

Empowering melon farmers in Magelang through AI-Based smart greenhouse technology

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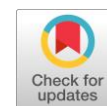
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ABSTRACT

The application of technology in the agricultural sector is a strategic step in addressing the challenges of production efficiency and adaptation to climate change. This study presents a community empowerment initiative through the implementation of an AI-based control system in a smart greenhouse to improve melon productivity in Magelang. The community service program was conducted by Ahmad Dahlan University (UAD) in collaboration with the Rukuntani Farmers Group in Salam Village, Magelang, through the introduction and implementation of the Artificial Intelligence Farming Control System (AFAS) in a smart greenhouse. The system integrates environmental sensors and leaf image cameras with Artificial Intelligence (AI) algorithms and the Internet of Things (IoT) to monitor plant conditions and automatically detect diseases. The activities were carried out in stages, including needs assessment, training, system installation, and weekly mentoring. The results showed a 25% increase in melon productivity and more consistent fruit quality. In addition, farmers' independence in operating the technology improved, and their work patterns shifted toward data-driven precision agriculture. This program demonstrates that a participatory approach supported by appropriate technology can have a significant impact on empowering farming communities and transforming local agriculture, as well as showing the potential of participatory smart farming programs in supporting sustainable agriculture in developing regions.



KEYWORDS

Smart greenhouse
Artificial intelligence
Smart farming
AFAS
Farmer empowerment
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1. Introduction

Agriculture is a fundamental sector that underpins economic development and food security on a global scale, particularly in developing countries such as Indonesia [1]–[6]. In addition to serving as a primary food source, it also plays a vital role in providing employment and supporting the welfare of rural communities. However, global challenges such as climate change, limited land and water availability, and increasing food demand due to population growth call for a transformation toward more efficient and sustainable agricultural systems. Many countries have begun to adopt precision agriculture approaches that leverage digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and automation systems to address these challenges. In Indonesia, although agriculture remains a key sector in the country's economic and social structure particularly in rural areas farming practices are still largely conventional with a low level of technology adoption [7]–[9]. This condition renders the production system vulnerable to issues such as pest and disease outbreaks, extreme weather, and inefficient use of agricultural inputs. As a result, national agricultural productivity tends to stagnate, and farmers' welfare remains relatively low. To overcome these challenges, the integration of digital technology is urgently needed to improve accuracy, efficiency, and the overall quality of agricultural outputs [2], [10]. One innovative solution developed is the Artificial Intelligence Farming Control System (AFAS), a smart

agricultural system that combines environmental sensors such as temperature, humidity, light intensity, and rainfall with AI algorithms capable of analyzing plant conditions and automatically detecting diseases through leaf image analysis [10], [11]. This system aims to reduce farmers' reliance on manual observation and enhance decision-making accuracy in agronomic practices. The technology supports the principles of precision agriculture, which has become a key element in the global digital transformation of farming. As part of its commitment to strengthening community based agricultural capacity, Universitas Ahmad Dahlan (UAD) initiated a community service program entitled "Enhancing the Capacity of Melon Farmers in Magelang Based on Modern Agriculture" [2]. This program engages the Rukuntani Farmers Group in Salam Village, Magelang Regency, as a partner community, with a primary focus on implementing smart greenhouse technology and the AFAS system in melon cultivation. Beyond mere technology transfer, the program includes intensive training and mentoring to improve farmers' digital literacy and foster independence in managing modern agricultural systems [12]–[14]. Based on program evaluations, there was a significant improvement in farmers' technical skills in operating smart agricultural systems, enhanced melon production quality, and expanded market access through more standardized and sustainable harvests. Thus, this program serves as a concrete example of how universities can contribute to empowering farmers to become more adaptive to technological advancements and the demands of the digital era. Location of the plantation in Paden Baturuno, Salam Village, Magelang Regency as show in Fig. 1.



Fig. 1. Location of the plantation in Paden Baturuno, Salam Village, Magelang Regency

2. Method

This study is part of a community service program that employs a participatory-collaborative approach, in which lecturers and farmers as key partners are actively involved in all stages of the activities. Given the nature of the intervention, this program adopts a Participatory Action Research (PAR) framework, integrating elements of applied research to evaluate and improve the implementation process in real-time. This methodological positioning emphasizes collaborative problem-solving, cyclical reflection, and active participation from the community. The method used is educational-applicative, focusing on community capacity building through technology transfer, training, and ongoing field mentoring [15]–[17].

2.1. Research Location

The activities were carried out in Peden Baturuno, Salam Village, Salam Subdistrict, Magelang Regency, a region with high potential for melon cultivation development under the coordination of the Rukuntani Farmers Group. The program was conducted over a one-year period, encompassing the stages of problem identification, training, technology installation, evaluation, and follow-up.

2.2. Implementation Stages

2.2.1. Problem and Partner Needs Identification

The implementation team conducted field observations, interviews, and focus group discussions (FGDs) with farmers to identify the challenges they face, particularly those related to melon crop productivity, dependence on weather conditions, and low levels of technological literacy.

2.2.2. Design and Installation of the AFAS System

The team designed the Artificial Intelligence Farming Control System (AFAS) as a monitoring and automatic detection system for melon cultivation. AFAS consists of modules for temperature, humidity, light intensity (LUX), and rainfall sensors, which function to record environmental conditions in real-time. In addition, the system is equipped with a camera for capturing leaf images, which are then analyzed using artificial intelligence (AI) algorithms to detect early signs of plant diseases. All components are integrated into an Internet of Things (IoT)-based platform, enabling automated data acquisition and control. The system was installed in the smart greenhouse owned by the partner farmers, and configured to respond adaptively to environmental changes, thereby supporting the practical and efficient implementation of precision agriculture [18].

2.2.3. Training and workshop

Farmers were given hands-on training on the concept of smart farming, an introduction to AFAS devices, and a simulation of crop monitoring through a dashboard interface. The training was delivered in stages using andragogical methods and field-based practice (learning by doing) to ensure effective knowledge transfer and practical understanding. Training and workshop as show in Fig. 2.



Fig. 2. Joint Training and Workshop

2.2.4. Mentoring and evaluation

During the program implementation, the team conducted weekly mentoring sessions to ensure that farmers could operate the Artificial Intelligence Farming Control System (AFAS) and understand the data it generated. Evaluation was carried out by comparing farmers' levels of understanding before and after the mentoring process, as well as by observing quantitative and qualitative changes in melon production outcomes. This approach aligns with the principles of empowerment program evaluation, which emphasize the importance of measuring various aspects, including improvements in farmers' capacity and production results.

3. Results and Discussion

Based on the results of a meeting with village officials on September 29, 2024, the farmers group and the UAD community service team successfully identified key agricultural challenges and formulated solutions, which culminated in the decision to develop greenhouse technology implementation in Peden, Baturuno Village. This is illustrated in Figure 3, which shows the Artificial Intelligence Farming Control System (AFAS)—a device developed by the Ahmad Dahlan University (UAD) team, designed to support smart farming practices. The device consists of three main components.

- A main control module with a touchscreen interface and visual display to monitor environmental conditions in real time.

- A processing and communication module, branded with the "AFAS" label and the UAD logo, serving as the central hub for sensor data integration and network connectivity.
- A high-resolution camera unit, mounted vertically, used for leaf image acquisition

This module is connected to various environmental sensors, including temperature, humidity, light intensity (LUX), and rainfall sensors, and is powered by an Internet of Things (IoT) system that enables automated and remote monitoring and decision-making. The camera acts as a visual input for the AI algorithms, allowing for early detection of plant disease symptoms through image analysis. The combination of AI computing and the sensor system enables farmers to manage crop growth conditions with precision, efficiency, and adaptability to weather changes and pest or disease outbreaks. With its portable and user-friendly design, the device is built to be easily used by partner farmers in a community empowerment context and supports the transformation from conventional farming to data-driven digital agriculture. This implementation serves not only as a technological intervention, but also as a proof of concept and a participatory empowerment model for smallholder farmers. AFAS Device as show in Fig. 3.



Fig. 3. AFAS Device

The implementation of the AFAS system received a positive response from partner farmers in Salam Village, Magelang. They demonstrated strong enthusiasm in learning and operating the system, reflecting their readiness to adapt to modern agricultural technology. This aligns with findings that empowering farmers through improved skills and knowledge in managing agricultural land contributes to increased productivity and well-being. During the implementation process, several challenges were identified, including the limited digital infrastructure in rural areas, such as unstable internet access, and the initial lack of understanding among farmers regarding new technologies. However, through intensive training and mentoring, farmers were able to overcome these barriers and began operating the system independently. Nonetheless, the scalability of the AFAS system remains a challenge. Effective deployment in broader contexts would require improvements in digital infrastructure, particularly stable internet connectivity, and increased technical literacy among rural communities. Similar challenges have also been identified in reports by Bappenas, which highlight that the adoption of technology in Indonesia's agricultural sector still faces obstacles such as limited land availability, financial constraints, and a shortage of human resources capable of operating the technologies. The program successfully enhanced farmers' independence in managing technology-based agriculture. Farmers were not only able to operate the AFAS system, but also capable of analyzing the data it produced to make more accurate decisions. This reflects the effectiveness of the participatory approach in empowering farming communities, as supported by studies on sustainable agricultural technologies that promote farmer autonomy. Following the implementation of the AFAS technology, there was a 25% increase in melon productivity compared to conventional methods. Additionally, the quality of the melons improved, with more consistent size and taste, giving them a greater competitive edge in the market. This outcome is consistent with research in precision agriculture, which shows that the integration of sensor-based and AI-driven systems can significantly improve both yield and crop quality through real-time monitoring and targeted intervention strategies [19], [20]. Mentoring on AFAS Operation and Maintenance as show in Fig. 4.



Fig. 4. Mentoring on AFAS Operation and Maintenance

The implementation of AFAS has driven a significant shift in farmers' work patterns from traditional approaches toward data-driven management. Farmers have begun adopting data-based decision-making, such as scheduling irrigation and fertilization based on information provided by the AFAS system. This reflects a transition toward more efficient and sustainable precision agriculture. To ensure the sustainability of the program, intensive training was provided to farmers so they could independently operate and maintain the AFAS system. In addition, local working groups were formed to support the system's day-to-day operations and maintenance. This sustainability strategy aligns with the empowerment approach used by P4S (Self-Reliant Agricultural and Rural Training Centers), which emphasizes the importance of training and mentoring in enhancing farmers' self-reliance.

4. Conclusion

The implementation of the smart greenhouse program based on the Artificial Intelligence Farming Control System (AFAS) in Salam Village, Magelang Regency, has demonstrated not only tangible improvements in productivity up to 25% and melon quality, but also transformative impacts on the technological capacity and self-reliance of local farmers. Through a participatory and collaborative approach, the program enabled farmers to adopt and operate AI-based precision agriculture systems independently, supported by intensive training and mentoring. More importantly, this initiative represents a scalable and replicable model for AI-enabled smart farming that aligns with broader national goals of agricultural modernization and rural development. By fostering shifts in work patterns toward data-driven decision-making and establishing sustainable local ecosystems through community-based working groups, this program contributes meaningfully to the transformation of traditional farming practices into resilient, adaptive, and future-ready agricultural systems. This model offers valuable insights for expanding smart agriculture across other rural regions in Indonesia, addressing challenges in food security, climate adaptation, and socio-economic empowerment in the digital era.

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Declarations

Author contribution. All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

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References

- [1] Y. Kurniadi, "The Role of the Agricultural Sector in Improving Food Security and the National Economy," *Nusant. J. Ilmu Pengetah. Sos.*, vol. 7, no. 2, pp. 408–420, 2020, [Online]. Available at: <https://jurnal.um-tapsel.ac.id/index.php/nusantara/article/view/16814>.
- [2] R. R. Rachmawati, "Smart Farming 4.0 to Build Advanced, Independent, and Modern Indonesian Agriculture," *Forum Penelit. Agro Ekon.*, vol. 38, no. 2, p. 137, Jun. 2021, doi: [10.21082/fae.v38n2.2020.137-154](https://doi.org/10.21082/fae.v38n2.2020.137-154).
- [3] Ministry of National Development Planning/Bappenas, "Strategic Priority Projects," 2019. [Online]. Available at: <https://share.google/maV1hQBVPORoFJT4S>.
- [4] I. Mukhlis and Ö. S. Gürçam, "The Role of Agricultural Sector in Food Security and Poverty Alleviation in Indonesia and Turkey," *Asian J. Agric. Extension, Econ. Sociol.*, vol. 40, no. 11, pp. 430–436, Nov. 2022, doi: [10.9734/ajaees/2022/v40i111728](https://doi.org/10.9734/ajaees/2022/v40i111728).
- [5] A. Pradana, I. Pujiastuti, and P. Pragna Paramita, "Regionalization of Agricultural Based Leading Sectors and Food Security in Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 338, no. 1, p. 012015, Nov. 2019, doi: [10.1088/1755-1315/338/1/012015](https://doi.org/10.1088/1755-1315/338/1/012015).
- [6] K. Pawlak and M. Kołodziejczak, "The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production," *Sustainability*, vol. 12, no. 13, p. 5488, Jul. 2020, doi: [10.3390/su12135488](https://doi.org/10.3390/su12135488).
- [7] D. Godoy *et al.*, *The future of food and agriculture: trends and challenges*, vol. 4, no. 4. 2014. [Online]. Available at: <https://share.google/RpvraCtbrautopDJH>.
- [8] K. Takahashi, R. Muraoka, and K. Otsuka, "Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature," *Agric. Econ. (United Kingdom)*, vol. 51, no. 1, pp. 31–45, Jan. 2020, doi: [10.1111/AGEC.12539](https://doi.org/10.1111/AGEC.12539).
- [9] G. N. Curry *et al.*, "Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world," *J. Rural Stud.*, vol. 88, pp. 422–431, Dec. 2021, doi: [10.1016/j.jrurstud.2021.07.022](https://doi.org/10.1016/j.jrurstud.2021.07.022).
- [10] F. Pertanian and U. Muhammadiyah, "Artificial Intelligence-Based Innovation in Improving Agricultural Production and Welfare of Village Farmers in Indonesia," in *Seminar Nasional*, 2024, pp. 1–14, [Online]. Available at: <https://share.google/FKLfncWH3VuL3hYSK>.
- [11] E. Wati and I. M. B. Suksmadana, "Implementation of Plant Disease Detection Using a Visual Analysis-Based Harvest Scan Application with Cloud Computing Integration," *J. Nas. Komputasi dan Teknol. Inf.*, vol. 7, no. 6, pp. 1836–1844, Dec. 2024, doi: [10.32672/jnkti.v7i6.8292](https://doi.org/10.32672/jnkti.v7i6.8292).
- [12] A. B. Santoso *et al.*, "Are Indonesian rice farmers ready to adopt precision agricultural technologies?," *Precis. Agric.*, vol. 25, no. 4, pp. 2113–2139, 2024, doi: [10.1007/s11119-024-10156-7](https://doi.org/10.1007/s11119-024-10156-7).
- [13] S. Wolfert, L. Ge, C. Verdouw, and M. J. Bogaardt, "Big Data in Smart Farming – A review," *Agric. Syst.*, vol. 153, pp. 69–80, 2017, doi: [10.1016/j.agsy.2017.01.023](https://doi.org/10.1016/j.agsy.2017.01.023).
- [14] M. Arangurí, H. Mera, W. Noblecilla, and C. Lucini, "Digital Literacy and Technology Adoption in Agriculture: A Systematic Review of Factors and Strategies," *AgriEngineering*, vol. 7, no. 9, p. 296, Sep. 2025, doi: [10.3390/agriengineering7090296](https://doi.org/10.3390/agriengineering7090296).
- [15] N. Nurliani, S. Suherah, and A. Agustrai, "Implementation of Farm Business Bookkeeping Model in Farmer Groups in Maros Regency, South Sulawesi," *Dedik. Pkm*, vol. 5, no. 2, pp. 345–352, 2024, doi: [10.32493/dkp.v5i2.38816](https://doi.org/10.32493/dkp.v5i2.38816).
- [16] E. Haryono *et al.*, "Methods for Implementing PkM (Community Service) for Higher Education," vol. 5, no. 2, pp. 1–21, 2024.
- [17] I. Nurhaida, A. Windah*, and A. Nina Yudha, "Transforming the Learning Paradigm: Collaboration and Active Participation Through the Socialization of the Teaching Practitioner Program," *Din. J. Pengabd. Kpd. Masy.*, vol. 7, no. 5, pp. 1315–1325, 2023, doi: <https://doi.org/10.31849/dinamisia.v7i5.15686>.
- [18] A. Kamilaris, A. Kartakoullis, and F. X. Prenafeta-Boldú, "A review on the practice of big data analysis in agriculture," *Comput. Electron. Agric.*, vol. 143, no. January, pp. 23–37, 2017, doi: [10.1016/j.compag.2017.09.037](https://doi.org/10.1016/j.compag.2017.09.037).

- [19] Y. Qiao, J. Valente, D. Su, Z. Zhang, and D. He, "Editorial: AI, sensors and robotics in plant phenotyping and precision agriculture," *Front. Plant Sci.*, vol. 13, no. November, pp. 1–5, 2022, doi: [10.3389/fpls.2022.1064219](https://doi.org/10.3389/fpls.2022.1064219).
- [20] T. Li, L. Zhang, and J. Lin, "Precision agriculture with YOLO- Leaf : advanced methods for detecting apple leaf diseases," no. October, pp. 1–15, 2024, doi: [10.3389/fpls.2024.1452502](https://doi.org/10.3389/fpls.2024.1452502).