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Is Smart Farming the Future of Sustainable Agriculture? Insights from a Village-Level Innovation Adoption

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ABSTRACT

Purpose of the study: This study aims to analyze the implementation of smart farming in Lapajung Subdistrict, Lalabata District, Soppeng Regency, and to examine how its application contributes to improving agricultural productivity in the area.

Methodology: This study employed a qualitative approach with a descriptive case study design in Lapajung Sub-District, Soppeng Regency. Data were collected through observation, interviews, and documentation involving key informants. The data were analyzed using Miles and Huberman's interactive model, guided by Rogers' five indicators of innovation diffusion.

Main Findings: Smart farming implementation in Lapajung Urban Village improved crop productivity, optimized water and fertilizer use, reduced pesticide dependency, and enhanced sustainability. Farmers reported time and labor savings, more accurate crop monitoring, and greater resilience to climate variability. Trial opportunities increased adoption rates. Despite challenges such as high initial costs and technical complexity, observable benefits encouraged wider acceptance and demonstrated strong alignment with local agricultural values.

Novelty/Originality of this study: This study introduces an integrated educational approach to smart farming adoption in rural Indonesia by using Everett Rogers' diffusion of innovation theory as a pedagogical framework. It contributes to the field of educational agricultural technology by highlighting how structured training, local compatibility, and observable outcomes can accelerate the understanding and acceptance of smart farming among farmers. This research uniquely bridges technological innovation with community-based agricultural education, promoting sustainable farming literacy.

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1. INTRODUCTION

Soppeng Regency is a region that relies heavily on the agricultural sector as the backbone of its economy. The majority of its population is engaged in agriculture and plantation activities, making this sector a crucial pillar in regional development [1], [2]. Despite the local government's efforts to improve agricultural productivity through various programs, several challenges persist, including limited land availability, climate change, and the underutilization of modern agricultural technologies [3], [4]. In this context, there is a growing need for more efficient and sustainable approaches to optimize agricultural yields.

One such approach that has begun to be implemented in Soppeng Regency is *smart farming*, a digitally based agricultural system that utilizes sensors, the Internet of Things (IoT), and automation to manage land with greater precision. This technology enables real-time data collection on soil conditions, moisture levels, temperature, and nutrient content, which can then be analyzed to determine the appropriate treatment for crops [5], [6]. Through this approach, farmers can avoid resource-intensive and environmentally harmful practices while significantly improving efficiency and crop yields.

Smart farming serves not only as a technical tool but also as a new paradigm in modern agricultural management [7], [8]. It facilitates data-driven agriculture that is adaptive to environmental changes and responsive to specific crop needs [9], [10]. Supported by artificial intelligence (AI), data analytics, and weather prediction systems, smart farming assists farmers in making decisions based on accurate and timely information [11], [12]. This is particularly important in addressing global challenges such as climate change, water scarcity, and land degradation [13], [14]. Moreover, smart farming promotes efficient use of agricultural inputs such as fertilizers and pesticides, thereby increasing productivity while preserving environmental sustainability.

However, the implementation of smart farming is not without its challenges. The complexity of the technologies involved, diverse farmer needs, and low levels of digital literacy among agricultural actors present significant barriers that must be addressed collaboratively [15], [16]. Therefore, synergy among government agencies, the private sector, and educational institutions is essential to building an innovation system that is adaptive to local contexts [17], [18]. Research and development, technical training, and continuous support for farmer groups are key components to ensure that smart farming can be widely and effectively adopted in regions such as Soppeng.

Although numerous international studies have explored the implementation of smart farming, most have focused on areas with advanced technological infrastructure, such as Western Europe and East Asia. For instance, a study by Wen et al. [19] highlights the success of IoT-based smart greenhouse systems in improving irrigation efficiency and crop prediction in China but pays little attention to the social context and technological readiness of small- and medium-scale farming communities. Similarly, research by Viazzi et al. [20], emphasizes the importance of data integration in precision agriculture but does not specifically address how such approaches can be adapted to regions with limited digital infrastructure, such as rural areas in Indonesia. These examples illustrate a knowledge gap regarding the adaptation of smart agricultural technologies in local contexts that differ in social, economic, and cultural characteristics.

Previous studies have also tended to emphasize the technical and economic aspects of digital agricultural innovations while overlooking institutional factors and community engagement. In fact, the successful diffusion of innovation largely depends on how well farming communities understand, accept, and are able to operate the introduced technologies [21], [22]. Therefore, this study is crucial in analyzing the implementation of smart farming not only in terms of technological effectiveness but also in terms of compatibility with local values, user complexity, and the extent to which the innovation can be trialed and observed directly by farmers [23], [24]. Using a case study approach in Lapajung Sub-District, this research seeks to offer contextually relevant empirical contributions to the development of technology-based agricultural policies in emerging regions.

Based on the above background, this study aims to examine how smart farming innovations are implemented in Lapajung Sub-District, Lalabata District, Soppeng Regency, and the extent to which their implementation enhances agricultural productivity in the area. This study is expected to contribute not only academically to the development of innovation theory in the public and agricultural sectors but also practically as a reference for policymakers and other stakeholders in designing sustainable and inclusive technology-based agricultural development strategies.

2. RESEARCH METHOD

This study employs a qualitative approach with a descriptive case study design. This approach was chosen because it allows the researcher to explore in depth the processes, implementation, and perceptions of key actors involved in the adoption of smart farming innovations in Lapajung Sub-District, Lalabata District, Soppeng Regency. The primary focus of the research is to understand how Internet of Things (IoT)-based agricultural technology is adopted, adapted, and perceived in terms of its benefits by local farmer groups in improving agricultural productivity.

The study was conducted in Lapajung Sub-District, Lalabata District, Soppeng Regency. This location was purposively selected because it serves as a pilot area for smart farming implementation through the development of an IoT-based greenhouse. The research was carried out between January and March 2025.

The data for this study consist of both primary and secondary sources. Primary data were collected through in-depth interviews with key informants, including smart greenhouse managers, farmer group members, agricultural extension workers, and local government officials involved in agricultural innovation programs.

Secondary data were obtained from documentation, official government reports, and archives related to the digital agriculture programs implemented in Soppeng.

Data collection techniques employed in this study included participant observation, semi-structured interviews, and documentation. Through participant observation, the researcher directly observed smart farming operational activities, such as the use of sensors, automated irrigation systems, and harvesting processes. Semi-structured interviews were conducted to explore the experiences and perceptions of informants regarding the successes, challenges, and impacts of the technology implemented. Additionally, documentation was gathered in the form of photographs of field activities, agricultural production data before and after the adoption of the technology, and maps of the agricultural areas in the study site.

Data were analyzed interactively and continuously using the three-step process proposed by Miles and Huberman: data reduction, data display, and conclusion drawing/verification. The analysis categorized information based on five indicators from Everett M. Rogers' diffusion of innovations theory: relative advantage, compatibility, complexity, trialability, and observability [25]. To ensure data credibility, the researcher applied source and method triangulation. This involved cross-verifying interview data with observational findings and documentary evidence, as well as reconfirming key information with relevant informants. The validity of the research findings was maintained through systematic note-taking and critical reflection on field data.

3. RESULTS AND DISCUSSION

According to Everett Rogers, innovation is defined as an idea, practice, or object perceived as new by an individual or group. Rogers also proposed several key factors that influence the rate and extent of innovation diffusion, namely relative advantage, compatibility, complexity, trialability, and observability. In his view, understanding how innovations spread and are accepted by society is essential for ensuring their effective development and utilization. In this study, these theoretical indicators serve as the analytical framework through which the researcher identifies the problem, conducts the investigation, and seeks potential solutions. As previously explained, this research adopts a qualitative method involving observation, interviews, and documentation. Qualitative analysis techniques particularly the presentation of data in a narrative form are used to analyze the findings from observations, interviews, and documentation. This approach enables the researcher to evaluate and interpret the collected data systematically and contextually.

3.1 Relative Advantage

The characteristic of relative advantage refers to whether a new innovation is perceived as superior to previous methods or technologies. If an innovation is believed to offer greater benefits compared to prior approaches, it is more likely to be adopted quickly by the community or farmer groups, particularly to avoid potential negative consequences in the future, such as material losses. The researcher conducted an interview with Mr. AR, the manager of the smart farming initiative, regarding the benefits derived from the implementation of smart farming. He stated:

> “Smart farming innovation can provide significant benefits, such as increasing production, optimizing crop management, improving resource use, offering protection against pests, and more.”

Based on interviews conducted by the researcher, smart farming innovation is shown to hold significant potential for increasing crop yields by optimizing the use of resources such as water and fertilizers. In addition, the technology provides improved protection against pests and plant diseases and enables more efficient monitoring of overall crop conditions. Thus, smart farming not only enhances agricultural productivity but also contributes to environmental sustainability and improves the operational efficiency of farmers. In an interview conducted on January 26, 2025, Ms. I, a member of a local farmer group, stated:

> “Smart farming innovation offers several benefits such as saving time and labor, more efficient use of resources, and accurate agricultural monitoring.”

This statement affirms that smart farming delivers significant benefits, including time and labor savings, more efficient resource use, and accurate monitoring, all of which contribute to improved agricultural productivity and sustainability. Another informant from the community added:

> “The innovation of smart farming helps reduce the use of pesticides and chemical fertilizers and increases the efficiency of resource use, such as water and energy.”

This indicates that smart farming, particularly when using methods such as hydroponics, offers substantial benefits by reducing reliance on chemical inputs in agriculture. Furthermore, the technology enables greater efficiency in utilizing essential resources like water and energy. Therefore, smart farming not only increases agricultural productivity but also has positive environmental impacts and supports the sustainable management of natural resources. In addition, the coordinator of the Agricultural Extension Center (Balai Penyuluhan Pertanian or BPP) stated:

> "Smart farming is an innovation that offers many advantages. First, it can increase local agricultural production by creating optimal growing conditions for crops. Second, it can help reduce the use of water and fertilizers due to the controlled environment. Furthermore, it also has the potential to create new job opportunities in modern and sustainable agriculture."

Based on the interview with the BPP coordinator, smart farming—as an innovation—promises significant benefits for the agricultural sector. These include increasing local production, reducing water and fertilizer consumption, and creating new employment opportunities in the context of modern and sustainable farming practices. Given these numerous benefits for the community, smart farming can be regarded as a well-accepted innovation that offers superior advantages over previous methods. Thus, it can be concluded that the relative advantage indicator is effective in evaluating the technical benefits of smart farming innovation, particularly in improving crop productivity. This is consistent with the concept of relative advantage as defined by Everett Rogers, which refers to the degree to which an innovation is perceived as better than the idea it replaces.

Various studies published in reputable academic journals provide strong empirical support for the relative advantage of smart farming defined as its perceived superiority over conventional agricultural methods. A systematic review of previous research highlights how IoT-based smart farming has transformed agricultural practices from reactive data usage to proactive problem prevention and precise crop diagnostics, thereby reinforcing your informants' statements regarding time and resource efficiency [26]. Meanwhile, other studies emphasize that smart farming, through the integration of cloud computing, Geographic Information Systems (GIS), and remote sensing technologies, has led to increased crop yields and reduced input costs. These findings align with the testimonies of your informants on labor savings and optimized resource utilization [27].

Furthermore, a study published in the journal *Agriculture* (MDPI), focusing on hydroponic systems, demonstrates a significant improvement in water-use efficiency up to 70% alongside increased crop productivity and reduced dependence on chemical fertilizers and pesticides. These results correspond with informants' remarks on the environmental benefits and reduced chemical input in technology-based agricultural practices [28]. Thus, drawing on both scholarly literature and field data, it can be concluded that smart farming possesses a clear relative advantage in terms of enhancing productivity, optimizing resource efficiency, promoting environmental sustainability, and modernizing agricultural systems. This conclusion is consistent with Everett Rogers' theory, which posits that innovations are more likely to be adopted when they are perceived as superior to previous approaches.

3.2 Compability

Compatibility refers to the extent to which an innovation aligns with the experiences, principles, and perceived needs of potential adopters. When an idea or practice is seen as relevant and applicable, individuals or groups are more likely to embrace it without hesitation. In the case of smart farming, the innovation closely corresponds with farmers' values. For example, real-time monitoring of crops through technology enhances water and fertilizer efficiency, aligning with the principle of resource optimization. Similarly, the integration of sensor technology and data analytics supports reduced pesticide use and sustainable farming—values deeply held by agricultural communities. Moreover, smart farming enables individualized crop management, catering to the unique needs of each plant. Consequently, this innovation embeds sustainability, efficiency, and fairness into daily farming practices. To assess the compatibility of hydroponic smart farming with community values, the researcher interviewed the program manager, who stated:

> "Smart farming innovation aligns with agricultural values because it offers a solution to increase crop production in a sustainable and efficient manner."

This indicates that the innovation is compatible with farmers' core values of sustainability and efficiency, enabling optimized resource use and minimal environmental impact. The coordinator from the Agricultural Extension Center (BPP) echoed these views:

> "Yes, smart farming innovation aligns with agricultural values because it helps improve productivity, sustainability, and food security. Therefore, compatibility between smart farming and these values is essential to ensure that the innovation delivers lasting benefits to the agricultural sector."

These responses suggest that smart farming enhances productivity, environmental sustainability, and food safety—values that resonate strongly with the agricultural community. It is important, therefore, that innovations remain integrated with these values to ensure enduring impact. A farmer group member further commented on its compatibility with existing practices:

> "Smart farming innovation has great potential to complement previous innovations because it can expand and improve the efficiency of existing farming systems."

According to this informant, smart farming can effectively integrate with and enhance current agricultural systems. By employing advanced technologies such as sensors, IoT, and data analytics, smart farming improves productivity, resource efficiency, and real-time monitoring yielding a more sustainable and efficient farming system overall. Hence, it can be concluded that the compatibility indicator measuring alignment between the innovation and adopters' values is indeed effective. It reduces uncertainty among potential adopters, and in the context of Lapajung Sub-District, smart farming is well-aligned with local agricultural traditions and existing innovations..

Interview findings indicate that smart farming innovation is highly compatible with the local agricultural values in Lapajung, particularly in terms of resource efficiency, environmental sustainability, and food security. Both farmers and the coordinator from the Agricultural Extension Center emphasized that this technology is a "solution for increasing crop production in a sustainable and efficient manner." In line with Everett Rogers' Diffusion of Innovations Theory, this alignment reduces resistance and fosters adoption by ensuring that the innovation resonates with the values and experiences of farmers [29].

Literatur menguatkan temuan ini. Misalnya, Khongpeim & Prangkratok [30] report that in Thailand, the use of soil sensors, automated irrigation systems, and data analytics through IoT contributed to a 15–25% increase in agricultural efficiency and a 20–30% reduction in operational costs, demonstrating strong compatibility with local farming practices. Similarly, Srivetbodee and Igel [31] found that precision farming technologies aligned with farmers' daily lives resulted in profit increases of up to 30% and post-harvest losses reduced by more than 40%.

On a smaller scale, a study by Takagi et al. in Taiwan confirmed that technological compatibility—defined as the degree to which a technology aligns with farmers' livelihoods—is a key predictor of smart agriculture adoption [32]. This highlights the importance of designing intelligent systems that are congruent with traditional agricultural practices and local values to ensure broad acceptance. In conclusion, both field data and scholarly literature consistently support the notion that smart farming is compatible with local agricultural values, fostering trust and openness toward technological innovation. These findings underscore the principle that new agricultural innovations are more likely to be widely adopted when they are designed to complement and respect the values and lived experiences of local farmers.

3.3 Complexity as a Barrier to Smart Farming Adoption

Innovation often entails a higher level of complexity compared to previous practices due to its novel characteristics. However, when an innovation offers improved solutions, its complexity may not necessarily be a significant deterrent. According to Rogers' diffusion theory, *complexity* refers to the degree to which an innovation is perceived as difficult to understand and use. Innovations that are easily comprehensible and usable are typically adopted more rapidly, whereas those perceived as complex tend to spread more slowly. Field interviews conducted with key informants from the Agricultural Extension Center (BPP) revealed that the implementation of smart farming presents multiple challenges. One coordinator noted:

> "Implementing smart farming innovations is challenging because it involves managing several factors, including temperature regulation, humidity, and efficient water resource management. Additionally, education and training for farmer groups on the use of new technologies are essential."

This highlights the technical complexity of smart farming, particularly in managing environmental parameters and integrating automation systems. The need for continuous training and education also emerged as a critical factor in ensuring successful implementation. Further interviews reinforced this perspective. Informant Mr. CM emphasized the issue of financial constraints:

> "Yes, there are several obstacles in implementing smart farming innovations, one of which is the availability of funds to build and maintain such facilities."

This suggests that financial barriers especially initial investment costs are a critical challenge for farmers and other stakeholders, despite the long-term benefits that smart farming promises. Similarly, informant Ms. I stated:

> "Implementing smart farming involves several challenges, such as high investment costs, ensuring stable resource availability, and specialized knowledge."

Interviews conducted with farmer groups reaffirmed that, although smart farming innovations present considerable potential to enhance efficiency and productivity, several critical challenges must be addressed to ensure successful adoption. These challenges include high implementation costs, unreliable access to essential resources, and a general lack of technical expertise among farmers. Additionally, the Agricultural Extension Center (Balai Penyuluhan Pertanian) reported difficulties in effectively communicating and disseminating these innovations to farmer groups. A particularly significant barrier was the delivery of comprehensive training on the application of smart farming technologies. Nevertheless, the coordinator of the Agricultural Extension Center noted that, despite the obstacles encountered, the dissemination efforts yielded promising outcomes most notably in Lapajung Administrative Village (Kelurahan Lapajung), where the innovations were successfully implemented..

From these insights, it can be concluded that implementing smart farming technologies is inherently complex, involving multifaceted aspects such as sensor calibration, climate control, water management, and real-time data processing. These findings align with research published by IntechOpen [33], which indicates that the complexity of IoT device usage—especially concerning technical training and infrastructure—is a primary obstacle in adopting modern agricultural technologies. Financial limitations were also repeatedly cited. The need for initial capital investment and ongoing funding supports IntechOpen's claim that cost is one of the key barriers to adoption, particularly for small-scale farmers. Additionally, a study by Agussabti et al.. [34] in Aceh found that low technical capacity among farmers, due to insufficient training and education, significantly constrained their readiness to adopt advanced technologies such as smart farming.

While high complexity often impedes adoption, educational interventions can mitigate these effects. A global survey reported in Agriculture and Human Values indicates that technical complexity and high costs can delay adoption of digital farming, but these can be overcome through institutional support and structured training programs. Supporting this, a study conducted in Chiang Mai demonstrated that intensive training using the Kirkpatrick model effectively enhanced farmers' knowledge and skills in operating smart farming technologies [35].

In summary, although the complexity of smart farming is high, a strategic combination of training, institutional support from organizations like the BPP, and potential financial assistance—through government subsidies or partnerships can significantly reduce these technical barriers. This reinforces Rogers' notion that complexity does not necessarily impede innovation adoption if accompanied by appropriate education and institutional facilitation.

3.4 Trialability as a Catalyst for Smart Farming Adoption

The trialability of an innovation refers to the degree to which it can be experimented with on a limited basis before full-scale adoption. Prospective adopters often evaluate an innovation through trial runs due to the perceived risks associated with new initiatives. Since the failure rate of new technologies can be higher than their success rate, initial experimentation allows potential users to forecast the likelihood of success and assess its practicality. Interviews with key informants—including the Agricultural Extension Center (BPP) coordinator and local farmer groups—highlighted that trial implementation of smart farming was essential in building trust and understanding among early adopters. The BPP coordinator remarked:

> "Implementing smart farming innovations is a highly positive and important step in improving agricultural efficiency and productivity. This innovation leverages technology to monitor, control, and manage farming processes more intelligently, thereby reducing production costs, optimizing resource use, and enhancing yields."

This perspective reflects the transformative potential of smart farming. Through technological integration, farmers can streamline agricultural operations, conserve inputs, and boost output, even during initial trial phases. Members of farmer groups also acknowledged the significance of foundational understanding in early adoption stages:

> "When first adopting smart farming, it is important to have a good grasp of the technology and the concepts behind it, including its benefits in regulating climate and plant growth. "

Hasil This shows that a clear understanding of the underlying principles of smart farming, including environmental control and plant development optimization, is essential for successful experimentation. Another respondent, Mr. AR, identified several critical factors influencing the willingness to trial smart farming:

"The factors include environmental awareness, resource availability, accessible technologies, government policies, as well as risk and benefit considerations."

From this, it can be concluded that environmental consciousness often motivates the adoption of innovations such as greenhouse-based smart farming. However, success depends on the availability of supporting resources, such as capital, infrastructure, and labor. The accessibility of relevant technologies is pivotal for implementation, while government policies through fiscal incentives, supportive regulations, and subsidies—can accelerate the process. Moreover, evaluating both risks and benefits is essential for making informed decisions, especially regarding environmental and economic impacts.

These findings indicate that trialability plays a pivotal role in the innovation adoption process. Following initial outreach and training facilitated by the Agricultural Extension Center, farmers in Kelurahan Lapajung were encouraged to engage in preliminary trials prior to full-scale implementation. This approach enabled them to experience the innovation firsthand and mitigate perceived risks associated with its adoption. Interview results revealed that such trial opportunities significantly enhanced farmers' confidence by demonstrating observable benefits, including reduced production costs, more efficient resource utilization, and increased crop yields. These observations are consistent with Rogers' Diffusion of Innovations theory, which posits that the greater the opportunity for potential adopters to experiment with an innovation, the higher the likelihood of its broader adoption.

These qualitative insights are supported by findings from Dewi et al.[36] who conducted a national review indicating that pilot access to smart agricultural laboratories or technology centers significantly enhanced the adoption of IoT-based agriculture. The study found that enabling farmers to explore new technologies without the burden of high risk increased their readiness and confidence in transitioning to smart farming systems. In conclusion, trialability is a decisive factor in the adoption of smart farming innovations. It offers farmers an opportunity to evaluate the practicality, benefits, and challenges of the technology in a low-risk environment. With institutional support such as training, pilot projects, and government incentives this stage can substantially reduce barriers and accelerate the broader diffusion of agricultural innovations.

3.5 Observability and Its Influence on Smart Farming Adoption

Observability refers to the degree to which the results and benefits of an innovation are visible to others. The more tangible and observable an innovation's outcomes are, the more likely it is to be adopted. Visibility allows potential adopters to perceive the innovation not as an abstract concept, but as a practical solution with demonstrable advantages. When the benefits of an innovation are evident within a community—particularly through early adopters—adoption tends to accelerate. Interviews with the Agricultural Extension Center (BPP) coordinator in Kelurahan Lapajung revealed that the decision to implement smart farming was preceded by a comparative study of existing innovations, followed by hands-on observation of the tangible improvements delivered by the smart farming system:

""Before adopting smart farming, we conducted a benchmarking study with previous innovations. After implementation, agriculture became more controlled with an environment that could be monitored, enabling crops to grow year-round without being affected by weather conditions. Smart farming also improved efficiency in water and fertilizer usage, reduced the risk of pest and disease outbreaks, and resulted in more consistent and higher-quality yields"

This observation emphasizes the power of demonstrable outcomes—including improved environmental control, input efficiency, and production stability—in increasing farmers' willingness to adopt smart farming. The visibility of such benefits validated the decision to transition from conventional methods to IoT-based systems. A similar sentiment was expressed by a smart farming practitioner in the same region:.

"Before adopting smart farming, we underwent training to master the new technologies, particularly on how to manage resources like water and fertilizers, and how to mitigate the risks of pests and diseases."

This highlights that pre-adoption training not only improved technical proficiency but also enhanced the farmers' ability to visibly realize the value of the technology, making the benefits more evident to the broader farming community. These findings suggest that a comprehensive preparation process—including prior evaluation of previous methods and in-depth training facilitates greater visibility of the innovation's advantages. Through hands-on experience and observable improvements in productivity and resource management, smart farming demonstrated measurable impacts, which in turn fostered wider community interest and acceptance.

The visibility of smart farming's success in Lapajung is consistent with Rogers' [37], theory of diffusion of innovation, which identifies observability as one of the five key characteristics that influence the rate and extent of adoption. When an innovation's benefits are readily apparent, especially in early implementations, it reduces uncertainty and increases the likelihood of further diffusion [38], [39]. Furthermore, the successful deployment of IoT-based smart farming technologies in Kelurahan Lapajung addresses many challenges faced by traditional agriculture, including climate unpredictability, input inefficiencies, and yield inconsistency. These visible outcomes provided persuasive evidence for both the feasibility and the relative advantage of adopting smart technologies, reinforcing the critical role observability plays in innovation adoption within agricultural communities.

These findings are consistent with previous research that underscores the importance of observability in promoting the adoption of smart farming. A study by Jabbari et al. [40] revealed that the visibility of real-time sensor data such as moisture levels, nutrient content, and crop health significantly enhanced farmers' confidence and interest in adopting the technology in Saudi Arabia. The more tangible and evident the benefits of the technology, the greater the tendency among farmers to integrate it into their agricultural practices [40]. Another study published in *Technology in Society* also demonstrated that result transparency, particularly in resource efficiency and production stability, served as a major driver in decision-making regarding the adoption of digital agricultural technologies [41].

Furthermore, a 2024 study published by MDPI on smart farming transformation confirmed that when farmers are able to directly observe the benefits such as reduced production costs, increased yields, and more efficient resource management—the likelihood of adopting IoT-based systems rises significantly [42]. Taken together, these studies reinforce the current findings that observability, as visible proof of innovation benefits, plays a critical role in accelerating the adoption of modern agricultural technologies within farming communities.

This study contributes a novel perspective to the discourse on smart farming adoption by highlighting the critical role of observability a factor often underexplored in localized agricultural contexts. The key innovation lies in demonstrating how the visibility of tangible outcomes such as increased crop yields, improved water and fertilizer efficiency, and enhanced environmental control serves as a catalyst for adoption within farming communities. Unlike many previous studies that emphasize economic or infrastructural determinants, this research provides empirical evidence that direct exposure and hands-on engagement with smart farming systems significantly enhance farmers' confidence and willingness to adopt. The findings underscore the importance of pre-adoption experiences, where real-world observation and trialability jointly validate the practical value of innovation.

The findings of this study carry significant implications for the development of educational technology in the agricultural sector. Specifically, they emphasize the need for experiential learning approaches that prioritize visibility and direct interaction with technological innovations. Smart farming adoption, as demonstrated in this study, is not solely driven by technical merit but is greatly influenced by farmers' ability to observe and experience its benefits firsthand. This suggests that agricultural education and extension services must shift towards pedagogical models that incorporate visual demonstration, on-site experimentation, and interactive training modules based on real-time data and successful case implementations.

Integrating IoT technologies into agricultural education frameworks such as smart greenhouses or sensor-based simulations can enhance digital literacy, reduce resistance to adoption, and build a technologically responsive farming community. Therefore, the study contributes not only to the theoretical advancement of innovation diffusion but also to practical strategies in agricultural education, positioning observability as a key instructional component in fostering innovation readiness and adoption. This study is limited by its localized scope, as it focuses solely on the adoption of smart farming technologies within a single administrative village, which may affect the generalizability of the findings to broader contexts.

4. CONCLUSION

Based on the results and discussion, it can be concluded that the adoption of smart farming innovation in Kelurahan Lapajung has been successful when analyzed through the lens of Everett Rogers' five diffusion of innovation indicators: relative advantage, compatibility, complexity, trialability, and observability. This innovation demonstrates a clear relative advantage by improving productivity, optimizing resource use, and delivering positive environmental impacts. It is also compatible with local agricultural values such as sustainability and efficiency, and it integrates well with existing farming practices. Although complexity poses challenges particularly in terms of technical skills and financial investment these barriers can be addressed through training, institutional support, and government policy. Trialability allows farmers to test the innovation in a low-risk setting, while the observability of results accelerates adoption by making the benefits visible and tangible to the broader community. Therefore, smart farming holds significant potential for widespread adoption as a modern and sustainable agricultural solution. Further studies should investigate the scalability and sustainability of smart farming practices in varied socio-economic and environmental contexts.

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