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THE MEDIATING ROLE OF DIGITAL LITERACY IN DIGITAL TECHNOLOGY ADOPTION AMONG SHALLOT FARMERS IN BANTUL REGENCY

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Abstract

Background: The adoption of digital technology is crucial for increasing efficiency and productivity in the agricultural sector. However, this development faces a digital paradox that must be addressed. However, adoption among farmers remains relatively slow and is associated with high resistance. This process of farmer adoption is influenced by the characteristics of innovation diffusion, particularly the ability to experiment and observe prior to full adoption.
Purpose: This study examined the effects of innovation diffusion characteristics on digital literacy and digital technology adoption. It also investigates the mediating role of digital literacy in the relationship between innovation diffusion and adoption decisions among shallot farmers in Bantul Regency.
Design/methodology/approach: A quantitative cross-sectional study was conducted with 100 shallot farmers in Bantul Regency. Respondents were selected using a multistage sampling method that combined purposive sampling for the study area and farmer groups with random sampling for the respondents. Data were analyzed using a structural equation model (SEM) in SmartPLS 4.
Findings/Results: Relative advantage, compatibility, trialability, and observability significantly influenced digital literacy, whereas complexity did not. Digital literacy drives adoption. Among the direct and mediated effects (through digital literacy) on adoption, only trialability and observability were significant, whereas relative advantage, compatibility, and complexity were not significant.
Conclusion: The digital technologies adopted by the shallot farmers in Bantul Regency depend on their ability to directly trial and observe the success of these innovations. Digital literacy drives adoption, but its effectiveness is influenced by the provision of concrete technology demonstration spaces for farmers.
Originality/value (State of the art): Previous research has generally analyzed innovation diffusion characteristics and digital literacy separately as predictors of adoption. However, this study positions digital literacy as a mediating variable that bridges farmer preferences and the final adoption decision, which remains limited.

Keywords: agricultural digitalization, diffusion of innovation, digital literacy, rural community, technology adoption

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INTRODUCTION

Agricultural digitalization has become a national priority in Indonesia to enhance food security and advance digital transformation in alignment with Indonesia Emas 2045. Yogyakarta, recognized as a cultural center, exceeded the national average in the 2025 Indonesian Digital Society Index (IDSI) with a score of 51.13 (BPSDM Komdigi Yogyakarta, 2026), reflecting a strong digital infrastructure and access, including Internet access, devices, and digital services. Despite this, a "digital paradox" has emerged: high levels of digital literacy among the general population do not translate into farmers' technical capabilities in the field and therefore do not consistently lead to improved agricultural outcomes in rural areas, as evidenced by the reality in the shallot farming center in Bantul Regency. Similarly, research in China reports a comparable gap between the national average digital literacy score (43.6) and the score for farmers (18.6) (Gong et al. 2024), underscoring that bridging the divide between societal digital progress and field-level agricultural transformation remains a challenge. Despite the high urgency of increasing production and market demand, both for household and industrial consumption, the availability of infrastructure and the introduction of various digitalization program initiatives, including automated irrigation systems integrated with Google Assistant, digital farming demonstration plots in collaboration with Bank Indonesia, and portable digital soil sensors from the Ministry of Communication and Digital Affairs, have not been linearly transformed into productive adoption at the farm level. Structural barriers, including limited digital skills and literacy, high implementation costs, and unaffordable training and extension services, hinder the effective use of these tools (Choruma et al. 2024; Gong et al. 2024; Gumbi et al. 2023).

Field data show that farmers use smartphone-based technology for secondary activities. In contrast, advanced technologies such as artificial intelligence, the Internet of Things, robotics, precision agriculture (including drones, sensors, and satellite/Global Positioning System), blockchain, and big data are seldom adopted. Most farmers in Bantul Regency own televisions, radios, mobile phones, smartphones, laptops, and VCDs/DVDs to access agricultural information (Christian & Subejo, 2018). They find communication technologies easy to use (Budiarti et al. 2024). The disparity between government program support and the prevalence of basic adoption highlights unresolved cognitive barriers. They typically prefer to trial and observe technologies before full adoption, and the relative advantages of digital technologies remain unclear because they have not been fully integrated into traditional farming practices. Consequently, digital adoption remains basic and has not resulted in significant productivity improvements.

In general, previous research on technology adoption in the agricultural sector has been fragmented theoretically. The innovation diffusion framework emphasizes how the characteristics of the innovation itself directly influence adoption (Adnan et al. 2022; Kaine & Wright, 2022; Rogers, 2003; Shang et al. 2021), while other studies position digital literacy as a determinant or independent variable that directly influences adoption (Gong et al. 2024; Liu et al. 2025; Topodriyo et al. 2026). These two approaches operate separately, creating a research gap in explaining why farmers with access to infrastructure and basic digital literacy still reject or fail to adopt advanced agricultural technology. Therefore, the novelty of this study lies in integrating these two research foci by positioning digital literacy not as a single independent variable but as a conditional mediator that mediates the relationship between innovation characteristics and actual farmer adoption decision-making.

The approach to resolving these theoretical gaps and the digital paradox phenomenon is to expand Rogers (2003) innovation-decision process theory model by positioning digital literacy as a mediating variable. The proposed theoretical justification is that the characteristics of innovation, consisting of relative advantage, compatibility, complexity, trialability, and observability, do not directly lead to adoption actions (implementation). In the era of digitalization, these characteristics of innovation must first be processed by users' cognitive capacity at the persuasion stage. Through a quantitative approach based on Structural Equation Modeling (SEM), digital literacy acts as a cognitive filter that facilitates farmers' understanding, evaluation, and translation of perceptions of technological attributes into real adoption decisions to address the gap between whether the failure to implement advanced technology is caused by the characteristics of the innovation itself or by the gap in farmers' digital capacity.

This study aims to analyze the direct influence of innovation characteristics on the decision to adopt digital technology among shallot farmers in Bantul Regency, examine how these innovation characteristics influence increases in farmers' digital literacy levels, and demonstrate the role of digital literacy as a mediator in the causal relationship between the two. By achieving these objectives, this study makes a theoretical contribution to the explanatory power of Rogers (2003) innovation-decision process model in the digital era by explaining how cognitive abilities serve as conceptual filters that translate perceptions of innovation into adoption actions. Practically, this study's contribution lies in providing policymakers in developing countries with a comprehensive explanation for addressing the adoption gap by shifting the focus of technology penetration from the initial-stage physical infrastructure procurement to strengthening farmers' cognitive capacity and digital readiness.

METHODS

The main research approach was quantitative analysis using cross-sectional data, and the study was conducted between April and May of 2025. This study was conducted in Bantul Regency, Yogyakarta. These areas are recognized as the largest regions for shallot cultivation, with the highest production rates in Yogyakarta. Observations indicate that shallot farmers are beginning to adopt agricultural machinery, drip irrigation, and digital marketing (Moekani et al. 2023), suggesting that the shallot sector is in the early stages of a digital transformation. The data primer included items measuring digital literacy (operational capabilities and capacities, content creation skills, security, and problem-solving), adoption of digital technologies (frequency and type of digital tools, scope of use in farming activities), and perceptions of innovation attributes, such as relative advantage, compatibility, complexity, trialability, and observability. Secondary data were obtained from the literature, organizations, and institutions that support this research.

A multistage sampling procedure was used. First, Imogiri and Sanden Districts were purposefully selected as the two main shallot-producing areas in Bantul. In the next stage, farmer groups were selected based on their involvement in or targeting by government or related agency digital technology programs. Respondents from this group were purposively selected based on the criterion of being shallot farmers who owned smartphones. Finally, simple random sampling was used to select respondents, ensuring equal representation of eligible farmers. Hair et al. (2014) recommend a minimum sample size of ten times the largest number of structural paths to a construct in the model. Ghozali and Latan (2015) observed that PLS-SEM can be used with smaller sample sizes, suggesting a range of 30–100 participants. Based on this, this study determined a minimum sample size of 50 participants across five predictor constructs and increased it to 100 participants (50 farmers from each region) to enhance reliability in the PLS-SEM analysis.

Primary data were collected through in-depth interviews and using a structured questionnaire. The main questionnaire consisted of 23 structured questions. The measurements were based on a five-point Likert scale ranging from strong disagreement (1) to strong agreement (5). The interview technique was conducted simultaneously with the questionnaire, using questions asked of the farmers. Additionally, providing a brief explanation of the statements in question helps avoid misinterpretation and maintain the validity of respondents' answers. In this study, the exogenous variables were relative advantage, compatibility, complexity, trialability, and observability. The endogenous variables were digital literacy and digital technology adoption. Digital literacy was the mediation variable. The operational definitions of the variables used in this study are presented in Table 1.

This study employed PLS-SEM for its effectiveness in theory development and prediction. Partial Least Squares structural equation modeling (PLS-SEM) was chosen to explore relationships among latent variables, as it is particularly suitable for predictive modeling, complex structural models, small sample sizes, and non-normally distributed data (Ghozali & Latan, 2015; Hair et al. 2014). PLS-SEM analysis consists of a multi-stage process, including model specification, evaluation of both the outer and inner models, and assessment of the strength of the relationships among variables. First, outer models, known as measurement models, are employed to evaluate the relationships between indicator variables and their associated constructs. These analyses should verify both the reliability and validity. The primary method for ensuring convergent validity involves selecting indicators with outer loadings ≥ 0.70 and average variance extracted (AVE) values for each construct > 0.50 and examining construct reliability using Cronbach's alpha and composite reliability, which must be > 0.70 (Hair et al. 2019). Additionally, the Heterotrait-Monotrait (HTMT) and Fornell-Larcker criteria were used to assess discriminant validity of the measurement model. Henseler et al. (2015), in their study, stated that Fornell and Larcker (1981) showed that the square root of the AVE for each construct must be greater than the correlations with other constructs in the model, while the HTMT value must remain below 0.9. This indicates that there was no overlap or multicollinearity in this study.

A structural model is guided by the following criteria: coefficient of determination (R2), cross-validated redundancy (Q2), path coefficients, and effect size (F2) (Hair et al. 2014). According to Hair et al. (2019), R^2 values of 0.75, 0.50, and 0.25 are considered substantial, moderate, and weak, respectively. Meanwhile, Q^2predict values > 0 are meaningful, whereas values ≤ 0 indicate that the model does not outperform the naïve benchmark. The f2 values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively (Ghozali & Latan, 2015). Additionally, multicollinearity was examined using the Variance Inflation Factor (VIF) to ensure that no collinearity issues existed among the predictors. Ideally, it should be lower than 3, but it is still considered acceptable in the range of 3–5 (Hair et al. 2019). Hypothesis testing was conducted using bootstrapping to assess the significance of the correlations identified in the model. Testing was conducted to assess the direct and indirect effects of the variables using the path coefficients. The criterion for this study was that if the calculated t-value was more than 1.65/1.96/2.58 or the p-value was less than 0.01/0.05/0.1 (α = 1/5/10%), then H0 was rejected, and there was a significant influence between the variables tested; otherwise, H0 failed to be rejected (Ghozali & Latan, 2015).

Table 1. Definition of operational variables: diffusion of innovation characteristic, digital literacy, and digital technology adoption

Variable	Indicator
Relative Advantage	RELADV1. Digital technologies can increase productivity
	RELADV2. Digital technologies enhance farming activities efficiently
	RELADV3. Digital technologies are reducing production costs
Compatibility	COMPAT1. Digital technologies are compatible with farmers' work styles
	COMPAT2. Digital technologies are compatible with farmers' financial resources
Complexity	COMPLX1. Digital technologies are difficult to use
	COMPLX2. Digital technologies are complicated to understand
	COMPLX3. Digital technologies require technical skills
Trialability	TRIAL1. Digital technologies can be tested before full adoption
	TRIAL2. Trial experiences help clarify the benefits of the technology
	TRIAL3. Trial experiences help clarify that technology has low risks
Observability	OBSERV1. Outcomes of using digital technologies are easily observable
	OBSERV2. Other farmers can easily observe the results of this technology
	OBSERV3. Digital technologies have visible changes in farm management
Digital Literacy	DIGLIT1. Ability to effectively use digital tools to browse, search, and filter data such as price or agricultural information
	DIGLIT2. Ability to use apps (such as WA/Fb) for online communication with others
	DIGLIT3. Use digital tools to create and post short videos or clips about agriculture
	DIGLIT4. Carefully sharing personal data or information when using digital apps
	DIGLIT5. Take the initiative to learn the use of digital devices to improve digital literacy ability
Digital Technology Adoption	DTA1. Obtain price information
	DTA2. Share and communicate farm-related information
	DTA3. Access technical agricultural information
	DTA4. Manage and oversee farming practices

Source: (Addison et al. 2024; Bontsa et al. 2023; Choruma et al. 2024; Giua et al. 2022; Gong et al. 2024; Gumbi et al. 2023; Hoang & Tran, 2023; Kaine & Wright, 2022; Liu et al. 2025; Nguyen et al. 2024; Shang et al. 2021)

The hypotheses of this study are as follows:

1. H1: Relative advantage, compatibility, trialability, and observability have a positive effect on digital literacy, whereas complexity has a negative effect.

Farmers' cognitive capacity can be influenced by their perceptions of the characteristics of technology. This idea is based on the diffusion of innovation theory developed by Rogers (2003). According to this theory, the adoption of new technology is strongly influenced by potential adopters' perceptions of its innovative attributes. When digital technology can provide useful information in agricultural activities (Wang & Zhang, 2025), provide a safe space for farmers to try and explore without financial loss (Liu et al. 2025), is aligned and appropriate to the social culture and habits of farmers in the field, and allows them to directly see other farmers who are adept at finding interesting information on the Internet (Aranguri et al. 2025), it allows farmers to quickly feel familiar, understand, and arouse high curiosity, thus becoming a major stimulant in motivating them to learn independently until they are proficient. Conversely, if the technology is complicated and confusing, it can lead to laziness before they have a chance to learn the digital skills (Bontsa et al. 2023).

2. H2: Relative advantage, compatibility, trialability, and observability have a positive effect, while complexity has a negative effect on digital technology adoption.

Farmers' decisions to accept or reject innovations are based on an evaluation of the risks and benefits. Rogers' (2003) diffusion of innovation theory posits that technological characteristics serve as stimuli that trigger individual behavioral responses to innovation decisions. If innovation is useful for improving the quality and quantity of production (Abiri et al. 2023; Bontsa et al. 2023), is compatible with their current farming routine (Nguyen et al. 2024), allows farmers to try and experiment (Hoang & Tran, 2023), and produces observable results (Giua et al. 2022), it will encourage adoption. In contrast, complexity is a barrier to the adoption process (Kaine & Wright, 2022). Complex technologies require significant time and effort; therefore, farmers often reject or halt their adoption.

3. H3: Digital literacy positively affects digital technology adoption.

The ability to adopt innovations depends not only on physical access but also on the user's cognitive capacity. Digital literacy is a crucial foundation for adopting digital technologies. These skills enable users to increase their understanding, accept new tools, reduce uncertainty, and improve their risk perception, making them more willing to experiment with new technologies. The relationship between digital skills and adoption can be observed, specifically including basic operational skills, communication, content creation, security, and problem-solving (Gong et al. 2024; Liu et al. 2025). Furthermore, digital literacy has significantly encouraged the adoption of green production technologies (Wang & Zhang, 2025) and digital marketing strategies (Topodriyo et al. 2026).

4. H4: Relative advantage, compatibility, trialability, and observability are positively correlated, while complexity has a negative effect on digital technology adoption, with digital literacy as a mediating variable.

In the context of digital technology adoption, the relationship between technology characteristics and the decision to adopt them is often complex. This requires a cognitive adaptation process that is facilitated by digital literacy. According to Giua et al. (2022), external stimuli from an innovation must be transformed into cognitive understanding and personal intention before a final decision is made to adopt a new technology or practice. Once farmers understand a technology's function and potential benefits, they are motivated to learn more about it. By integrating technology into their habits, farmers become more familiar with technology. The freedom and sense of safety that come with exploring free applications can empower farmers to develop their skills independently. Additionally, seeing their peers succeed motivates farmers to enhance their skills more quickly. This growth in cognitive abilities reduces the fear of failure, fosters a positive attitude toward learning, and promotes the adoption of new techniques (Aranguri et al. 2025; Geng et al. 2024; Liu et al. 2025; Xu et al. 2026). However, this initial complexity discourages farmers from engaging in the learning process, which can hinder their development of digital literacy and fail to drive the adoption of the technology.

Figure 1 illustrates that this research framework presents a digital paradox: high scores on the Indonesian Digital Society Index (IDSI) are not aligned with technology utilization in agriculture. This may occur due to farmers' low cognitive abilities and limited digital skills, which can trigger resistance to innovation. Therefore, the diffusion of innovation theory was used to analyze how farmers perceive technological characteristics to reduce their cognitive burden. These characteristics stimulate greater digital literacy among farmers. With digital literacy, farmers can maximize the potential of technology to enable the successful and sustainable adoption of digital agricultural technology.

RESULTS

Farmers Characteristics

Most respondents were male (80%), and the age demographic leaned towards the productive age group, with 48% from Generation X, 34% from Generation Y, and 18% from Generation Baby Boomer. Educationally, many participants had only reached secondary education or lower: 25% completed elementary school, 43% junior high, 28% senior high, and the remainder completed university. With over 20 years of experience, most farmers are cautious about disruptive innovations; however, this extensive experience enhances their cultivation techniques and risk management skills.

Types of Digital Technologies Used by Farmers

Digital transformation in the agricultural sector enables farmers to adopt various types of digital technologies to support the sustainability of farming businesses. In addition to smartphones, 8% of farmers used laptops, whereas only 2% used computers. Smartphones have many functions beyond communication, such as facilitating social interactions and information sharing among farmers. In contrast, laptops and computers are often unaffordable for many farmers and are rarely needed for agricultural purposes, but are used for educational or work-related purposes. The usage rate for applications, particularly social media platforms such as WhatsApp, Facebook, Instagram, YouTube, and TikTok, was very high at 76%. Digital services, including search engines such as Google, Yahoo, and Wikipedia, were used by 35% of farmers. However, the adoption of specialized services such as weather forecasting (8%) and e-commerce (5%) remains low, likely due to a lack of understanding of how these technologies work. This suggests that smartphone-based technology adoption among shallot farmers is still in the early cognitive-informative phase. Advanced technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) show even lower usage rates, at 3% and 1%, respectively. Barriers to adopting this advanced technology are often cognitive and financial, leading farmers to prefer safer and easier alternatives.

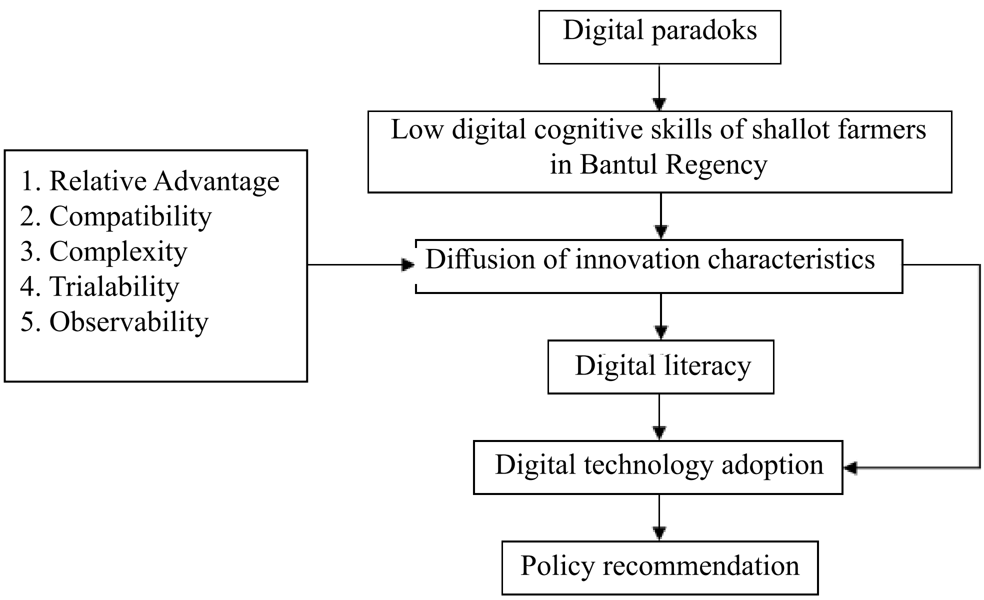

Figure 1. Research framework

SEM-PLS Analysis

1. Measurement Model

Table 2 presents the results of the measurement model evaluation, including the convergent validity and reliability of the research instrument. Based on the data obtained, all indicators and latent variables met the threshold criteria required for the outer model analysis. Convergent validity was assessed based on outer loading and Average Variance Extracted (AVE). The results show that all questionnaire items have loadings ranging from 0.705 to 0.899, which exceed the recommended threshold of 0.70 and can therefore be considered valid. The AVE values for all constructs, starting from relative advantage (0.627), compatibility (0.789), complexity (0.677), trialability (0.688), observability (0.650), digital literacy (0.621), and digital technology adoption (0.734), exceeded the critical limit of 0.50. This confirms that, on average, the research constructs explain more than half of the variance in the indicators, thus meeting the convergent validity criterion. Next, the instrument's reliability was evaluated using Cronbach's alpha (CA) and Composite Reliability (CR) to assess internal consistency. As shown in the table, all constructs had CA and CR values greater than 0.70. The digital technology adoption variable demonstrated the highest reliability, with a CA of 0.879, and a CR of 0.917. Meanwhile, the relative advantage variable demonstrated the lowest reliability, with a CA value of 0.707, and a CR of 0.834. The visualization of the PLS algorithm results is shown in Figure 2, which includes the values of the outer loadings, path coefficients, and determination coefficients.

Table 2. Outer loadings, reliability, and validity of the characteristics of innovation diffusion, digital literacy, and digital technology adoption

Constructs	Indicator	CA	CR	AVE	Loadings	Conclusion
Relative advantage	RELADV1	0.707	0.834	0.627	0.849	Valid
	RELADV2				0.746	Valid
	RELADV3				0.777	Valid
Compatibility	COMPAT1	0.733	0.882	0.789	0.899	Valid
	COMPAT2				0.877	Valid
Complexity	COMPLX1	0.762	0.862	0.677	0.755	Valid
	COMPLX2				0.857	Valid
	COMPLX3				0.853	Valid
Trialability	TRIAL1	0.773	0.869	0.688	0.842	Valid
	TRIAL2				0.836	Valid
	TRIAL3				0.811	Valid
Observability	OBSERV1	0.730	0.848	0.650	0.793	Valid
	OBSERV2				0.835	Valid
	OBSERV3				0.789	Valid
Digital literacy	DIGLIT1	0.846	0.891	0.621	0.705	Valid
	DIGLIT2				0.805	Valid
	DIGLIT3				0.842	Valid
	DIGLIT4				0.860	Valid
	DIGLIT5				0.716	Valid
Digital technology adoption	DTA1	0.879	0.917	0.734	0.850	Valid
	DTA2				0.896	Valid
	DTA3				0.863	Valid
	DTA4				0.815	Valid

Note: CA = cronbach's Alpha; CR = composite reliability; AVE = average variance extracted

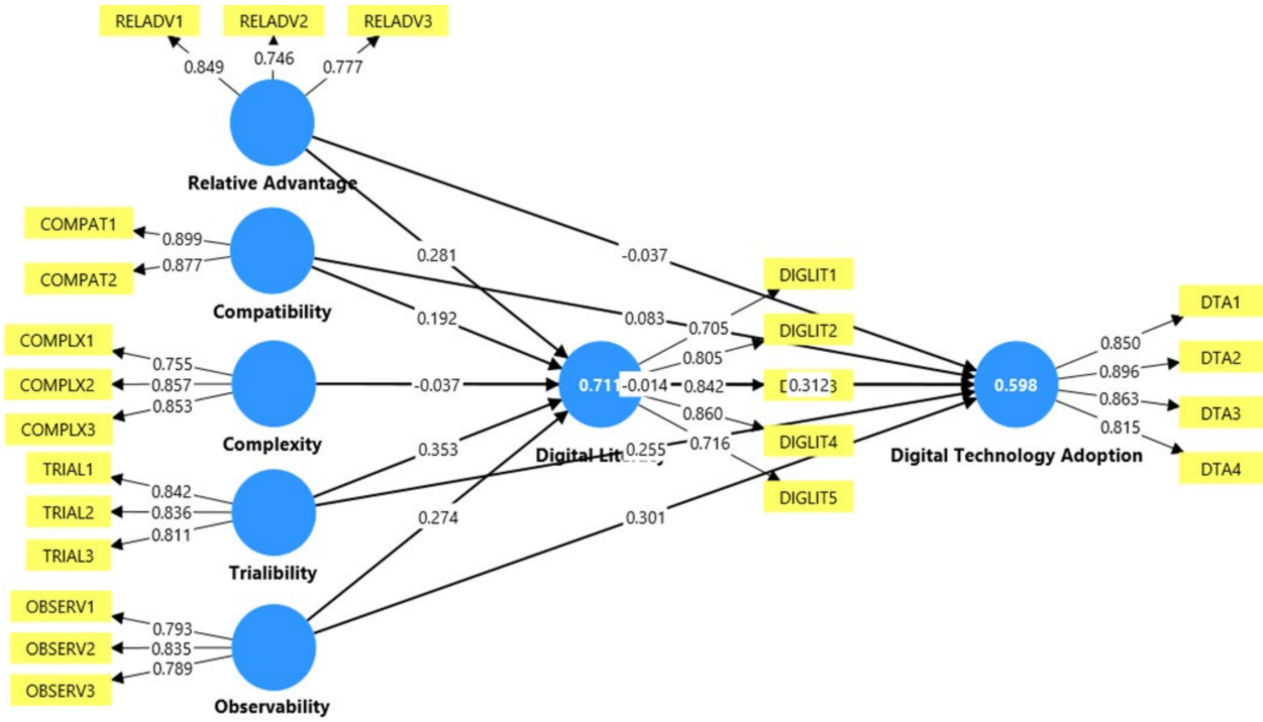

Figure 2. PLS Algorithm Analysis Result

In addition, discriminant validity was assessed using the Heterotrait-Monotrait (HTMT) and Fornell-Larcker criteria. Table 3 shows that the Fornell-Larcker criteria are met because the square root of the AVE value in the diagonal position is greater than the correlation value between the latent variables in the same column and row. Meanwhile, based on the analysis, the HTMT values for all the variable pairs ranged from 0.113 to 0.866. The lowest value was observed in the relationship between complexity and compatibility (0.113), and the highest was in the relationship between trialability and digital literacy (0.866). Each construct in this study demonstrated adequate empirical differentiation, with an HTMT value below 0.9.

2. Structural Model

Before evaluating the structural relationships in PLS-SEM, it is important to assess multicollinearity among the predictor constructs using the inner VIF, a commonly used diagnostic metric. In this study, the VIF values varied from 1.153 to 3.462, indicating the absence of multicollinearity. These results confirm that multicollinearity does not threaten the interpretation and validity of the structural model estimates (Hair et al. 2019). After ensuring the absence of multicollinearity in the model, the structural model was evaluated using R-squared, Q^2 predict, and F-squared. The R^2 indicator assesses how well the independent variables explain the dependent variable, Q^2 predict measures the model's predictive ability, and F^2 measures the influence of each exogenous variable on the endogenous variable. The R^2 value was 0.711 (moderate) for digital literacy. This value indicates that 71.1% of the variability in the digital literacy construct is explained by variation in innovation characteristic variables, while the remainder is explained by factors outside the research model. The R^2 value for the digital technology adoption variable was 0.598, indicating that innovation characteristics and digital literacy together explained 59.8% of the variance in farmers' decisions to adopt digital technology, with the remainder attributable to other variables outside the scope of this study. Meanwhile, the Q^2 values for the digital literacy and digital technology adoption variables were 0.665 and 0.501, respectively. Both values were above zero, confirming that the proposed structural model had strong predictive validity for all tested endogenous constructs (Hair et al. 2019). In addition, the F2 values indicate that trialability (0.293), relative advantage (0.184), and observability (0.174) make moderate contributions to the prediction of digital literacy, whereas the other constructs have weak effects. Meanwhile, all identified predictors made only weak contributions to the digital technology adoption variable, with observability being the largest at 0.129.

Table 3. Heterotrait-Monotrait Ratio (HTMT) and fornell-larcker criterion of the characteristics of innovation diffusion, digital literacy, and digital technology adoption

Variables	Compat	Complx	Diglit	DTA	Observ	Reladv	Trial
HTMT							
Compatibility							
Complexity	0.113						
Digital Literacy	0.623	0.269					
Digital Technology Adoption	0.514	0.243	0.802				
Observability	0.496	0.134	0.816	0.806			
Relative Advantage	0.437	0.131	0.816	0.563	0.595		
Trialability	0.409	0.450	0.866	0.774	0.668	0.681	
Fornell-Larcker criterion							
Compatibility	0.888						
Complexity	-0.049	0.823					
Digital Literacy	0.495	-0.216	0.788				
Digital Technology Adoption	0.414	-0.200	0.707	0.857			
Observability	0.364	-0.102	0.646	0.647	0.806		
Relative Advantage	0.328	-0.077	0.647	0.454	0.433	0.792	
Trialability	0.310	-0.340	0.707	0.638	0.503	0.515	0.830

Note: Reladv = relative advantage; Compat = compatibility; Complx = complexity; Trial = trialability; Observ = observability; Diglit = digital literature; DTA = digital technology adoption

Hypothesis Testing

This study tested four hypotheses by estimating the path coefficients and testing their significance using bootstrapping with 5,000 subsamples (Hair et al. 2019). Hypothesis testing in this study was conducted at a 10% (0.1) significance level, with a t-statistic threshold of > 1.65. This value was chosen because the research object is farmer behavior in the field, which is highly dynamic and vulnerable to uncontrollable external factors. Table 4 presents the results of the analysis, which show that relative advantage ($\beta = 0.281$, $p < 0.1$), compatibility ($\beta = 0.192$, $p < 0.1$), trialability ($\beta = 0.353$, $p < 0.1$), and observability ($\beta = 0.274$, $p < 0.1$) all have statistically significant positive effects on digital literacy. In contrast, complexity was not significant ($\beta = -0.037$, $p > 0.1$). Based on Hypothesis 2, trialability ($\beta = 0.255$, $p < 0.1$) and observability ($\beta = 0.301$, $p < 0.1$) have statistically positive effects on the adoption of digital technology. Meanwhile, relative advantage ($\beta = -0.037$, $p > 0.1$), compatibility ($\beta = 0.083$, $p > 0.1$), and complexity ($\beta = -0.014$, $p > 0.1$) were not significant. Digital literacy significantly impacted the adoption of digital technology ($\beta = 0.312$, $p < 0.1$), thereby validating H3. Finally, trialability ($\beta = 0.110$, $p < 0.1$) and observability ($\beta = 0.085$, $p < 0.1$) significantly affected adoption, with digital literacy serving as a mediator. Meanwhile, relative advantage ($\beta = 0.088$, $p > 0.1$), compatibility ($\beta = 0.060$, $p > 0.1$), and complexity ($\beta = -0.011$, $p > 0.1$) were not significant. A visualization of the path diagram for the significance test is presented in Figure 3.

Influence of Relative Advantage, Compatibility, Complexity, Trialability, And Observability on Digital Literacy

Table 4 presents the analysis results, which indicate that relative advantage, compatibility, trialability, and observability have statistically significant and positive effects on digital literacy. In contrast, complexity was not significant. This phenomenon indicates that technological attributes serve as cognitive stimulants that trigger farmers' curiosity. The characteristics of the technology they use daily are used to solve practical problems, such as accessing agricultural information and cultivation techniques. This habit motivates them to learn independently. Furthermore, the openness of smartphones for exploration without financial risk when errors occur gives farmers more freedom to practice their operational and problem-solving skills. This willingness to explore serves as internal capital, enabling farmers to adopt sustainable digital agriculture. This aligns with the findings of Wang and Zhang (2025) and Xu et al. (2026), who found that in the context of implementing green agricultural practices, unhindered access to agricultural information enhances farmers' ability to learn independently, including their understanding of the benefits and practical efficacy of digital technology. Furthermore, the shallot farming community in Bantul is actively involved in strengthening it. This is aligned with Aranguri et al. (2025), who found that the community environment and networks among farmers contribute to the development of digital skills by observing each other's successful adoption practices, particularly through community leaders and pioneer farmers. This motivation encourages farmers to interact more closely with digital tools.

Meanwhile, the complexity of digital tools does not affect digital literacy. This finding contradicts Bontsa et al. (2023), who stated that complex and confusing technology is a barrier to learning digital skills. This difference in results occurs because the digital tools used by shallot farmers are easy to use and within their basic operational and informational capabilities. Furthermore, the high profitability of shallots stimulates farmers' problem-solving skills and encourages them to independently seek information to sustain their production.

Influence of Relative Advantage, Compatibility, Complexity, Trialability, And Observability on Adoption of Digital Technology

Based on the analysis, only trialability and observability had statistically significant positive effects on the adoption of digital technology. However, relative advantage, compatibility, and complexity were not significant. This lack of significance may be attributed to the fact that technology adoption among farmers is currently in the informative cognitive absorption phase, with smartphones being used to access price information, share agricultural information, engage in digital discussions, access agricultural technical information, and manage cultivation practices with low financial risk and low operational costs. Furthermore, farmers are motivated to adopt this technology when they see fellow farmers achieving higher prices or obtaining effective solutions to pest and disease challenges. Budiarti et al. (2024) showed that farmers are more likely to accept innovations if they can trial them on a small scale on their own land and adapt them to the available resources. Giua et al. (2022) asserted that farmers adopt innovations after observing successful outcomes from their peers, community demonstrations, or digital platforms that highlight these success stories.

Table 4. Direct and indirect effect analysis of the characteristics of innovation diffusion on both digital literacy and digital technology adoption

Type of variable		Mediation	Type of influence		Decision
Predictor	Response		Direct	Indirect	
RELADV	DIGLIT		0.000***		Supported
COMPAT	DIGLIT		0.009***		Supported
COMPLX	DIGLIT		0.502 ns		Unsupported
TRIAL	DIGLIT		0.000***		Supported
OBSERV	DIGLIT		0.000***		Supported
DIGLIT	DTA		0.045**		Supported
RELADV	DTA	DIGLIT	0.741 ns	0.117 ns	Unsupported
COMPAT	DTA	DIGLIT	0.266 ns	0.109 ns	Unsupported
COMPLX	DTA	DIGLIT	0.857 ns	0.580 ns	Unsupported
TRIAL	DTA	DIGLIT	0.018**	0.066*	Supported
OBSERV	DTA	DIGLIT	0.001***	0.090*	Supported

Note: Reladv = relative advantage; Compat = compatibility; Complx = complexity; Trial = trialability; Observ = observability; Diglit = digital literature; DTA = digital technology adoption; ***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.1$; ns: not significant

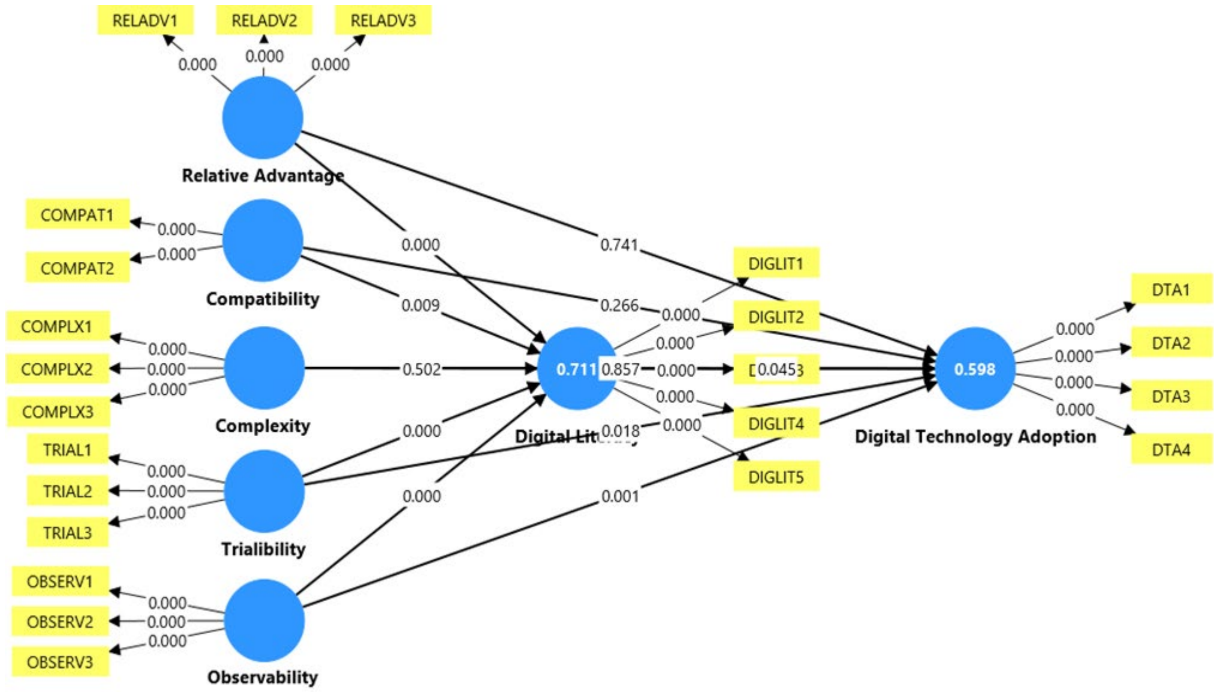

Figure 3. Bootstrapping analysis result

In contrast, relative advantage and compatibility were not significantly influential. This finding contradicts the classical theory of Rogers (2003) and Abiri et al. (2023), which states that relative advantage and compatibility are determining factors in innovation adoption. This is because the benefits, such as increased productivity and reduced production costs, remain unclear and inadequate. This discrepancy may stem from differences in the technological infrastructure of the studies, which does not facilitate the direct implementation of advanced technologies in the field. Farmers used social media, search engines, and various digital applications on smartphones to gather agricultural information. This is in line with Nguyen et al. (2024), who noted that technology integrated with farmers' daily routines is more likely to be adopted; otherwise, adoption tends to be low. Furthermore, complexity has not been shown to hinder farmers' access to information, contradicting Kaine and Wright's (2022) research, which identified complexity as a barrier to adoption. In this case, farmers believe that they can effectively navigate technological complexity; therefore, technical aspects are no longer a barrier to adoption.

Influence of Digital Literacy on Digital Technology Adoption

According to Table 4, digital literacy has a positive and significant effect on digital technology adoption. Within Rogers (2003) innovation decision process framework, adoption cannot occur instantly but must begin with stages of knowledge and persuasion. Operational and communication skills are indicators of digital literacy, making them key drivers in the initial stages. Farmers with digital skills can access price data, learn agricultural cultivation techniques, and engage in digital discussions. Furthermore, competence in crop documentation and basic problem-solving enables farmers to use smartphones consistently and sustainably to address daily farming challenges. This mental capacity and skill readiness enable farmers to process technological information and ultimately decide to adopt it in their farming practices. This finding is reinforced by Topodriyo et al. (2026), who emphasized that digital literacy significantly influences the effectiveness of farmers' production decisions by enabling faster access to accurate information, such as prices and consumer preferences, thus supporting data-driven production planning.

Influence of Relative Advantage, Compatibility, Complexity, Trialability, And Observability on Digital Technology Adoption with Digital Literacy as a Mediation Variable

The findings in Table 4 indicate that trialability and observability significantly influence adoption, with digital literacy acting as a mediator. Meanwhile, relative advantage, compatibility, and complexity were insignificant. The success of partial mediation can only be determined through observation and trials. This confirms that, through trials and field evidence, the effects will be much stronger and more sustainable if cognitive interventions are implemented first, followed by stimulating increased digital literacy. Curiosity drives the adoption of informative communications. This increase in digital skills is what they consider when strengthening their independent adoption decisions. These findings are supported by the literature studies of Aranguri et al. (2025), Xu et al. (2026), and Gong et al. (2024), which conclude that independent observation and experimentation based on fellow farmers' successful practices can transfer digital knowledge, effectively improve farmers' skills and confidence, and thus foster their willingness to adopt technology.

Conversely, digital literacy failed to mediate the influence of relative advantage, compatibility, and complexity on digital technology adoption, indicating cognitive disconnection. Although farmers cognitively understand the cultural appropriateness of digitalization through their daily smartphone use, they fail to translate this into concrete actions on the farm, remaining at the level of information communication. The reality of this disconnected mediation pathway is evident in the discontinuation of Bank Indonesia's Smart Farming program and the Ministry of Communication and Digital's Portable Soil Sensor program in shallot farming areas in Bantul Regency, Yogyakarta. Both programs faced obstacles in developing advanced operational skills, ultimately fueling apathy and a perception that the technology was irrelevant to their daily field activities. Most farmers are comfortable with conventional methods, which are considered more solution-oriented and immediate, such as sprinkler irrigation, which has proven successful in overcoming cultivation challenges in shallot irrigation. Therefore, farmers consider learning new and complex digital technologies less urgent; thus, they ignore the cognitive mediation path when implementing land management and remain in their comfort zone, which they consider much safer and more familiar. This is in line with Budiarti et al. (2024) and Liu et al. (2025), who stated that farmers are willing to allocate their cognitive abilities to learn and adopt innovations if the technology is clearly beneficial, low-risk, easy to use, and if they feel confident using it.

Managerial Implication

These findings emphasize the importance of providing digital demonstration plots and pilot units that enable farmers to independently experiment with technology. Furthermore, digital technology adoption can begin by directly integrating it into automated drip irrigation systems that farmers already trust, thereby avoiding resistance stemming from digital skill gaps. The demonstrated success of these digital technologies will motivate their adoption through validated literacy processes and supportive incentives. Strategies to improve digital literacy should include intensive, targeted training modules on topics such as basic digital skills, agricultural apps, digital tools for weather and market information, and online data security. Training can be delivered through onsite workshops, field demonstrations, farmer-to-farmer mentoring, and interactive video tutorials in the local language. Such targeted training and concrete incentive programs will better equip farmers to integrate digital technologies into their farming practices. Furthermore, this study extends Rogers (2003) innovation-decision process framework by demonstrating that digital literacy serves as a conditional mediator, filtering technological attributes based on the user’s cognitive capacity. Theoretically, this finding confirms that the adoption of digital technology at the basic level is determined not only by the innovation’s objective superiority but also by the need to meet a minimum digital literacy threshold that facilitates the transition from the knowledge stage to implementation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Innovation diffusion characteristics were shown to influence farmers’ cognitive capacities: relative advantage, compatibility, trialability, and observability were linearly associated with higher digital literacy, whereas complexity was not a barrier, as farmers’ cognitive capacities were shaped by smartphone functionality. Furthermore, technology adoption was driven more by visual evidence of success and physical demonstrations prior to implementation than by the promise of economic benefits. Although model testing showed that increased digital literacy directly influenced adoption, it served only as a partial mediator in the trialability and observability pathways and failed to mediate the effects of other variables. These findings significantly support the classic theory regarding the importance of physical innovation attributes in driving adoption decisions but also contrast with the common assumption in the digitalization literature that digital literacy is a universal mediator. Overall, the adoption of digital technology by farmers in this study remains limited to secondary smartphone-based needs and has not been effectively integrated into the operation of sophisticated farm digitalization devices due to limited advanced digital skills of the farmers.

Recommendations

This study has limitations because it focuses on smartphone-owning farmers and members of farmer groups targeted by digitalization programs. Furthermore, the findings are highly specific to the shallot farmers in Bantul Regency. Future research is recommended to expand the scope to a more heterogeneous farmer population, explore more complex digital technologies beyond mobile device use, and allow for the addition of other variables as mediators.

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REFERENCES

Abiri, R., Rizan, N., Balasundram, S. K., Shahbazi, A. B., & Abdul-Hamid, H. (2023). Application of Digital Technologies for Ensuring Agricultural Productivity. *Heliyon*, *9*(12), 1–21. https://doi.org/10.1016/j.heliyon.2023.e22601

Addison, M., Bonuedi, I., Arhin, A. A., Wadei, B., Owusu-Addo, E., Fredua Antoh, E., & Mensah-Odum, N. (2024). Exploring the Impact of Agricultural Digitalization on Smallholder Farmers' Livelihoods in Ghana. *Heliyon*, *10*(6), 1–19. https://doi.org/10.1016/j.heliyon.2024.e27541

Adnan, S. S., Zaman, N. B. K., & Othman, N. M. I. (2022). Factors Influencing the Adoption of Information and Communication Technology (ICT) among Oil Palm Settlers in Felda Wilayah Alor Setar, Kedah: A Survey. *IOP Conference Series: Earth and Environmental Science*, *1059*(1), 012012. https://doi.org/10.1088/1755-1315/1059/1/012012

Aranguri, M., Mera, H., Noblecilla, W., & Lucini, C. (2025). Digital Literacy and Technology Adoption in Agriculture: A Systematic Review of Factors and Strategies. *AgriEngineering*, *7*(296). https://doi.org/10.3390/AGRIENGINEERING7090296

Bontsa, N. V., Mushunje, A., & Ngarava, S. (2023). Factors Influencing the Perceptions of Smallholder Farmers towards Adoption of Digital Technologies in Eastern Cape Province, South Africa. *Agriculture*, *13*(8), 1471. https://doi.org/10.3390/AGRICULTURE13081471

BPSDM Komdigi Yogyakarta. (2026, February 11). *Jateng, DIY, dan Bali Lampaui Rata-Rata Nasional - IMDI 2025 Tunjukkan Kekuatan Digital di Pusat Kebudayaan Indonesia*. Badan Pengembangan Sumber Daya Manusia Komunikasi Dan Digital. https://bpsdm.komdigi.go.id/upt/yogyakarta/berita-jateng-diy-dan-bali-lampaui-rata-rata-nasional-imdi-2025-tunjukkan-kekuatan-5-92

Budiarti, S. W., Cahyaningrum, H., Haryuni, H., Widowati, R., & Anshori, A. (2024). Farmers' Perceptions and Level of Adoption of Technological Innovation in Shallot Cultivation. *E3S Web of Conferences*, *595*, 01007. https://doi.org/10.1051/E3SCONF/202459501007

Choruma, D. J., Dirwai, T. L., Mutenje, M. J., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., & Mabhaudhi, T. (2024). Digitalisation in Agriculture: a Scoping Review of Technologies in Practice, Challenges, and Opportunities for Smallholder Farmers in Sub-Saharan Africa. *Journal of Agriculture and Food Research*, *18*, 101286. https://doi.org/10.1016/j.jafr.2024.101286

Christian, A. I., & Subejo, S. (2018). Access, Functions, and Use Pattern of Information and Communication Technology (ICT) in Commercial Area in Bantul Regency. *Journal of Agriculture Socio-Economics*, *11*(2), 25–30. https://doi.org/https://doi.org/10.19184/jsep.v11i2.9233

Geng, W., Liu, L., Zhao, J., Kang, X., & Wang, W. (2024). Digital Technologies Adoption and Economic Benefits in Agriculture: a Mixed-Methods Approach. *Sustainability*, *16*, 4431. https://doi.org/10.3390/SU16114431

Ghozali, I., & Latan, H. (2015). *Partial least squares: concepts, techniques and applications using SmartPLS 3.0*. Diponegoro University Press.

Giua, C., Valentina Cristiana Materia, & Luca Camanzi. (2022). Smart Farming Technologies Adoption: Which Factors Play a Role in the Digital Transition. *Technology in Society*, *68*, 101869. https://doi.org/10.1016/j.techsoc.2022.101869

Gong, S., Sun, Z., Wang, B., & Yu, Z. (2024). Could Digital Literacy Contribute to the Improvement of Green Production Efficiency in Agriculture? *Sage Open*, 1–18. https://doi.org/10.1177/21582440241232789

Gumbi, N., Gumbi, L., & Twinomurinzi, H. (2023). Towards Sustainable Digital Agriculture for Smallholder Farmers: a Systematic Literature Review. *Sustainability*, *15*, 12530. https://doi.org/10.3390/SU151612530/S1

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to Use and How to Report the Results of PLS-SEM. *European Business Review*, *31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Hair, Joe F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial Least Squares Structural Equation Modeling (PLS-SEM): an Emerging Tool in Business Research. *European Business Review*, *26*(2), 106–121. https://doi.org/10.1108/EBR-10-2013-0128

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135. https://doi.org/10.1007/S11747-014-0403-8

Hoang, H. G., & Tran, H. D. (2023). Smallholder Farmers' Perception and Adoption of Digital Agricultural Technologies: an Empirical Evidence from Vietnam. *Outlook on Agriculture*, *52*(4), 457–468. https://doi.org/https://doi.org/10.1177/00307270231197825

Kaine, G., & Wright, V. (2022). Relative Advantage and Complexity: Predicting the Rate of Adoption of Agricultural Innovations. *Frontiers in Agronomy*, *4*, 967605. https://doi.org/10.3389/FAGRO.2022.967605/BIBTEX

Liu, H., Chen, Z., Wen, S., Zhang, J., & Xia, X. (2025). Impact of Digital Literacy on Farmers' Adoption Behaviors of Green Production Technologies. *Agriculture*, *15*, 303. https://doi.org/https://doi.org/10.3390/agriculture15030303

Moekani, D. M., Darwanto, D. H., Waluyati, L. R., Wardi, & Shantosi, A. (2023). Technical Efficiency of Millennial Farmers Shallot Farming in Bantul District. *Jurnal Agro Ekonomi*, *41*(2), 115–127.

Nguyen, L. L. H., Khuu, D. T., Halibas, A., & Nguyen, T. Q. (2024). Factors That Influence the Intention of Smallholder Rice Farmers to Adopt Cleaner Production Practices: an Empirical Study of Precision Agriculture Adoption. *Evaluation Review*, *48*(4), 692–735. https://doi.org/https://doi.org/10.1177/0193841X231200775

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Shang, L., Heckelei, T., Gerullis, M. K., Börner, J., & Rasch, S. (2021). Adoption and Diffusion of Digital Farming Technologies - Integrating Farm-Level Evidence and System Interaction. *Agricultural Systems*, *190*, 103074. https://doi.org/10.1016/J.AGSY.2021.103074

Topodriyo, P., Basuki, A. T., & Ma'ruf, A. (2026). The Impact of Digital Literacy and E-Commerce Utilization on Horticultural Farmers' Production Decisions in Kulon Progo Regency. *Jurnal Manajemen Motivasi*, *22*(1), 2123–2133. https://doi.org/10.29406/JMM.V22I1.8810

Wang, W., & Zhang, M. (2025). How Does Farmers' Digital Literacy Affect Green Grain Production? *Agriculture*, *15*, 1488. https://doi.org/10.3390/AGRICULTURE15141488

Xu, A., Radzi, N. A. M., Liu, Y., & Sieng, L. W. (2026). The Role of Digital Literacy in Agricultural Technology Adoption and Efficiency: a Systematic Literature Review. *Sustainability*, *18*, 1138. https://doi.org/10.3390/SU18021138/S1