and CAMAgriMarket (Ministry of Industry, Science, Technology, and Innovation of Cambodia, 2025). On-farm digitalisation includes the application of technologies such as IoT, AI, drones, and data-driven systems for land management and production. In practice, these technologies have been used for digital soil mapping, crop monitoring using deep learning, agricultural geographic information systems (GISs), and satellite-based greenhouse gas emission measurements. In addition, technologies such as smart irrigation, drones for spraying, and digital platforms for market access are being introduced as part of the transformation towards smart agriculture. The Cambodian government has also demonstrated a strong commitment through the development of the Agricultural Technology Roadmap (AgriTech Roadmap), a guiding document that identifies critical technology candidates and development pathways up to 2030, positioning technology and innovation as key drivers of productivity and competitiveness in the agricultural sector (Ministry of Industry, Science, Technology, and Innovation of Cambodia, 2022).

### 3.1.3 Indonesia

The Indonesian government demonstrates its commitment to promoting digitalisation through various strategic policies, such as the National Medium-Term Development Plan and the Golden Indonesia 2045 vision. Agricultural digitalisation is part of efforts to increase the productivity of priority economic sectors (Darmawan et al., 2023). The Ministry of Agriculture has also incorporated digitalisation into its strategic plan, covering agricultural modernisation and human resources capacity-building programmes. The acceleration of agricultural digitalisation is also aligned with the national development agenda under the Asta Cita framework, particularly the commitment to strengthening food security, advancing technological transformation, and improving rural economic productivity. Through this agenda, digital agriculture is positioned as a strategic instrument to modernise the agricultural sector by promoting the adoption of smart farming technologies, expanding digital infrastructure in rural areas, and enhancing farmers' access to market information, financing, and innovation (Ministry of Agriculture of Indonesia, 2025).

In Indonesia, the implementation of agricultural digitalisation has shown significant progress. Various innovations, such as smart irrigation systems, sensor-based crop condition monitoring, drone use, and digital agricultural management platforms, are being adopted. One concrete example is the use of remote sensing-based information systems such as the Standing Crop Information System (SISCrop) to monitor crop conditions and land productivity in real time. In addition, the government has established the Agriculture War Room (AWR), a national command centre that integrates various agricultural data, including SISCROP, IoT, weather, and supply chain data. This system serves as a national dashboard, providing real-time information and supporting early warning systems and policy co-ordination. Digitalisation is not only applied to the production stage, but also to the distribution and marketing of agricultural products. Through collaboration between the government and the private sector (public-private partnerships), various innovations have been developed, including QR code-based traceability systems, digital payment systems, and virtual marketing platforms such as e-commerce and marketplaces (Ministry of Agriculture of Indonesia, 2025). The emergence of agritech start-ups offering marketplace services, digital financing, and advisory platforms has strengthened Indonesia's digital agricultural ecosystem (Mangurai et al., 2022). Indonesia has experienced rapid growth in agritech start-ups such as Eratani, Semaai, Segari, and Sayurbox, signalling a shift from pilot projects towards commercial digital agriculture ecosystems. The sector has, however, proved volatile: several early flagship ventures, including eFishery and TaniHub, have ceased operations following governance and financing failures, underlining that

commercial viability rather than technology alone determines whether digital agriculture services endure. Nevertheless, adoption remains concentrated in certain commodities and regions, while millions of smallholder farmers still lack access to digital agricultural tools (Montesclaros, Teng, and Caballero-Anthony, 2023). Indonesia can therefore be classified at the early commercialisation stage. A more detailed analysis is presented in the Indonesia case study in Section 3.3.

#### **3.1.4 Lao PDR**

The Lao PDR is at the pilot and experimental stage of digital agriculture implementation, with most initiatives heavily focused on climate adaptation and sustainability rather than commercial smart farming. Agricultural digitalisation in the Lao PDR is beginning to develop through the application of information and communication technology (ICT) in various aspects of agricultural production and management. One key innovation is the development of the Laos Climate Services for Agriculture (LaCSA) platform, which provides data-driven agroclimatic information to support farmers' decision-making. This platform enables farmers to access weather and climate information, plan planting seasons, and reduce the risk of crop failure due to climate change. Other digital applications include a sustainable land management database system, a biodiversity database, and digital-based training modules for sustainable agriculture, alongside climate change adaptation technologies such as flood- and drought-resistant rice varieties (Ministry of Agriculture and Forestry of the Lao PDR, 2024).

The Lao government has demonstrated its commitment to agricultural transformation through a range of strategic policies. In its Agriculture Development Strategy 2025–2030, the government emphasises the importance of modernising the agricultural sector, strengthening agricultural value chains, increasing farmer productivity and incomes, and developing sustainable, climate-resilient agriculture (Ministry of Agriculture and Forestry of the Lao PDR, 2024). In a broader context, the government is also developing a national digital economy strategy to drive digitalisation across various sectors, including agriculture. This strategy includes strengthening digital infrastructure, developing digital services, and enhancing human resources capacity (World Bank, 2022). This is consistent with the International Fund for Agricultural Development (IFAD) recommendation that agricultural transformation in the Lao PDR focus on enhancing the resilience of smallholder farmers, developing inclusive value chains, and integrating technology into production and distribution systems (IFAD, 2025).

### 3.1.5 Malaysia

Malaysia demonstrates a more systematic approach to promoting agricultural digitalisation through a comprehensive policy framework. Based on national policy documents, Malaysia has developed the National Agrofood Policy 2.0 (2021–2030), which emphasises the adoption of smart agriculture and precision farming as key strategies (Ministry of Agriculture and Food Security of Malaysia, 2025). The integration of digital technologies such as IoT, AI, and data analytics is further strengthened through the Fourth Industrial Revolution policy and the Malaysia Digital (MD) initiative, both of which encourage the growth of agritech start-ups and a broader digital ecosystem. Clear institutional structures, such as the involvement of research institutions (Malaysian Agricultural Research and Development Institute (MARDI)) and marketing authorities (Federal Agricultural Marketing Authority (FAMA)), as well as collaboration with the private sector, are crucial factors in the successful implementation of digitalisation (Ministry of Agriculture and Food Security of Malaysia, 2025).

From a technological perspective, the development of smart farming technologies in Malaysia involves the use of sensors, drones, IoT, cloud computing, and big data to monitor crop conditions, optimise input use, and improve production efficiency (En and Hui, 2023). These technologies also help reduce production costs and improve environmental sustainability. Beyond the farm level, agricultural digitalisation in Malaysia is closely linked to the national economic transformation strategy. Through the Malaysia Digital Economy Blueprint (MyDIGITAL) framework, digitalisation is positioned as a key driver of innovation-based economic growth (Krishnan, 2025). This blueprint has six main objectives, including increasing economic competitiveness, building digital infrastructure, and developing digital talent. Technologies such as AI, blockchain, and 5G play a crucial role in increasing agricultural sector productivity and strengthening integration with other sectors, such as manufacturing and services. Thus, digitalisation impacts not only the agricultural sector but also the overall economic transformation towards a knowledge-based economy. Digital agriculture in Malaysia has reached the commercial stage. However, integration remains uneven across different areas and sectors. Malaysia is therefore categorised at the commercialisation to partial integration stage.

### 3.1.6 Myanmar

Agricultural digitalisation in Myanmar is progressing through the integration of ICT into various aspects of the agricultural system, including extension services, research, and information distribution to farmers. In Myanmar, ICT use includes

online and in-person farmer technical forums, a website platform for agricultural technology information, a tablet-based data collection system, and information dissemination via digital platforms. For example, farmer technical forums are held regularly to reach farmers in remote areas through a combination of offline and online methods, demonstrating a hybrid approach to digital extension. The development of digital platforms aims to share agricultural data, connect institutions, and provide farmers with research and technology information (Ministry of Agriculture, Livestock and Irrigation of Myanmar, 2024). Beyond government-led efforts, the private sector and agritech start-ups increasingly play a significant role in digitalisation. Apps such as Htwet Toe and Golden Paddy provide weather information, market prices, and data-driven financing services, helping farmers increase productivity and efficiency (Tin, 2025).

The digitalisation of agriculture in Myanmar is highly dependent on the state of the national digital infrastructure. A World Bank report showed that access to digital technology is influenced by the availability of telecommunications networks and stable connectivity (World Bank, 2026). This limited infrastructure poses a major challenge to implementing digital technologies such as IoT, mobile apps, and data-driven systems in the agricultural sector. Myanmar can be categorised as being in the experimental ICT-based stage, where digitalisation is present but lacks institutional and infrastructural maturity for commercialisation or integration.

### **3.1.7 The Philippines**

Agricultural digitalisation in the Philippines includes implementing technologies such as decision support systems; digital agricultural apps (AgRiDOC, LCC, Seed Inspector, and iFarm); e-commerce; agricultural fintech; and precision technologies, such as drones and remote sensing. According to a study by the Philippine Institute for Development Studies, the adoption of digital technology in Philippine agriculture is still in its early stages (pilot to early commercialisation stage), with some technologies such as extension applications and online marketing platforms already well developed, while others are still in the pilot or prototype stage (Briones, Galang, and Latigar, 2023). At the Agriculture 4.0 level, technologies include drones for fertilisation and land monitoring, remote sensing for weather and crop yield prediction, data-driven systems for farm management, and digital platforms such as the Agricultural and Biosystems Engineering Management Information System (ABEMIS) for agricultural project monitoring (Cordero and Park, 2023). These technologies enable farmers to access real-time data, increase production efficiency, and reduce the risks posed by climate change and natural disasters.

The Philippine government has prioritised digitalisation as part of its national

development strategy. The government has emphasised the importance of strengthening digital infrastructure and regulatory reform to foster innovation, develop a digital workforce, and enhance cybersecurity. The Philippine government's agricultural transformation strategy also includes enhancing mechanisation and modernising production, strengthening post-harvest and logistics systems, increasing access to domestic and international markets, and improving data-driven decision-making through digitalisation. In addition, the government encourages the integration of digital platforms through the development of the National Information Network (NIN) to support data-driven policymaking (Department of Agriculture of the Philippines, 2024). The One DA Reform Agenda also highlights digitalisation as part of modernising the agricultural sector through technological innovation and increased mechanisation (Cordero and Park, 2023).

### **3.1.8 Singapore**

Singapore is an example of a country that has successfully implemented intensive agricultural digitalisation despite limited land resources. The country relies on technologies such as controlled environment agriculture (CEA), vertical hydroponics, and AI-based automation systems to increase agricultural productivity (Singapore Food Agency, 2025). Unlike other agricultural countries, Singapore adopts a high-tech innovation-based approach encompassing fully controlled greenhouses, vertical farming, hydroponics and aquaponics, IoT sensors for environmental monitoring, AI for production optimisation, big data analytics for decision-making, automation and robotics to reduce reliance on labour and improve operational efficiency, and digital value chain integration (traceability systems, digital distribution platforms, and data-driven logistics integration) to increase transparency and efficiency in food distribution.

These technologies enable food production in limited spaces with high efficiency. For example, vertical farming systems enable year-round production with more efficient water use and optimal environmental control. The use of IoT sensors also allows for real-time monitoring of temperature, humidity, and plant nutrients, thereby increasing productivity and reducing the risk of crop failure (Schroeder, Lampietti, and Elabed, 2021; Singapore Food Agency, 2025). Pedida (2026) showed that implementing closed hydroponic systems can increase water-use efficiency by 90%–95% compared with conventional farming. Additionally, the integration of IoT, AI, and cyber-physical systems in Agriculture 4.0 enables the automation of production processes and reduces reliance on human labour. Singapore's strategy also emphasises the importance of food security through local production to address disruptions to global supply chains, as seen during the COVID-19 pandemic

(Singapore Food Agency, 2025). Based on these developments, Singapore is the most advanced AMS in agricultural digitalisation and is closest to Japan in implementation maturity. The country has also integrated digital technologies into its national food security strategy, supported by strong policy frameworks and investment ecosystems. Therefore, Singapore can be categorised as being at the advanced stage of commercialisation integration.

### **3.1.9 Thailand**

Thailand has progressed beyond the pilot stage and is positioned at the early commercialisation to partial integration stage of digital agriculture implementation. The country has introduced various smart farming technologies through both government-led initiatives and private sector participation. The Thai government has integrated the concept of smart agriculture into its long-term national development strategy, specifically within the framework of the Thailand 20-Year National Strategy (2018–2037). This transformation aims to enhance the added value of agricultural products, improve production efficiency, and boost global competitiveness (Meechoovet and Siriwato, 2023). Agricultural digitalisation in Thailand encompasses the application of advanced technologies, including IoT, AI, drones, big data, and decision support systems, all of which support data-driven decision-making and improve production efficiency. For example, digital technology enables land mapping (Agri-Map), crop health monitoring, and sensor-based automatic irrigation management. Together, these technologies demonstrate that Thailand is progressively moving towards implementing the Agriculture 4.0 concept (Ministry of Agriculture and Cooperatives of Thailand, 2024).

The implementation of digitalisation in Thailand's agricultural system encompasses production technology, supply chain management, and market access. In the production phase, digital technology is used to increase efficiency and productivity through sensors and big data for real-time monitoring of crop conditions, pest and disease prediction, fertiliser application based on soil data, and irrigation based on groundwater conditions. Apps such as the Department of Agricultural Extension's Pest Forecast and Ru Din Ru Pui help farmers make data-driven decisions. IoT and robotic automation also enable the use of automated tractors, weed-control robots, IoT-based irrigation systems, and smart greenhouses. Digitalisation in the supply chain and marketing includes product traceability systems supporting quality standards (Good Agricultural Practices and Hazard Analysis and Critical Control Points), and data platforms such as the Thailand Agricultural Data Collaboration Platform. These systems increase the transparency and efficiency of agricultural product distribution (Ministry of Agriculture and Cooperatives of Thailand, 2024).

### 3.1.10 Timor-Leste

Timor-Leste is one of the least digitally developed agricultural systems in Southeast Asia and remains at an early experimental and infrastructure-building stage. According to a United States Agency for International Development (USAID) assessment, the use of digital technology in the agricultural sector remains sporadic and dependent on specific project initiatives or development programmes (Woodard, 2022). Some examples of digital technology use include mobile phones for communication between farmers and traders, access to market information through digital media, and basic digital tools. However, a comprehensive agricultural digital system, such as an agricultural data platform, a climate information system, or digital-based value chain integration, has yet to be developed at scale. Broløs and Taylor (2023) indicated that Timor-Leste has a very limited number of digital agricultural applications compared with other AMS, reflecting its low level of digital technology adoption.

The Government of Timor-Leste has demonstrated its commitment to digitalisation through various policies, such as the Timor Digital 2032 strategy, which aims to strengthen digital infrastructure, improve digital literacy, and encourage technological innovation. In addition, the government has begun investing in ICT infrastructure (including submarine cables and data centres), strengthening digital regulations, and developing human resources capacity (UNESCO, 2025). However, the integration of digital technology into the agricultural sector remains limited and requires a more specific and targeted policy approach going forward.

### 3.1.11 Viet Nam

The agricultural digital technology in Viet Nam has rapidly expanded. Several technologies are already in commercial use by agribusinesses and export-oriented producers (Pham and Tran, 2025). However, fragmentation of systems and unequal adoption by large enterprises and smallholders remain significant issues. Viet Nam can therefore be categorised at the commercial expansion stage, moving gradually towards integration. Key technologies being applied include IoT, AI, big data, blockchain, and e-commerce platforms. These technologies are being implemented across several regions, such as Lam Dong and the Mekong Delta, with results demonstrating increased productivity and resource efficiency. For example, the application of IoT in irrigation systems can reduce water use by up to 30%, while AI in crop monitoring can reduce production costs by up to 20% and improve crop quality. Blockchain technology has also been used by companies such as VinEco to increase the transparency and value addition of agricultural products in international markets (Pham and Tran, 2025). This transformation also includes

integrating technology throughout the agricultural value chain, from production to consumers. Technologies such as drones, cloud computing, and blockchain are being used to improve the overall efficiency of the agri-food system (Burra et al., 2021).

The Vietnamese government has positioned digitalisation as a key pillar of national development. Viet Nam's presentation at the ASEAN–Japan Symposium on Accelerating the Digitalisation of the Agriculture and Food System in the ASEAN Region in 2024 stated that digitalisation is a strategic breakthrough for increasing the productivity, quality, and competitiveness of the national economy. The Ministry of Agriculture and Rural Development (now the Ministry of Agriculture and Environment) has established several strategic directions for agricultural digitalisation, including the development of an agricultural data platform and traceability system, the construction of digital infrastructure and data centres, the development of e-government in the agricultural sector, the application of digital technology for farmers, and the strengthening of cybersecurity measures and digital regulatory frameworks. The government also encourages the integration of e-commerce in the agricultural sector, where the value of digital trade is projected to increase significantly, reaching tens of billions of United States dollars in the next few years (Ministry of Agriculture and Rural Development of Viet Nam, 2024). The ministry has promoted the use of digital platforms, integrated databases, drones, remote sensing, e-commerce, and electronic traceability systems to modernise production and supply chains. The ministry is also developing shared agricultural databases and data-driven governance systems to improve public services and policy implementation (Ministry of Agriculture and Environment of Viet Nam, 2025).

### **3.1.12 Japan**

Japan is at the advanced ecosystem stage of digital agriculture implementation. Technologies such as autonomous tractors, AI-driven crop monitoring, agricultural robotics, drone spraying, and smart irrigation systems have moved beyond experimentation into large-scale commercialisation (Fukuda, 2025). These technologies are applied comprehensively across the entire agricultural production cycle, from land preparation to harvest. According to Fukuda (2025), smart agriculture in Japan is defined as the use of digital technology to improve operational efficiency and agricultural productivity through automation and data analysis. Specific applications include autonomous tractors with GPS navigation, water and soil sensors for irrigation management, drones for pesticide spraying, and satellite imagery-based crop analysis.

The Japanese government plays an important role in promoting agricultural digitalisation through various strategic policies and programmes. Japan's presentation at the ASEAN–Japan Symposium for Promoting Sustainable Agricultural Development in ASEAN: Focusing on Decarbonisation and Digitalisation in 2025 stated that more than 217 smart agriculture projects are underway across Japan, aiming to accelerate the adoption of digital technology in the agricultural sector (Kawamoto, 2025). The Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF) has also developed a smart farming road map covering four key areas: strengthening research and development (R&D); fostering collaboration amongst government, academia, and the private sector; developing digital infrastructure such as the Agricultural Data Collaboration Platform (WAGRI); and establishing regulations for the use of drones and autonomous vehicles (ECOS, 2021). In addition, national policies such as the Society 5.0 concept emphasise the integration of the physical and digital worlds to create a technology-based economic system, including in the agricultural sector (Broeckaert, 2022).

### 3.1.13. Comparison of Agricultural Technology Digitalisation in Japan and ASEAN

Japan and AMS demonstrate different approaches to adopting digital technology in the agricultural sector. Japan is developing a high-tech smart agriculture model, while ASEAN is at an early stage of digital adoption, with heterogeneous characteristics across countries. This comparison is important for understanding the dynamics of the digital divide and the potential for technology transfer between Japan and ASEAN (Table 1).

**Table 1: Comparison of Agricultural Technology Digitalisation in Japan and ASEAN**

| Aspect                  | Japan                                                                                                          | ASEAN                                                                                                         |
|-------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Transformation approach | <b>Technology-driven.</b> Focuses on AI, IoT, robotics, and automation to improve efficiency and productivity. | <b>Development-driven.</b> Digitalisation is used to improve productivity, food security, and farmer welfare. |
| Stage of digitalisation | <b>Advanced stage.</b> Smart farming technologies are widely implemented and integrated nationally.            | <b>Nascent–intermediate stage.</b> Adoption varies across countries and is still developing.                  |
| Agricultural structure  | <b>Semi-industrialised farming.</b> Agriculture is increasingly mechanised and technology-based.               | <b>Smallholder-based farming.</b> Most farmers operate on small-scale with conventional systems.              |
| Government role         | <b>Strong government co-ordination.</b> Policies, subsidies, and R&D are centrally managed.                    | <b>Uneven government capacity.</b> Policy support differs significantly amongst ASEAN Member States.          |

| Aspect                        | Japan                                                                                                    | ASEAN                                                                                                       |
|-------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Motivation for transformation | <b>Labour shortages and ageing farmers.</b> Technology is used to replace declining agricultural labour. | <b>Economic development and food security.</b> Technology supports productivity and income improvement.     |
| Cost and infrastructure       | <b>High costs and integration issues.</b> Advanced technologies require large investments.               | <b>Infrastructure and access limitations.</b> Internet access and digital infrastructure remain inadequate. |
| Human resources               | <b>Highly skilled but ageing workforce.</b> Strong technological expertise but limited young farmers.    | <b>Large workforce but low digital literacy.</b> Many farmers lack digital and technical skills.            |
| Innovation ecosystem          | <b>Integrated ecosystem.</b> Strong collaboration amongst government, academia, and industry.            | <b>Fragmented ecosystem.</b> Innovation systems are less co-ordinated across countries.                     |

AI = artificial intelligence, ASEAN = Association of Southeast Asian Nations, IoT = internet of things, R&D = research and development.

Source: Compiled and analysed by the author based on secondary data collected during the study.

### 3.1.14. Market Segmentation of Digital Agriculture Technology Implementation in Japan and ASEAN

The analysis of digital agriculture across Japan and ASEAN shows significant differences in the level of technological adoption, commercialisation, and ecosystem readiness. These differences reflect variations in infrastructure capacity, policy support, market readiness, and the predominant farm size and production scale in each country. Based on the implementation stage and digital maturity, the countries can be grouped into three major market segments: advanced markets, growing markets, and emerging markets (Table 2). This segmentation helps explain the unequal pace of digitalisation in the region and underscores the gap between the advanced technologies developed in Japan and the varying needs and capacities of AMS.

**Table 2: Market Segmentation of Digital Agriculture Technology Implementation in Japan and ASEAN**

| Market segment  | Countries        | Characteristics                                                                                                                             | Stage of digital technology implementation           |
|-----------------|------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
| Advanced market | Japan, Singapore | Highly integrated smart agriculture ecosystems supported by AI, IoT, robotics, automation, big data, and strong institutional co-ordination | Advanced commercialisation and ecosystem integration |

| Market segment  | Countries                                                               | Characteristics                                                                                                                                                                  | Stage of digital technology implementation                |
|-----------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Growing market  | Indonesia, Malaysia, Thailand, Viet Nam                                 | Expanding adoption of smart farming technologies, agritech start-ups, precision agriculture, and digital market platforms; implementation increasingly commercialised but uneven | Early commercialisation to partial integration            |
| Emerging market | Brunei Darussalam, Cambodia, Lao PDR, Myanmar, Philippines, Timor-Leste | Fragmented, pilot-based, or donor-driven initiatives; limited infrastructure, low digital literacy, and weak ecosystem integration                                               | Pilot, experimental, or selective commercialisation stage |

AI = artificial intelligence, ASEAN = Association of Southeast Asian Nations, IoT = internet of things.  
Source: Compiled and analysed by the author based on secondary data collected during the study.

The segmentation demonstrates that ASEAN cannot be treated as a single uniform market for digital agriculture. This has an important implication for ASEAN–Japan co-operation, as technologies developed in Japan are generally designed for advanced, capital-intensive agricultural ecosystems, making them more suitable for growing and advanced markets such as Indonesia, Singapore, Thailand, and Viet Nam. However, emerging markets require more affordable, scalable, and context-sensitive technologies that align with smallholder farming systems and limited infrastructure conditions. Technology transfer from Japan to ASEAN should therefore follow a differentiated approach, tailored to the readiness level of each market segment.

## 3.2. Gap Between Digital Technology Needs in ASEAN and Available Digital Technologies in Japan

### 3.2.1. Digital Technology Needs in ASEAN

AMS face various structural challenges in the agricultural sector, including low productivity, vulnerability to climate change, and the dominance of smallholder farmers. In this context, the primary needs for agricultural digitalisation in ASEAN revolve around three main areas.

**Improved productivity and food security.** Agricultural productivity in ASEAN tends to stagnate, while food demand continues to increase. Digital technologies such as IoT and data analytics have the potential to improve production efficiency and adaptation to climate change (Montesclaros, Teng, and Caballero-Anthony, 2023). However, their adoption remains limited. The urgency of addressing food security underscores the need for digital solutions. According to the Food and Agriculture

Organization of the United Nations (FAO, 2026), the prevalence of undernourishment in ASEAN in 2024 was 5.4%. This indicates that a significant portion of the population lacks access to sufficient daily calories. In addition, in the same year, severe food insecurity affected 1.9% of ASEAN's population, indicating that a significant portion of the population still lacks adequate access to food, underscoring the urgency of improving agricultural productivity through digitalisation. In the regional context, while AMS compare favourably against many global regions, rural–urban disparities and unequal access to healthy diets continue to drive these numbers.

**Affordable and inclusive access to technology.** Most farmers in ASEAN are smallholders with limited capital. Therefore, the primary need is not high-cost, sophisticated technology, but affordable, easy-to-use technology adapted to local conditions. A report by ERIA (2024) indicated that technology costs and limited access are key barriers to the adoption of agricultural digitalisation. Addressing these barriers requires not only the development of more affordable technologies, but also inclusive business models and supportive policies that ensure smallholder farmers are not left behind in the digitalisation process.

**Digital infrastructure and literacy.** The digital infrastructure gap between urban and rural areas poses a significant challenge. Limited access to the internet, electricity, and digital devices hinders the widespread implementation of technology. Low digital literacy amongst farmers is also a major barrier to technology adoption (Montesclaros, Teng, and Caballero-Anthony, 2023). Addressing these gaps, therefore, requires targeted investments in rural connectivity and energy access, alongside sustained capacity-building programmes to strengthen farmers' digital skills. These enabling conditions are fundamental to the success of agricultural digitalisation in ASEAN.

### 3.2.2. Availability of Digital Technology in Japan

Unlike ASEAN, Japan has established a highly developed digital agricultural ecosystem. Agricultural digitalisation in Japan is driven by the need to address the labour crisis caused by an ageing population (Ishii et al., 2021). Japan's digital agriculture strengths can be categorised as follows:

**High technology and automation.** Japan has adopted a wide range of advanced technologies, including autonomous agricultural robots, AI-based drones, smart irrigation and fertilisation systems, smart pest control systems based on remote sensing and IoT, and national data platforms (e.g. WAGRI (<https://wagri.naro.go.jp/>)). These technologies enable productivity increases of 10%–25% and help prevent pest and disease attacks (JICA, 2023).

**Data-driven system integration.** Digital platforms and applications support the entire agricultural value chain by integrating farm production, logistics, advisory services, financing, and marketplace linkages, enabling farmers and stakeholders to improve productivity, access markets, and make data-driven decisions.

**Policy and funding support.** The Japanese government provides strong support through policies such as the Smart Agriculture Act (Act on the Promotion of Smart Agricultural Technology Utilisation, fully enacted in October 2024), which provides low-interest financing for the adoption of digital technologies (ERIA, 2024). Together, these policies demonstrate Japan's advantage in terms of technological capacity, digital infrastructure, and institutional support for agricultural digitalisation.

### 3.2.3. Gap Analysis: Mismatch Between Technology Supply and Demand

The gap between the digital technology available in Japan and the technology needs of AMS is not only quantitative (adoption rates), but also qualitative and structural. This gap reflects a misalignment between supply-side innovation (developed technologies) and demand-side needs (users' actual needs), particularly amongst smallholder farmers in ASEAN. To understand this dynamic more deeply, the analysis elaborates on five key dimensions of the gap:

1. **Technological complexity.** Digital technologies developed in Japan generally fall at the high end of the innovation spectrum, such as autonomous robotics, machine learning-based AI, and big data-driven precision farming systems. These technologies are designed to increase efficiency in integrated, capital-intensive modern agriculture (ECOS, 2021; Fukuda, 2025). However, the technology needs in ASEAN are more inclined towards appropriate technology solutions – technologies that are simple, affordable, and easy for smallholder farmers to operate. According to the FAO, the success of agricultural digitalisation in developing countries depends largely on the suitability of the technology for local conditions rather than on its sophistication (Trendov, Varas, and Zeng, 2019). In this context, an over-engineering problem occurs, where available technology is too complex for the user's needs. This results in low adoption rates because farmers lack the capacity to operate or maintain the technology (Fuglie et al., 2020). In other words, this gap is not due to a lack of technology, but rather because the available technology is not fit for purpose for the ASEAN context.
2. **Farming systems differences.** The differences in agricultural structures between Japan and ASEAN are a fundamental factor in the digitalisation gap. Japan has moved towards highly modernised agriculture, with a high level

of mechanisation and better land consolidation. In contrast, the agricultural sector in ASEAN is dominated by smallholder farming systems, characterised by small land holdings, limited capital, and reliance on family labour (Montesclaros, Teng, and Caballero-Anthony, 2023). Japanese technology is generally designed for structured, more integrated production scales. This leads to scale incompatibility, where technology cannot be effectively implemented in fragmented smallholder farming systems. According to IFAD (2021), technological innovations that fail to account for local agrarian structures are unlikely to be adopted by smallholder farmers because they are incompatible with their economic and social realities. Thus, this gap is structural, not merely technological.

3. **Digital infrastructure readiness.** The success of agricultural digitalisation depends heavily on supporting infrastructure, such as internet connectivity, electricity access, national data systems, and platform interoperability. Japan has a mature and integrated digital infrastructure, including national data platforms that enable the real-time integration of agricultural information (ECOS, 2021). In contrast, many AMS still face infrastructure limitations, particularly in rural areas. Asia-Pacific Economic Cooperation (APEC, 2022) reported that internet access in rural areas can be up to four times lower than in urban areas, directly hampering the implementation of digital technologies. Schroeder, Lampietti, and Elabed (2021) asserted that this gap creates the 'infrastructure paradox', in which technology is available but cannot be optimally utilised due to a lack of supporting infrastructure.
4. **Human capital.** Agricultural digitalisation depends not only on technology but also on users' ability to operate it. In this regard, there is a significant gap in digital literacy between Japan and ASEAN. Japan has a relatively technologically prepared workforce, supported by a robust education and training system. In contrast, in many AMS, farmers still face limitations in digital literacy, access to training, and technological understanding (Trendov, Varas, and Zeng, 2019). According to Xu et al. (2026), low digital literacy is a major barrier to the adoption of agricultural technology in developing countries – even more significant than limited infrastructure. This creates a capability gap, where even available and affordable technologies remain underutilised due to insufficient digital skills amongst farmers.
5. **Innovation ecosystem.** Fundamental differences are also evident in the innovation models between Japan and ASEAN. Japan adopts a top-down, R&D-driven innovation model, supported by strong collaboration amongst government, industry, and academia. Innovation focuses on developing advanced technologies on a national scale. In contrast, in ASEAN, innovation is more bottom-up and fragmented, often driven by donor projects, small

start-ups, and local initiatives (Montesclaros, Teng, and Caballero-Anthony, 2023). According to Hall et al. (2017), an unco-ordinated innovation system will yield unsustainable technologies that are difficult to adopt widely. This gap indicates that the main problem is not just technology but ecosystem readiness to support innovation.

Therefore, solutions cannot focus solely on technology transfer; they must also include technology adaptation (localisation), strengthen local capacity, and build an inclusive digital ecosystem. The required approach is context-sensitive innovation, in which technology is adapted to local conditions and supported by appropriate policies, infrastructure, and human capacity. Without this approach, the digital divide will not only persist but also risk widening inequalities within ASEAN's agri-food system.

### **3.3. Case Study of Digital Technology Implementation in Agriculture in Indonesia: Stakeholder Perspectives, Success Stories, and Challenges in Adopting Japanese Technology**

Digitalisation in the agricultural sector is a crucial strategy in addressing global challenges such as climate change, limited land, and a declining agricultural workforce. In Indonesia, the adoption of digital technologies such as IoT, sensors, drones, and data-driven systems is growing, although not evenly distributed.

#### **3.3.1. Digital Technology Implementation in Indonesia**

**Implementation at the user level (farmers and companies).** Interview data show that digital technology has been used across various commodities but remains predominantly semi-automated. However, in large companies with substantial financial resources, digital technology has been widely and extensively implemented. For example, one large agribusiness company integrates digital technology with mechanisation and breeding methodologies, including the use of sensors, automated greenhouses, and speed breeding to increase research and production efficiency. The modern horticulture site visited during the study implements a vertical hydroponic system with pump-based nutrient circulation and automatic lighting, but pH and nutrient monitoring are still performed manually due to cost considerations. A similar approach is used in an urban farming community, where IoT sensors monitor pH, nutrient levels, and water quality in hydroponic, aquaponic, and aquaculture (fishpond) systems. Here, IoT is also used for irrigation, but it is not yet fully based on real-time conditions; it is still carried out semi-automatically. In food crop cultivation, the use of drones for spraying pesticides and fertilisers has led to significant efficiency gains. This allows for faster and more precise application without damaging crops, particularly rice and corn. For fruit

commodities, the technology used is simpler and based on basic needs, such as drip irrigation, which increases water and labour efficiency, although it is still done manually or semi-automatically. These findings indicate that technology adoption is strongly influenced by the type of commodity and the scale of the business.

**Implementation by technology providers.** Private companies, as technology providers, play a crucial role in driving digitalisation by developing data-driven systems. Universities are also significant incubators for technological innovation, providing technology tailored to field needs. A respondent for IoT start-ups explained that they are developing various devices, such as soil sensors, weather stations, and automatic irrigation systems, capable of increasing water and fertiliser use efficiency by 40%–60%. This technology reflects the application of precision agriculture, which aligns with the global concept of precision farming (Wolfert et al., 2017). Meanwhile, drone technology developed by one of the respondents is reported to overcome labour constraints and increase operational efficiency, with a spraying capacity of up to 1 hectare in 10–15 minutes. In the aquaculture sector, one company has developed UV-based water sterilisation and electrolysis technology as an innovative approach to sustainably improving the quality of the aquaculture environment.

**Implementation from a government perspective.** From the government's perspective, digital technology has been used through big data, remote sensing, and agricultural information systems. Systems such as Simotandi and SISCrop enable extensive monitoring of agricultural conditions, although data integration challenges remain. The government also plays a role in technology dissemination through extension workers, demonstration plots, and assistance programmes. However, technology distribution remains uneven and relies more on government programmes than on independent adoption.

### 3.3.2. Required Technology: An Appropriate Technology Approach

Interview results confirmed that the required technology is not the most advanced, but rather the most appropriate for local conditions. Technology needs to meet the principle of 'appropriate technology', meaning it is suited to agro-ecological conditions, economic capabilities, and user capacity. This aligns with the literature, which emphasises the importance of technological suitability in increasing adoption rates (Rogers, 2003). Digital technology should also transform data into information that supports decision-making, which is central to the implementation of smart agriculture. This is key to implementing smart agriculture. Based on the interviews, the required technology should have the characteristics outlined in Table 3.

**Table 3: Characteristics of Required Technology in Indonesia**

| Criteria                      | Explanation                                  |
|-------------------------------|----------------------------------------------|
| Suitable for local conditions | Must consider agroecology and business scale |
| Affordable                    | Low investment and operational costs         |
| Easy to use                   | Does not require high technical expertise    |
| Adaptive                      | Can work in a limited infrastructure         |
| Needs-based                   | Solve real-world problems for farmers        |

Source: Processed from interview results.

Based on the interviews, the required technologies for Indonesia are specified in Table 4.

**Table 4: Required Digital Technology in Indonesia**

| Digital technology category           | Required technology                        | Brief description                                                                                                            | Relevance to Indonesian agriculture                                                                                          |
|---------------------------------------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| Input efficiency technologies         | Smart drip irrigation                      | A sensor-based and automated irrigation system that distributes water efficiently according to crop needs.                   | Highly needed to address water scarcity and improve water-use efficiency in horticulture, hydroponics, and dry land farming. |
|                                       | Soil sensors                               | IoT-based soil sensors used to monitor moisture, pH, temperature, and nutrient levels in real time.                          | Helps farmers optimise fertiliser and water usage while supporting precision agriculture practices.                          |
| Environmental monitoring technologies | IoT-based environmental monitoring systems | Monitoring systems that integrate temperature, humidity, light intensity, and cultivation conditions through IoT technology. | Essential for greenhouse farming, hydroponics, and urban farming to maintain optimal growing conditions.                     |
|                                       | Weather stations                           | Digital systems used to monitor local weather conditions such as rainfall, temperature, humidity, and wind speed.            | Important for crop scheduling, seasonal prediction, and climate risk mitigation.                                             |
| Mechanisation technologies            | Smart tractors                             | Digitally enabled and GPS-based tractors that improve operational efficiency and precision in land preparation.              | Needed to increase labour efficiency and support agricultural modernisation, especially in large-scale food crop production. |
|                                       | Agricultural drones                        | Drones used for pesticide/fertiliser spraying, land mapping, and crop monitoring.                                            | Highly relevant for overcoming labour shortages and improving operational efficiency, particularly in rice and corn farming. |
| Data-driven technologies              | Recommendation systems                     | AI- and data-based systems that provide recommendations for cultivation practices,                                           | Helps farmers make more accurate decisions based on field and weather conditions.                                            |

| Digital technology category | Required technology | Brief description                                                                                             | Relevance to Indonesian agriculture                                       |
|-----------------------------|---------------------|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
|                             |                     | fertilisation, and crop management.                                                                           |                                                                           |
|                             | Prediction systems  | Big data– and AI-based systems used to predict weather, pest outbreaks, productivity, and agricultural risks. | Needed to improve climate resilience and reduce the risk of crop failure. |

AI = artificial intelligence, IoT = internet of things.

Source: Processed from interview results.

### 3.3.3. Challenges of Adopting Japanese Technology in Indonesia

Although Japan is known as a pioneer in smart farming, the adoption of its technology in Indonesia faces various obstacles. Overall, the challenges of adopting Japanese technology in Indonesia are multidimensional, encompassing technical, economic, social, and institutional aspects. Some literature indicates that factors such as cost, infrastructure, human resources capacity, and contextual suitability are key determinants of agricultural technology adoption (FAO, 2022; Dibbern, Romani, and Massruhá, 2024). This corroborates the interview findings that successful technology transfer cannot be achieved directly but needs to go through a process of local adaptation. Some of the challenges identified in the interviews are as follows:

- 1. Mismatch between socio-economic and land-use contexts.** Japanese agricultural technology develops within a very specific context: a farming system with a high level of mechanisation, stable infrastructure, and strong policy support for digitalisation. Japan even promotes smart farming to address workforce issues and farmer ageing through significant investments in robotics and automation (Jie et al., 2023). In contrast, Indonesia's agricultural structure is dominated by smallholder farmers with fragmented landholdings, which often makes large-scale adoption of technology uneconomical. Interviews confirmed that many advanced technologies cannot be adopted due to their incompatibility with local conditions. Theoretically, this incompatibility relates to the concept of compatibility in the diffusion of innovation, in which technology is difficult to adopt if it does not align with users' values, experiences, and needs (Rogers, 2003). Studies also indicate that the diversity of agricultural practices and land use conditions is a major obstacle to the implementation of smart farming (Talero-Sarmiento, Parra-Sanchez, and H. Lamos-Diaz, 2022). Thus, high-tech Japanese technology is often incompatible with the conditions of

smallholder farming in Indonesia, with fragmented land and limited capital.

2. **Economic barriers and technology affordability.** One of the most significant barriers is high initial investment costs. Technologies such as drones, IoT sensors, and automation systems require significant capital out-of-pocket costs that are difficult for smallholder farmers to afford. Interviews revealed that digital technology is considered expensive for most farmers in Indonesia. For example, drones can cost more than Rp150 million, making them only accessible through service-based models such as drone-as-a-service, where farmers pay per session or per hectare, or through government assistance programmes. Complete IoT devices also cost Rp20 million–Rp50 million, depending on specifications, leading many smallholder farmers to improvise by building their own. For example, one farmer decided to make their own version of an IoT device to cut costs. Automation systems also require a continuous, stable internet connection and an uninterrupted electricity supply, making energy costs a significant consideration for smallholder farmers' adoption of this technology. Globally, cost is a major barrier to the adoption of digital agriculture, particularly in developing countries. The FAO (2022) emphasised that financial constraints in developing countries are a major barrier to smallholder farmers' access to digital technology. Furthermore, a study conducted by ERIA (2025) and a report from the European Patent Office (2025) indicated that cost and the digital divide are amongst the biggest barriers to the adoption of modern agricultural technology. Manzoor et al. (2025) pointed out that this unequal access can widen the gap between large and small farmers. Technology tends to be adopted by actors with substantial capital, such as large-scale commercial farming operations, creating a technology divide in the agricultural sector.
3. **Digital literacy, human resources capacity, and farmer mindset.** In addition to economic factors, social and cognitive aspects are also major barriers. Many farmers still have low digital literacy and rely more on experience than data-driven technology. This was reflected in interviews with technology providers, where farmers tended to require concrete evidence before adopting technology. Technology users (especially small farmers) feared crop failure due to the lack of a system that could guarantee yields from their cultivation. This phenomenon aligns with the diffusion of innovation theory, which states that technology adoption is influenced by perceived benefits and risks (Rogers, 2003). A lack of technical knowledge and training is also a major barrier to the transition to digital agriculture (Dibbern, Romani, and Massruhá, 2024). In the Indonesian context, this is exacerbated by low levels of farmer education and suboptimal technological

support. Thus, technology adoption is not only about the availability of tools, but also human readiness to use them.

4. **Limited infrastructure and supporting ecosystem.** Infrastructure is a crucial factor in the successful implementation of digital technology. Japanese technology is generally designed for environments with stable electricity access, high internet connectivity, and adequate technical support. However, in Indonesia, especially in rural areas, there is still limited electricity access, unstable internet connectivity, and a shortage of field technicians. Adoption is further hampered by the limited availability of spare parts and the relatively high prices of technological products. This is reinforced by government sources, who stated that limited electricity, internet access, and access to spare parts and maintenance are significant barriers to the implementation of technology. Globally, the digital infrastructure gap (digital divide) is a major obstacle to the adoption of agricultural technology in developing countries (Manzoor et al., 2025). Limited communication networks in rural areas also hamper the effectiveness of real-time data-based technology (Zheng, Zhu, and Jia, 2022). Without adequate infrastructure, even advanced technology will remain underutilised.
5. **Business models and economic sustainability of technology.** Another often-overlooked challenge is the business model. Many agricultural technologies are not accompanied by economic schemes benefitting farmers. For example, interview data show that in hydroponic systems, operational costs such as nutrients and electricity are often disproportionate to the selling price of the product, leading farmers to discontinue using the technology. This suggests that technological success is determined not only by technical aspects but also by economic feasibility. In the literature, this is known as economic viability, the condition in which the benefits of the technology must outweigh its costs (FAO, 2022). Studies have also shown that the perceived price value is a critical factor in farmers' technology adoption decisions (Harmak and El Aissaoui, 2024). If a technology is perceived as not providing tangible benefits, adoption rates will be low. Therefore, advanced Japanese technology needs to be adapted to business models that align with market conditions and Indonesian farmers' purchasing power.

The findings of this study indicate that the application of digital technology in Indonesian agriculture has progressed but remains partial and uneven. The success of digital technology implementation depends heavily on its suitability for the local context. Overly complex technologies that fail to consider user needs tend not to be adopted. Collaboration amongst the government, technology providers,

and farmers is also essential. The role of extension workers and field demonstrations has proven effective in increasing technology adoption. Therefore, technology development strategies must focus on a locally driven approach and sustainable business models.

#### **3.3.4. Success Story of Digital Technology Adoption in Agriculture in Indonesia: Case Study of a Leading Horticultural Seed Company in Indonesia**

The following case is based on fieldwork conducted during this study in one of Indonesia's leading horticultural seed companies, presented as an illustrative example of successful digitalisation in Indonesian agribusiness. The company focuses on producing superior horticultural seeds, with the goal of developing plant varieties that are adaptable to diverse agroclimatic conditions, increasing farmer productivity, and reducing cultivation risks. In addition to seed production, the company conducts intensive R&D, making technology an integral part of its business processes. In carrying out its activities, the company adopts various technologies that can be grouped into three main categories: methodology-based technologies (knowledge systems), mechanisation technologies, and digital technologies (smart systems). Digital technology, in particular, serves as a key pillar of the company's precision agriculture system.

Digitalisation in this company is realised through the implementation of various integrated technologies to support seed production and plant variety research. Some of the applied technologies are outlined below:

**IoT-based environmental monitoring system.** The company utilises environmental sensors and automatic weather stations to monitor real-time environmental parameters, including air temperature, humidity, and rainfall. The resulting data are used to better understand environmental conditions and support data-driven agronomic decision-making. Soil sensors and tensiometers are also used to measure soil moisture and soil water potential, enabling researchers to simulate drought conditions and other field conditions more precisely.

**Automated irrigation system.** The company developed an automated irrigation system that operates based on sensor data. This system can automatically activate or stop watering when certain parameters reach predetermined thresholds. Implementing this technology reduces reliance on operators and human error, while increasing the efficiency of water and labour use.

**Data integration and analytical dashboard.** All data from various sensors and digital devices are integrated into a visualised dashboard using an analytics platform such as Microsoft Power BI. This dashboard enables management to monitor operational and research conditions in real time, while accelerating the

strategic decision-making process. According to the company, using visual dashboards helps top management obtain more comprehensive, easily understood information than conventional reporting methods.

**Utilisation of GIS and spatial mapping.** GIS technology supports the development and expansion of the company's research areas. Through spatial mapping, the company can plan land use and manage research facilities more effectively and efficiently.

The adoption of digital technology by this company has significantly increased efficiency, precision, and innovation in the agricultural sector. The integration of IoT sensors, automatic irrigation systems, weather stations, GIS, and analytical dashboards has helped the company build a data-driven agricultural system that supports real-time, evidence-based decision-making. Some of the impacts and benefits experienced by the company include:

1. **Increased precision in decision-making.** Digital sensors and analytical dashboards have shifted agronomic decision-making from experience-based observation to objective, real-time data. This is particularly valuable in crop variety research, where environmental factors such as temperature and humidity directly influence outcomes.
2. **Operational efficiency and human error reduction.** Automated systems have replaced many manual activities, significantly reducing labour requirements and improving process consistency. This also minimises the risk of human error in crop management and research operations.
3. **Increased research and innovation effectiveness.** The integration of environmental sensors, smart greenhouses, and automated climate control enables researchers to simulate specific growing conditions without large-scale field trials. As a result, research processes have become faster and more efficient.
4. **Improved risk management and biosecurity.** Real-time environmental monitoring allows earlier detection of disease threats and more effective biosecurity protocols. This was demonstrated in the company's improved response to threats such as Bacterial Fruit Blotch.
5. **Organisational transparency and accountability.** Digitalisation enables systematic documentation of all operational and research activities, supporting more objective performance evaluation and reporting. Staff assessments are now based on measurable, verifiable technical data rather than subjective observation.

While the implementation of digital technology has not changed the company's core business model as a horticultural seed producer, digitalisation has transformed the way the company operates. This change has resulted in a more measurable,

transparent, and efficient work culture. This transformation demonstrates that successful digitalisation does not always require changing business models but can also involve improving organisational capabilities and decision-making quality, ultimately enhancing a company's competitiveness.

Despite its numerous benefits, implementation also faces several challenges, including the need to adapt human resources to new technology, a learning curve of 3–6 months, dependence on vendors for maintenance and technical support, and limited in-house expertise in digital agriculture. To address these challenges, the company has begun strengthening its internal capacity by recruiting experts such as biosystem engineers and improving the competency of existing staff.

### **3.3.5 Summary of Indonesia Case Study**

Digitalisation in Indonesian agriculture has progressed across multiple stakeholder levels, yet adoption remains partial and uneven. Interview data indicate that technology use varies considerably by commodity type and business scale. Large agribusiness companies have implemented integrated digital systems, encompassing IoT-based environmental monitoring, automated irrigation, GIS, and analytical dashboards, as part of a comprehensive precision agriculture approach. In contrast, smaller-scale operations rely on semi-automated or improvised solutions due to cost constraints. These findings indicate that technology adoption is strongly influenced by the type of commodity, the scale of the business, and the availability of financial resources.

The adoption of Japanese agricultural technology in Indonesia faces certain challenges, including economic, social, infrastructural, and institutional dimensions. For smallholder farmers, economic barriers remain the most significant obstacle, as the cost of technologies such as drones and IoT devices is well beyond their financial reach. These constraints are compounded by low digital literacy, limited rural infrastructure, and the absence of sustainable business models that ensure technology remains economically viable for small-scale operators. For large-scale farming, on the other hand, the case of a leading horticultural seed company demonstrates that successful agricultural digitalisation is achievable when technology selection is grounded in real operational needs. The integration of sensor-based systems, automated processes, and data analytics platforms has yielded measurable gains in decision-making precision and operational efficiency. This suggests that Japanese technology holds potential for adoption within Indonesia's large-scale agribusiness sector.

The findings of this study suggest that technology transfer from Japan to Indonesia would benefit from a process of local adaptation, rather than direct replication. Appropriate technology that is affordable, easy to use, adaptable to limited infrastructure, and responsive to actual farmer needs is more likely to be adopted sustainably than technically advanced technologies that do not suit local conditions. Multi-stakeholder collaboration between the government, technology providers, and farmers also remains a critical enabling condition. In particular, extension workers and field demonstrations have proven effective in increasing adoption rates. Technology development strategies should therefore prioritise locally driven approaches underpinned by economically sustainable business models.

### **3.4. Opportunities for Adopting Japanese Digital Agricultural Technology in ASEAN**

Japan's agricultural technology offers significant opportunities for transfer to ASEAN. Japan has developed a fully integrated smart farming ecosystem, covering the entire production cycle from land preparation to harvest. Strong government co-ordination, extensive R&D investment, and well-established public-private-academia collaboration underpin this technological maturity. Importantly, Japan developed these technologies primarily to address labour shortages and an ageing farming population. These challenges share common ground with ASEAN's own agricultural problems, including low productivity, climate vulnerability, and declining youth participation. This shared context creates a meaningful basis for collaboration, where Japan can act as a technology provider and knowledge partner while ASEAN serves as an adaptive implementation region.

However, for this collaboration to be effective, technology selection should be grounded in ASEAN's actual needs and conditions. Based on the findings, the recommended Japanese technologies for ASEAN include:

1. **IoT sensors and smart farming platforms.** Findings from Indonesia, Singapore, Thailand, and Viet Nam indicate that agricultural companies are increasingly in need of soil moisture sensors, microclimate sensors, greenhouse monitoring, automated fertigation systems, and environmental monitoring. Japan has strong advantages in high-precision sensors, edge computing (which enables data to be processed locally on the device rather than relying on cloud connectivity), real-time monitoring systems, and the integration of IoT with AI analytics. These technologies are highly relevant for seed production, food crop and horticultural production, greenhouse utilisation, and the development of high-value crops. At the same time, smallholder farmers across ASEAN also stand to benefit from more

accessible IoT-based solutions, particularly for climate change adaptation and more efficient use of water and agricultural inputs, highlighting the importance of developing affordable and simplified versions of these technologies for wider adoption. Key technologies include soil moisture sensors, microclimate sensors, greenhouse monitoring, automated fertigation, and environmental monitoring integrated with AI analytics.

2. **Smart greenhouses and CEA.** As demonstrated by a leading horticultural seed company in Indonesia, automated greenhouses with temperature controls, automatic exhaust fans, cooling systems, and environmental sensors have been successfully implemented. Singapore further illustrates the potential of advanced greenhouse technologies, where CEA, vertical hydroponics, IoT-based environmental monitoring, and AI-driven automation systems have been successfully deployed to maximise productivity within highly limited land resources. Singapore's experience demonstrates that advanced agricultural technologies can be effectively integrated into a national food security strategy when supported by strong policy frameworks and investment ecosystems. This offers valuable lessons for the broader adoption of smart greenhouse and precision farming solutions across ASEAN. As demand for premium horticultural production grows across ASEAN, Japan's leadership in smart greenhouse systems and automated climate control presents strong prospects for adoption, particularly for commercial-scale farms. Key technologies include AI-based climate control, automated fertigation, and plant factories.
3. **Precision agriculture and remote sensing.** There is a growing need for weather forecasting, remote sensing, agricultural big data, land suitability mapping, and climate-smart agriculture. Japan possesses strong competencies in agricultural satellites, GIS, drone monitoring, digital twin agriculture, and AI-based decision support systems, positioning it well to support AMS in improving farm productivity and climate resilience. Key technologies include agricultural satellites, GIS, drone monitoring, digital twin agriculture, and AI-based decision support systems.
4. **Robotics and agricultural automation.** While full robotics adoption remains limited due to investment costs, the need for autonomous spraying, robotic harvesting, autonomous greenhouse operation, and precision seeding/irrigation/fertilisation will continue to increase as the agricultural workforce dwindles. Japan is a global leader in agricultural robotics and holds significant opportunities in the medium- and large-scale agribusiness segment. Key technologies include autonomous spraying; robotic harvesting; autonomous greenhouse operation; and precision seeding, irrigation, and fertilisation.

5. **Integrated Pest Management technology.** This technology is highly relevant across ASEAN, given the increasing demand for food safety standards and export market requirements. Japan holds strong expertise in Integrated Pest Management (IPM) solutions, including monitoring sensors, trapping systems, sterile insect techniques, and integrated pest management systems. For instance, Japan–Indonesia co-operation collaborated in fruit fly control technology to support horticultural export access, where Japanese IPM techniques have been applied to meet strict phytosanitary requirements for exports to Japan. This type of collaboration demonstrates the broader potential for Japan to support AMS in meeting international food safety and trade standards through targeted technology transfer. Key technologies include monitoring sensors, trapping systems, and sterile insect techniques.
6. **Data platform and traceability.** As export market demands increase, the need for farm management systems; traceability; QR-based tracking; environmental, social, and governance (ESG) reporting; and carbon accounting is growing as well. Japan has strong experience in integrating agricultural data and the food supply chain, positioning it well to support ASEAN's growing demand for transparent and sustainable food supply chain management. Key technologies include farm management systems, QR-based tracking, ESG reporting, carbon accounting, and food supply chain integration.

The need for agricultural transformation towards a more efficient, labour-saving, climate-adaptive, and data-driven system creates significant opportunities for Japanese technology. Therefore, ASEAN is viewed as a strategic market for expanding Japanese agricultural technology, in line with Japan's vision of internationalising smart agriculture, as promoted by the MAFF policy (Ministry of Agriculture, Forestry, and Fisheries of Japan, 2019; 2025). In addition, with more than 100 million farmers and a significant share of regional food production, similar technological needs are emerging across several AMS, including Malaysia, the Philippines, Thailand, and Viet Nam. Amongst these, Indonesia stands out as a key entry point for the expansion of Japanese technology into ASEAN.

Overall, the prospects for Japanese digital agricultural technology in ASEAN remain promising. Amid competition from other countries, Japan maintains significant advantages in precision, quality, reliability, and technological integration. Recommendations to strengthen adoption are discussed in Chapter 4.

## Chapter 4

### Conclusion and Recommendations

#### 4.1. Conclusion

Agricultural digitalisation in the ASEAN region is a strategic step towards addressing global challenges, such as rising food demand, climate change, limited resources, and the continued dominance of smallholder farmers. This study shows that the level of digital technology implementation in ASEAN varies widely, ranging from the experimental stage in countries such as Myanmar and Timor-Leste to advanced digital ecosystems as seen in Singapore. Japan holds a key position as a strategic partner given its advanced smart agriculture ecosystem. However, a significant gap exists between Japanese technology and ASEAN's actual needs, driven by differences in technological complexity, farming structures, infrastructure, and human resources capacity. The case study of Indonesia shows that the application of digital technology has developed across various commodities and sectors, but remains partial, uneven, and heavily influenced by the suitability of the technology for local conditions. These findings suggest that successful agricultural digitalisation in ASEAN cannot rely solely on technology transfer. Instead, it requires a co-creation approach, appropriate and affordable technology, stronger infrastructure, improved digital literacy, multi-stakeholder collaboration, and sustainable business models – all working together to build a more inclusive and sustainable agri-food system in the region.

#### 4.2. Recommendations

Based on the analysis results, several recommendations are proposed for Japan to support the successful transfer and adoption of Japanese technologies in ASEAN, as outlined below:

1. **Prioritise appropriate, affordable, and scalable technologies.** Digital agriculture development in ASEAN should prioritise affordable, simple, and suitable technologies for smallholder farming systems, which dominate the region. Technologies that require high investment costs, advanced infrastructure, and complex technical skills are less likely to be widely adopted. Therefore, greater emphasis should be placed on practical technologies such as low-cost IoT sensors, smart drip irrigation, mobile-based agricultural advisory systems, weather-monitoring applications, and semi-automated farming technologies. Scalable and modular systems are particularly important

because they can be gradually adopted according to farmers' financial capacity and local infrastructure conditions. At the same time, for larger-scale agribusinesses, more advanced and integrated technologies present viable opportunities, as demonstrated by the successful adoption of IoT systems, automated greenhouses, and data-driven platforms in commercial farming operations in Indonesia and Singapore. A differentiated approach that addresses both smallholder and commercial farming segments is therefore essential to ensure inclusive digital agriculture development across ASEAN.

2. **Promote service-based and co-operative implementation models.** One of the major barriers to the adoption of digital agriculture in ASEAN is the high upfront cost of technology. To overcome this challenge, technology implementation should focus on shared-use and service-based models rather than individual ownership. Approaches such as drone-as-a-service, subscription-based monitoring systems, leasing schemes, and co-operative technology-sharing models can significantly improve access for smallholder farmers. These approaches also reduce operational risks and make technology adoption more economically feasible, especially in rural areas where farmers have limited capital and fragmented landholdings.
3. **Strengthen multi-stakeholder collaboration and local ecosystem development.** The successful implementation of digital agriculture requires strong collaboration amongst governments, universities, agritech start-ups, farmer groups, financial institutions, and technology developers. Multi-stakeholder partnerships are essential to support technology adaptation, pilot projects, farmer assistance, and the development of digital agriculture ecosystems. Collaboration with local actors is particularly important to ensure technologies are adapted to local agricultural practices, cultural conditions, and market needs. Demonstration farms, joint innovation projects, and public-private partnerships can also accelerate technology uptake and build farmer confidence in digital solutions.
4. **Focus initial expansion on AMS with stronger digital readiness.** Countries such as Indonesia, Malaysia, Thailand, and Viet Nam offer the most immediate opportunities for digital agriculture expansion because they already possess growing agritech ecosystems, improving digital infrastructure, and expanding commercial agriculture sectors. These countries also demonstrate increasing adoption of technologies such as drones, IoT systems, precision farming, and digital marketplaces. Prioritising these markets can provide faster scalability and stronger commercial viability. Expansion into emerging markets such as Cambodia, the Lao PDR, Myanmar, and Timor-Leste could follow as infrastructure and digital readiness improve.
5. **Support farmers' digital literacy and technical capacity.** Limited digital

literacy and technical knowledge remain major barriers to technology adoption across ASEAN. Therefore, the implementation of digital agriculture should be accompanied by continuous farmer training, field demonstrations, mentoring programmes, and digital extension services. Strengthening farmer capacity is primarily led by AMS governments through their respective agricultural extension systems. Japan can contribute by supporting collaborative training programmes, knowledge exchange initiatives, and technical assistance – such as joint field demonstrations, mentoring schemes, and digital extension services co-developed with local institutions. Practical and hands-on approaches are important because farmers are generally more willing to adopt technology after seeing direct evidence of productivity improvements and economic benefits. Strengthening the role of agricultural extension workers, local technology facilitators, and farmer communities will also help improve long-term technology adoption and sustainability.

6. **Develop localised and climate-smart agricultural solutions.** Digital technologies should be designed and adapted to ASEAN's tropical agricultural conditions, fragmented farming systems, and increasing climate-related risks. Priority should be given to technologies that support climate resilience and resource efficiency, such as smart irrigation systems, climate prediction tools, pest and disease monitoring systems, and AI-based recommendation platforms. Localisation is essential because technologies developed for highly mechanised agricultural systems may not be directly suitable for ASEAN conditions. A context-sensitive approach will help ensure that digital agriculture supports not only productivity growth but also sustainability, food security, and long-term resilience in the region.
7. **Optimise Japan's role in technology transfer and co-creation.** Japan has significant potential to support agricultural digitalisation in ASEAN through its experience in developing smart agriculture. However, this should go beyond conventional technology transfer and adopt a co-creation approach, in which technology is collaboratively developed and adapted to suit local conditions. Through collaborative research, training, and technology adaptation, Japan can help create more applicable and sustainable solutions for ASEAN farmers.

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