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MORALITY BEFORE KNOWLEDGE

Improving agricultural productivity: Strengthening smart farming implementation in Indonesia's agriculture sector

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ABSTRACT
Background: Food security is still one of the main issues in Indonesia. Indonesia's agricultural sector is undergoing an unbalanced transformation, where the decline in the agricultural sector's contribution to GDP is occurring faster than the decline in the number of workers, indicating that agricultural productivity still needs to be improved. The Indonesian government has developed a Smart Farming policy to optimize technology in agriculture, but its implementation is still constrained by various barriers. The purpose of this study is to examine the implementation of the Smart Farming policy in Indonesia, identify barriers, and provide recommendations for strengthening the policy. **Methods**: The method used is a literature review related to the implementation of Smart Farming, especially in Indonesia, including the challenges faced by farmers, such as resistance to technology, low regeneration of young farmers, and limited infrastructure and access to finance. **Findings:** The results show that despite supportive policies, barriers still reduce the effectiveness of Smart Farming implementation. Based on these findings, this study recommends strengthening policies through educational incentives for young farmers, improving technology research that is locally appropriate, and developing community-based financing. **Conclusion**: In addition, it is necessary to improve digital infrastructure in agricultural areas and standardize technology so that the adoption of Smart Farming can be more optimal and sustainable. **Novelty/Originality of this article:** The novelty of this study lies in its comprehensive synthesis of Smart Farming policy implementation in Indonesia, with a specific focus on the interplay between technological advancement and socio-structural barriers.

KEYWORDS: smart farming; food security; agricultural policy; agricultural technology; community strengthening.

1. Introduction

Food security is one of the fundamental aspects of a country's development, as it is directly linked to people's well-being, health and socio-economic stability. In 2015, the United Nations (UN) launched the Sustainable Development Goals (SDGs) agenda, particularly SDG 2 which aims to end hunger, achieve food security and promote sustainable agriculture. However, the reality is that approximately 733 million people still face hunger and malnutrition globally.

(WHO, 2024). If this trend continues, it is estimated that around 582 million people will be acutely malnourished by 2030 (WHO, 2024). Indonesia itself has a Global Hunger Index value of 16.9, which is in the middle category. To alleviate hunger, fulfill nutrition and accommodate global population growth, it is estimated that food production must increase

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by 70% by 2050. However, agriculture's contribution to global GDP has declined to just 3%, a third of its contribution a few decades ago (Rauf et al., 2023). The reality is that very little innovation is currently taking place in the agricultural industry, and in many cases, there are indications that food scarcity and hunger will remain a major problem in the coming decades (De Clerq et al., 2018). This emphasizes the need for drastic changes in the development of food production, including in the agricultural sector.

In Indonesia, the challenges related to food security are also significant. Although the country is one of the largest food producers in Southeast Asia, food security is still a major issue with high levels of malnutrition in some areas, especially in rural and remote areas. The prevalence of stunting in Indonesia shows fluctuations from year to year, where it increased in the 2010- 2013 period, then decreased between 2014-2018. Based on data from the Ministry of Health (2022), the prevalence of stunting decreased by 3.3%, to 24.4%, and in 2022 it decreased again to 21.6%. The contribution of the agricultural sector to Indonesia's GDP also appears to have decreased from 21.5% in 1990 to 12.7% in 2020. However, the number of workers in the agricultural sector only decreased slightly, from 51% in 1990 to 33% in 2020 (Sudaryanto et al., 2021). This shows that Indonesia is experiencing an unbalanced transformation, where the decline in the contribution of the agricultural sector to GDP is faster than the decline in the number of workers in the sector. These matters are one of the triggers for Indonesia to continue to improve its food security efforts.

Improving food security in Indonesia requires a more holistic approach, including technological innovation in the agricultural sector and food distribution system. One solution that is considered to be able to help in achieving SDG 2 is the application of technology modern agriculture, such as the use of the Internet of Things (IoT), big data and artificial intelligence (AI) to improve the efficiency of food production and distribution (Rauf et al., 2023). Moreover, these technologies also have the potential to reduce food waste and increase the resilience of the agricultural sector to climate change, which is increasingly becoming a major challenge in the future (Tevapitak & Bert, 2019).

On the other hand, the application of IoT and modernization is still experiencing obstacles because the agricultural culture in Indonesia still tends to be conventional. Although Indonesia has a large agricultural potential with an agricultural land area of 70 million hectares, its productivity is still not optimal due to limitations in the adoption of modern technology. One of the main obstacles in the implementation of IoT in Indonesia's agricultural sector is the inadequate technological infrastructure, especially in rural areas (Abiri et al., 2023). Although the contribution of the agriculture, forestry, and fisheries sectors ranks third in Indonesia's Gross National Product (GNP), the number of internet users in these sectors is low, at only 2.77%, or about 6.01% of total internet users in Indonesia (Sudaryanto et al., 2021). In addition, the high initial investment costs for implementing IoT systems and limited access to funding are serious obstacles for small and medium-sized farmers. This situation is exacerbated by the lack of technical support and assistance from relevant parties in the transition process towards technology-based agriculture (Santoso, 2023). These challenges mean that Indonesia's agricultural sector is still dominated by conventional practices that tend to be less efficient and less responsive to changes in environmental conditions and market dynamics.

Based on the existing problems, this research aims to examine the implementation of the Smart Farming policy in Indonesia, identify existing barriers, and provide recommendations for strengthening the policy. This research is a qualitative study using the literature review method. The literature study was conducted by collecting, reviewing, and analyzing various relevant literature sources, such as journals, books, government reports, and other reliable sources that discuss the development of the Agricultural Sector in Indonesia. By conducting a holistic study of the actual implementation of Smart Farming in Indonesia, it is hoped that existing policies can be strengthened by focusing on the problems found throughout the implementation of the Smart Farming program.

2. Methods

This study uses a qualitative approach with a literature review method. The study was conducted by collecting, reviewing, and analyzing various relevant literature sources, such as scientific journals, books, government reports, and other official documents discussing the development of the agricultural sector in Indonesia, particularly related to the implementation of Smart Farming 4.0 policies. The literature reviewed includes global studies on the evolution of agriculture from Agriculture 1.0 to Agriculture 4.0, as well as an analysis of the challenges of implementing technology in the agricultural sector in Indonesia.

The literature search focused on relevant recent sources, including government policies, data from the Ministry of Agriculture, and previous research on digital transformation in the agricultural sector. The data obtained were analyzed using a descriptive-qualitative approach with a thematic focus, identifying key themes emerging from various sources, such as infrastructure barriers, human resource limitations, and social and economic factors influencing the implementation of Smart Farming. The findings from this analysis were used to formulate policy recommendations that could strengthen the implementation of Smart Farming in Indonesia in a more adaptive, inclusive, and sustainable manner.

3. Results and Discussion

3.1 Approach and results

The development of the industrial revolution in the agricultural sector has gone through several stages that reflect technological developments and innovations in farming methods. It started with Agriculture 1.0 in the 18th century, where the first agricultural revolution was driven by the invention of mechanized farming tools such as the iron plow, as well as the shift from subsistence farming systems to commercial farming systems. This period was also marked by the invention of crop rotation and the use of fertilizers that began to increase agricultural yields. Agriculture 2.0 occurred in the mid-19th to early 20th century with the introduction of mechanization and large machines such as tractors, which replaced human and animal labor in tilling the soil. Other innovations included the widespread use of pesticides and chemical fertilizers, which increased agricultural productivity significantly. Agriculture 3.0, which began to develop in the late 20th century, is an era of digitalization with the application of information technology, automation systems, and the use of computers to manage farms. Technologies such as GPS, sensors, and automated irrigation systems are being used to increase efficiency and minimize waste in the farming process.

Currently, the world is in the era of Agriculture 4.0 which is part of the Industrial revolution 4.0, where advanced technology allows farmers to make informed decisions faster and more precisely. In addition, the use of these technologies enables full automation in various aspects of farming, such as fertilization, watering, and harvesting, which reduces reliance on human labor and significantly increases agricultural yields (Deloitte, 2020). Thus, Agriculture 4.0 not only optimizes productivity, but also focuses on sustainability, by minimizing environmental impacts and reducing resource wastage (Wolfert et al., 2017). This concept can be elaborated as follows (Rauf et al., 2023): smart Products: Intelligent products with memory that can actively participate in the system, learning patterns to optimize its performance; smart Machines: Machines capable of self-organizing in a production network, enabling flexible and agile manufacturing processes. These machines become Cyber-Physics System (CPS) with autonomous components and local control intelligence, enabling communication with other machines, production lines, and products through open networks and semantic descriptions; smart Planners: Intelligence that manages production activities based on real-time production data, ensuring efficient and responsive production processes; smart Operators: Utilizing technology to understand production activities through context-sensitive information and merging virtual information with the real world, also known as augmented reality (AR). This approach helps manage increasing technical complexity, enabling better decision-making and more efficient operations.

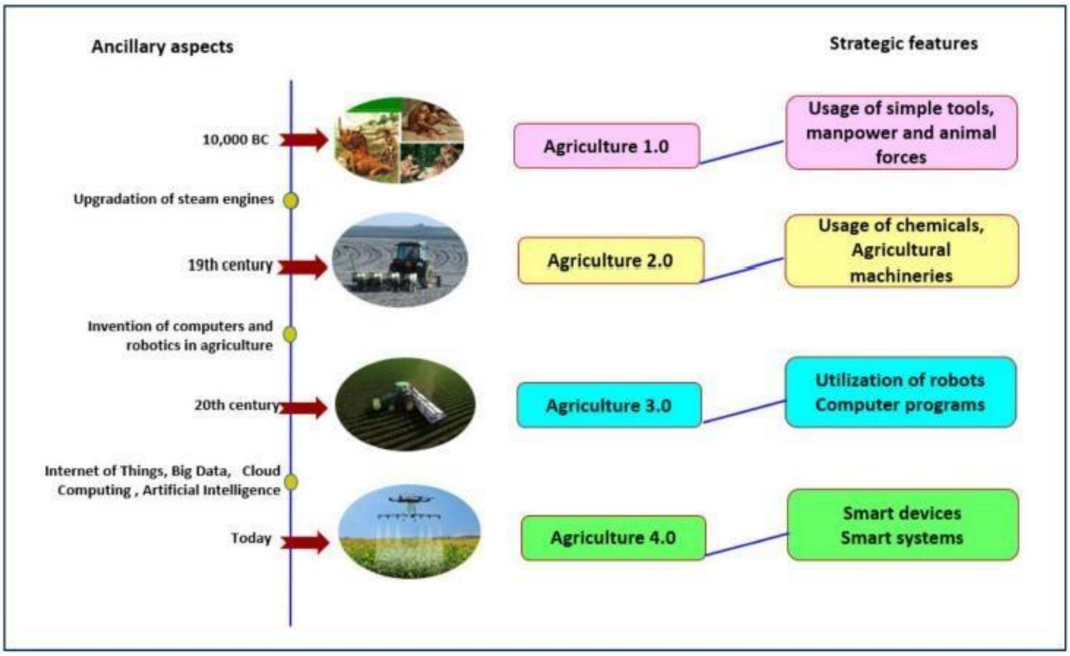

Fig. 1. Development of agriculture sector
(Dhanaraju et al., 2022)

Smart Farming that utilizes Smart Products, Machines. Planners, and Operators are developed based on technological advances to drive agricultural transformation to increase agricultural productivity towards food sustainability (Sudaryanto et al., 2022). This requires the development of digital business technologies in the agricultural sector involving partnerships between the public and private sectors, supported by appropriate policies and legal frameworks. The utilization of technology in agriculture can be applied in various agricultural processes, for example through automation, control with sensors, agricultural technical information, pest management, access to financial services, and other facilities (Agussabti et al., 2022).

In Indonesia, the Ministry of Agriculture has launched the Smart Farming program 4.0 that utilizes big data technology and artificial intelligence (AI) to help farmers work more efficiently. Smart farming is designed as a tool that can make farmers' jobs easier, enabling more scalable farm management and integrated with more sophisticated systems. This concept connects farmers with digital technology, which has now been implemented globally in many countries. The Agricultural Revolution 4.0 includes various technologies such as the Internet of Things (IoT), artificial intelligence, human-machine interfaces, robotics, satellite imagery, and sensor technology with 3D capabilities (Sudaryanto et al., 2022).

The implementation of Smart Farming 4.0 aims not only to improve efficiency, but also to increase sustainable agricultural yields. With technologies such as IoT and AI, farmers can monitor crop and soil conditions in real-time, allowing them to make faster and more informed decisions in the management of agricultural resources. Furthermore, the use of these technologies can also reduce wastage and negative impacts on the environment. Therefore, the adoption of these technologies is expected to change the way Indonesian farmers work and improve the competitiveness of the agricultural sector in the global market (Sudaryanto et al., 2021).

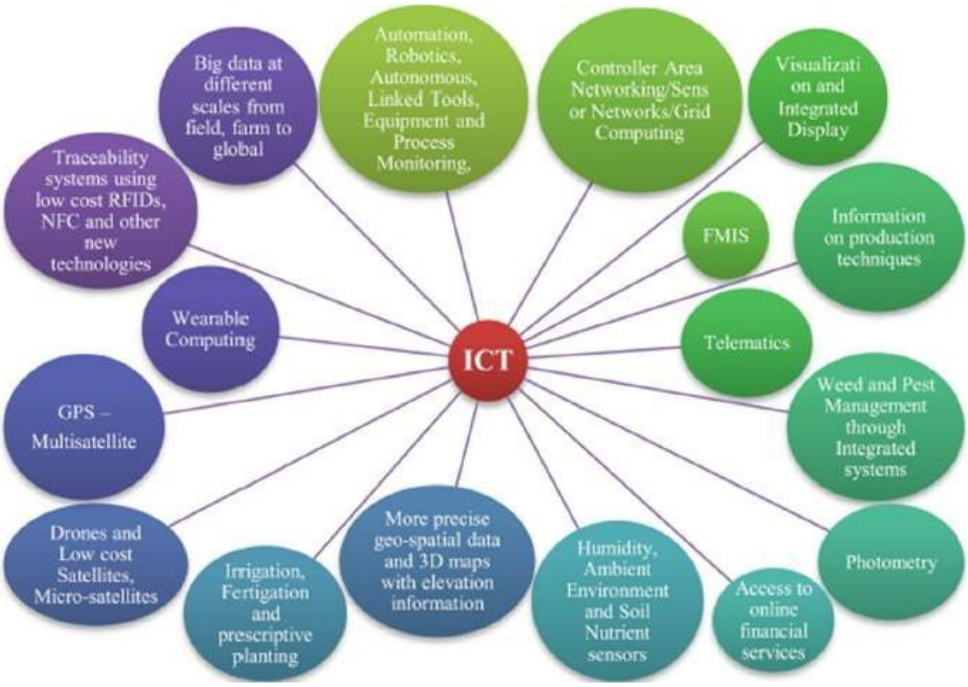

Fig. 2. Application of information and communication technology in the agricultural sector (Agussabti et al., 2022)

Although the concept of the Smart Farming 4.0 policy seems promising, the reality is that implementation in the field is often not in accordance with the existing concept design. Actual conditions in the field show the dominance of conventional agricultural practices that still rely on traditional methods and hereditary knowledge. While the Smart Farming concept was developed with the hope of optimizing the use of advanced technology and automation systems, the majority of agricultural practices in Indonesia still rely on manual methods and empirical experience. Overall, the barriers faced in Indonesia are consistent with the challenges of implementing Smart Farming in general by Dhanaraju et al. (2022), such as untrained labor, concerns with new technologies, low standards, poor connectivity coverage, and high investment costs.

Research by Fajarini & Okdinawati (2022) shows that the generation gap between young and old farmers is one of the main obstacles in the adoption of Smart Farming technology. Farmers in developing countries generally consist of smallholders who are limited in terms of capital and knowledge of modern technology (Handayati et al., 2015; Myeni et al., 2021). Data from the Agricultural Extension and Human Resource Development Agency/*Badan Penyuluhan dan Pengembangan Sumber Daya Manusia Pertanian* (BPPSDMP) of the Ministry of Agriculture shows an alarming fact: only about 8% of the total farmers are categorized as young farmers, while more than 90% are old generation.

The difference in perception of innovation between the older and younger generations creates a significant gap (Fajarini & Okdinawati, 2022). Older farmers tend to view innovation in a limited way, limited to the practical application of technology. They lack understanding of the broader benefits of digitalization, such as the potential of big data and cloud computing in improving agricultural sustainability. On the other hand, younger and middle-generation farmers are more enthusiastic about agricultural digital innovations, with a more holistic and systemic understanding of the value of data in modern agriculture. However, young farmers tend to be less resilient and want instant results, so in their role in agriculture, their results tend to be inconsistent (Fajarini & Okdinawati, 2022).

On the other hand, from a technical point of view, poor communication coverage can be a significant obstacle in the implementation of Smart Farming, especially in rural areas or regions where there is a lack of communication (Dwiyatno et al., 2022). Inadequate communication infrastructure, such as internet networks and cellular signals, can make it difficult for farmers to access important information related to modern agricultural technology, such as sensor-based monitoring systems, land management applications, or data analysis to improve productivity. Without stable and fast access, farmers also find it difficult to connect with agricultural experts, share knowledge, or take part in training related to Smart Farming. As a result, while these technologies can improve farming efficiency and yield, the lack of effective communication hinders their dissemination and adoption among farmers, reducing the potential benefits of Smart Farming.

Another actual condition felt by farming communities is limited government support (Fajarini & Okdinawati, 2022). While the government has made efforts to connect communities with investors and increase their exposure at the national level, direct benefits for the majority of community members are still minimal. The absence of specific policies for community-based innovation and agricultural community development programs leaves farmers to fend for themselves. Financial limitations are a serious obstacle to equitable distribution of innovations in the agricultural sector. Although some communities are able to develop independently, without adequate financial support, the spread of innovations remains hindered and results in low levels of innovation development overall.

These conditions create a paradox in the development of Indonesia's agricultural sector. On the one hand, global demands lead to the implementation of precision agriculture and Smart Farming, but on the other hand, Indonesian agriculture is still struggling with fundamental problems. This gap is not only about technology, but also about the inadequate readiness of infrastructure, human resources, and supporting ecosystems. Therefore, the transformation towards Smart Farming in Indonesia requires a comprehensive and systematic approach.

Mathematical equations, variables, and anything representing a value should be italicized. Formulae should be numbered consecutively throughout the manuscript as Eq. 1. In cases where the derivation of formulae has been abbreviated, it is of great help to the reviewers if the full derivation can be presented on a separate sheet (not to be published). Formulae should be centered and numbered. In this case the number will appear in the right margin.

3.2 Policy recommendation

Scaling up Smart Farming in Indonesia requires a comprehensive set of integrated policies. Existing policies need to be strengthened with relevant solutions to the problems faced during the implementation of previous policies. Development in terms of human resources, finance, infrastructure and technology needs to be enhanced through policy strengthening as illustrated in Figure 3 below.

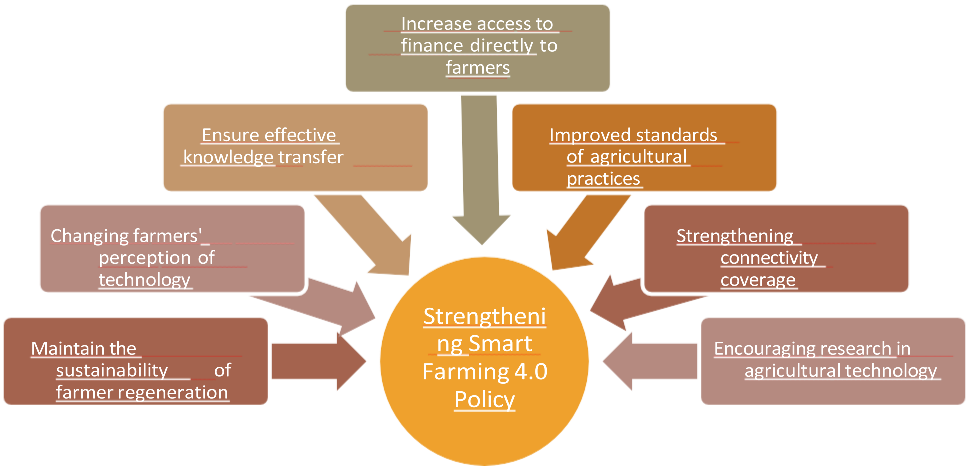

Fig. 3 Strengthening the smart farming 4.0 policy in Indonesia

The government faces several challenges in reforming human resources in the agricultural sector. Given the small percentage of young farmers in the demographics of agricultural workers, the regeneration of workers in the sector must be improved. Several things can be done to attract the younger generation to the agricultural sector, for example through educational incentive programs, special scholarships in agricultural technology, and providing access to capital specifically for young farmers. The development of vocational and higher education curricula that integrate digital technology with modern agricultural practices also needs to be strengthened. Technology-based agricultural business training and incubation programs can be an additional attraction for the younger generation to enter the sector.

The government also needs to develop policies that focus more on supporting community- based innovation, especially in terms of funding and capacity building. Consistent character building in the younger generation can be strengthened through programs such as seminars and farmers' camps, which are crucial for the sustainability of the agricultural sector. Character development of the younger generation in modern agriculture is not only about mastering technology, but also about building resilience and persistence in the face of challenges. Senior farmers' perceptions of technological innovation should also be improved, while still respecting their experience. Perception transformation senior farmers towards technology requires a more personalized and sustainable approach. The formation of learning groups with intensive mentoring, direct demonstration of the benefits of agricultural technology, and socialization programs tailored to the local context can help change their views. It is important to point out that technology is not to replace traditional knowledge, but rather to complement and improve the efficiency of existing farming practices.

These challenges can actually be opportunities for communities to evolve to become more adaptive and responsive to change. Training programs that bridge the generation gap are also important to ensure effective knowledge transfer between senior and junior farmers. Knowledge transfer between generations in agriculture requires structured platforms and mechanisms. Structured mentoring programs between senior and junior farmers, systematic documentation of traditional knowledge integrated with modern technology, and the establishment of integrated agricultural learning centers can facilitate this process. The development of mobile applications that facilitate documentation and knowledge sharing between generations can also be an effective solution. Thus, the digital transformation of Indonesia's agricultural sector can be more equitable and sustainable. Through a combination of the right policy support, community empowerment, and intergenerational collaboration, Indonesia's agricultural sector can transform into a more modern one without leaving behind valuable traditional wisdom.

Finance also plays a key role in the adoption of Smart Farming. In addition to increasing the farming community's exposure to investors, the government needs to develop special financing schemes with low interest rates for investment in agricultural technology, subsidy programs for the procurement of Smart Farming equipment, and tax incentives for companies investing in agricultural technology. The development of alternative financing models such as agricultural crowdfunding and partnerships with the private sector should also be encouraged to expand access to finance. This includes increased funding to support connectivity infrastructure. Accelerating the development of digital infrastructure in agricultural areas, developing rural broadband internet networks, and providing agricultural data processing facilities need to be policy priorities. The Universal Service Obligation (USO) program can be directed specifically to reach agricultural production centers.

Improving agricultural standards and strengthening technological research are also key to the sustainability of Smart Farming. Agricultural standardization is an important foundation in the development of Smart Farming. Operational standards for the implementation of agricultural technology, digital competency certification for farmers, and standardization of agricultural data need to be developed. These standards should include aspects of food safety, environmental sustainability and production efficiency that are aligned with modern agricultural practices. Adequate research budget allocation, establishment of centers of excellence in digital agriculture research, and triple helix collaboration between government, academia, and industry need to be strengthened. The focus of research can be on developing technologies that are appropriate to Indonesia's local context, such as tropical climate-resilient IoT systems or AI applications for local crop varieties. Improving agricultural standards requires a holistic approach that covers the entire agricultural value chain. The development of digital agricultural product certification systems, standardization of technology-based production processes, and implementation of digital traceability systems need to be implemented in stages. These standards should be aligned with the needs of the global market while still considering local conditions.

Implementation of these policy recommendations requires strong coordination among stakeholders and a phased approach tailored to the conditions of each region. Periodic monitoring and evaluation are required to ensure the effectiveness of the policies and make necessary adjustments. With proper implementation, these policies can encourage the transformation of Indonesia's agricultural sector towards a more advanced and sustainable Smart Farming era.

4. Conclusions

To improve Indonesia's food security, the implementation of Smart Farming concepts based on modern agricultural technology is necessary. The use of technologies such as automation, sensors, pest management, and other digital applications can optimize the farming process and strengthen the agricultural sector. However, the implementation of Smart Farming is still constrained by several challenges, such as conventional farming culture, low regeneration of young farmers, and infrastructure and financial barriers. To overcome these challenges, policies that focus on empowering young farmers, strengthening vocational education and curricula that integrate digital technology, as well as the implementation of Smart Farming are needed.

The development of community-based innovation policies is a strategic step that needs to be strengthened. In addition, the development of adequate digital infrastructure, agricultural technology-based financing, and improved research and operational standards for modern agriculture will accelerate the adoption of Smart Farming in Indonesia. Programs that support intergenerational knowledge transfer, as well as incentivizing technology adoption, will help accelerate the transformation of a more adaptive and sustainable agricultural sector. With good coordination between the government, the community, and the private sector, as well as the implementation of the right policies, Indonesia's agricultural sector can develop towards a more advanced digital agriculture era without abandoning existing local wisdom.

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All author contributed fully to the writing of this article.

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