

Digital Literacy and Agricultural Transformation in South Aceh

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Abstract

Agricultural digitalization has become an important strategy for improving efficiency and farmers' welfare; however, its implementation in rural areas remains constrained, particularly by limitations in human resource capacity. This study aims to analyze the factors associated with digital literacy among rice farmers, focusing on its relationship with digital economic participation, expectations toward agricultural digitalization, and farmers' socio-economic characteristics. The study was conducted in Kluet Utara and Kluet Selatan Sub-districts, Aceh Selatan Regency, with rice-farming households as the unit of analysis. Primary data were collected through a survey using a structured questionnaire and analyzed quantitatively. Descriptive analysis was employed to depict the socio-economic conditions and levels of farmers' digital literacy, while the relationships among variables were examined using Spearman's rank correlation due to the ordinal scale and non-normal data distribution. The results indicate that farmers' digital literacy remains at a low to moderate level, accompanied by very limited digital economic participation, particularly in online marketing of agricultural products. In contrast, farmers exhibit relatively high expectations regarding the benefits of agricultural digitalization. The correlation analysis reveals that digital literacy is positively and significantly associated with digital economic participation and farmers' expectations, while socio-economic characteristics show varying relationships. These findings indicate a gap between farmers' attitudes and actual digital practices. Therefore, strengthening digital literacy through practical training and supportive digital market ecosystems is crucial to fostering inclusive and sustainable agricultural digital transformation.

Keywords: digital literacy, rice farmers, digital economy, Spearman correlation.



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1. INTRODUCTION

Agricultural digitalization is one of the key strategies for improving production efficiency, expanding market access, and enhancing farmers' welfare amid the rapid development of information technology (Kitole et al., 2024; Fharaz et al., 2022). Digital technologies enable farmers to obtain production and price information more quickly, improve the quality of farm decision-making, and build broader marketing networks. Nevertheless, agricultural digitalization in many rural areas continues

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to face structural challenges, particularly those related to human resource readiness, levels of digital literacy, and the limited availability of supporting ecosystems at the local level.

Several studies indicate that the adoption of digital technologies in agriculture is strongly influenced by farmers' socio-economic characteristics, including age, educational attainment, farming experience, and business scale. Younger and better-educated farmers, as well as those operating larger farms, tend to be more receptive to innovation and the use of digital technologies (Chowdhury & Hoque, 2026; Huyen et al., 2025; Lindow et al., 2026). Empirical evidence also shows, however, that farmers mainly use digital technologies to access information, while their involvement in transactional digital economic activities, such as online marketing, remains relatively limited (Fahmi & Sari, 2020; Kartiasih et al., 2023). This condition suggests that agricultural digitalization often remains at the informational stage and has not yet developed optimally into productive participation in the digital economy.

Research on agricultural digitalization shows a shift in focus from the mere adoption of production technologies toward a broader understanding of digital literacy, technology-use behavior, and the effects of technology on farmers' welfare (Asiedu & Shortland, 2025; Dibbern et al., 2024; Lindow et al., 2026). Digital literacy—which encompasses conceptual understanding, self-confidence, training experience, and the ability to use digital information—strongly shapes farmers' perceptions of and expectations toward technology (Adesiji et al., 2024; Fharaz et al., 2022). However, research remains limited on the relationships of digital literacy and use with digital economic participation and farmers' expectations, particularly among rural farmers in developing countries.

In Indonesia, empirical studies that integrate digital literacy, digital economic participation, and farmers' expectations remain relatively limited, particularly at the micro level and within local contexts. Most studies tend to emphasize the adoption of production technologies or the use of particular applications without comprehensively linking them to farmers' attitudes, expectations, and participation in the digital economy (Fahmi & Sari, 2020; Keefe et al., 2024; Trinugroho et al., 2022). Yet understanding the relationships among these dimensions is essential for designing more effective, adaptive, and inclusive agricultural digitalization policies.

This study is based on the central hypothesis that digital literacy and the use of digital technologies are positively associated with digital economic participation and farmers' expectations regarding agricultural digitalization, while socio-economic characteristics serve as contextual factors that influence the strength of these relationships.

This study aims to examine the relationships of digital literacy and use with digital economic participation and the expectations of rice farmers in Kluet Utara and Kluet Selatan Sub-districts, South Aceh Regency. By applying a nonparametric correlational approach, the study enriches empirical evidence on the position and dynamics of agricultural digitalization among rural farmers. It also provides an analytical basis for formulating agricultural digitalization policies that focus on sustainably improving farmers' welfare, managing expectations, and strengthening human capacity.

2. CONCEPTUAL FRAMEWORK

Based on its theoretical foundation, this study positions digital literacy and use as the main determinants of digital economic participation and farmers' expectations, while socio-economic characteristics serve as contextual factors that shape variation in technology adoption. The

conceptual framework proposes that digital literacy and use promote digital economic participation both directly and through the formation of perceptions and readiness. Their influence is expected to be stronger on farmers' expectations, which represent an adoption stage that develops more rapidly than actual digital economic practices.

The research framework views agricultural digitalization as a gradual process that begins with stronger digital literacy and use, proceeds through the formation of farmers' attitudes and expectations, and ultimately encourages participation in the digital economy. Digital literacy is positioned as the main determinant, while socio-economic characteristics function as contextual factors influencing farmers' literacy, expectations, and digital economic engagement. Expectations are positioned as a transitional stage that links digital capabilities with economic practices and simultaneously signals a potential gap between attitudes and the implementation of agricultural digitalization among rural farmers.

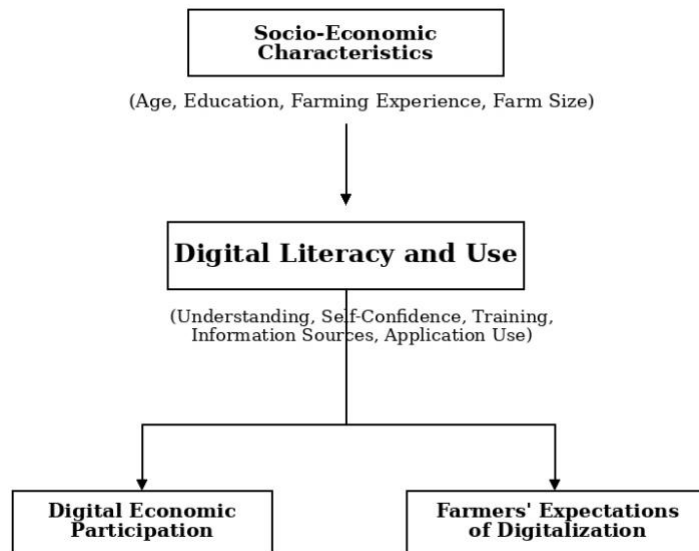


Figure 1. *Research Conceptual Framework*

3. METHODS

The population of this study comprised 5,325 rice farmers in Kluet Utara and Kluet Selatan Sub-districts, South Aceh Regency (BPS 2024), selected using a purposive sampling approach. A sample of 99 respondents was drawn using stratified random sampling.

The target variable in this study was digital literacy (DL), whose relationships with three groups of variables—digital economic participation, farmers' expectations, and socio-economic characteristics—were analyzed. Empirically, the Spearman correlation model was specified as follows:

$$\rho_{LD, PED} = \text{corrs}(LD_i, PED_i)$$

$$\rho_{LD, EKS} = \text{corrs}(LD_i, EKS_i)$$

$$\rho_{LD, Zk} = \text{corrs}(LD_i, Z_{ik})$$

Where LD_i is the digital literacy score of farmer i , PED_i is the digital economic participation score of farmer i , EKS_i denotes the farmer's expectation score regarding agricultural digitalization, Z_{ik} is socio-economic characteristic k of farmer i (age, education, farming experience, and farm size), and ρ is the Spearman rank correlation coefficient.

Mathematically, Spearman's rank correlation coefficient was calculated using the following formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

Where d_i is the difference between the ranks of the two variables for observation i , and n is the number of observations (99 respondents). The correlation coefficient ranges from -1 to $+1$; its sign indicates the direction of the relationship, while its absolute value reflects the strength of the relationship between variables. In this study, Spearman's rank correlation was used to analyze the relationships of digital literacy with digital economic participation and farmers' expectations, as well as the role of socio-economic characteristics in explaining variations in digital literacy. Significance was tested at the 95% and 99% confidence levels. The following table presents the definitions of the research variables.

Table 1. Definitions of Research Variables

Code	Variable Dimension	Description
A.1	Socio-Economic	Farmer's age
A.2	Socio-Economic	Formal education
A.3	Socio-Economic	Farming experience
A.4	Socio-Economic	Cultivated land area
A.5	Socio-Economic	Main employment status
A.6	Socio-Economic	Ownership of production facilities
A.7	Socio-Economic	Household income
A.8	Socio-Economic	Access to extension services
A.9	Socio-Economic	Participation in farmer groups
A.10	Socio-Economic	Income-source diversification
B.1	Digital Literacy	Understanding of digital concepts
B.2	Digital Literacy	Access to digital information
B.3	Digital Literacy	Digital self-confidence
B.4	Digital Literacy	Digital training experience
B.5	Digital Literacy	Use of digital applications
C.1	Digital Use	Frequency of digital-device use
C.2	Digital Use	Internet access for agriculture
C.3	Digital Use	Agricultural social media
C.4	Digital Use	Production/market applications
C.5	Digital Use	Intensity of digital use
D.1	Digital Economic Participation	Access to price and market information
D.2	Digital Economic Participation	Digital marketing
D.3	Digital Economic Participation	Digital transactions
D.4	Digital Economic Participation	Digital economic networks
D.5	Digital Economic Participation	Income improvement
E.1	Digitalization Expectations	Farm efficiency
E.2	Digitalization Expectations	Income expectations
E.3	Digitalization Expectations	Access to digital markets
E.4	Digitalization Expectations	Farm competitiveness
E.5	Digitalization Expectations	Sustainability of digitalization

4. RESULTS AND DISCUSSION

The descriptive analysis in this section aims to describe respondents' socio-economic characteristics and the conditions of the main research variables as an initial representation of the empirical setting. This description provides a basis for interpreting the correlation results while considering the social context surrounding rice farmers in rural areas.

This study analyzes the relationships among socio-economic characteristics, digital literacy and use, digital economic participation, and the expectations of rice farmers in Kluet Utara and Kluet Selatan Sub-districts, South Aceh Regency. All variables were measured on ordinal scales and were not normally distributed; therefore, relationships among variables were analyzed using Spearman's rank correlation. Descriptive analysis was used to provide an initial overview of the respondent profile and the distribution of the research variables.

Demographically, respondents were predominantly working-age to older farmers with relatively extensive farming experience, reflecting rice agriculture that remains grounded in experience and traditional practices. Educational attainment was generally at the primary to secondary level, while landholdings were predominantly small to medium-sized. Economically, farm households continued to rely on rice farming as their principal source of income, with limited diversification into non-agricultural activities. This condition restricts their capacity to access technologies and digital training.

Descriptive statistics on the socio-economic characteristics of rice farmers in the study area are presented in Table 2, including age, education, farming experience, farm size, and household income sources.

Table 2. Socio-Economic Characteristics of Rice Farmers (Resume A1-A.10)

Characteristic	Dominant Category	General Description
Age	Working-age–older	Most farmers are middle-aged or older
Education	Primary–upper secondary school	Formal education is relatively low–moderate
Farming experience	>10 years	Relatively extensive farming experience
Farm size	Small–medium	Relatively limited farming scale
Income source	Rice farming	High dependence on farming

Source: Primary data (processed, 2026).

The respondents' socio-economic characteristics show that most rice farmers were of working age to older and had formal education predominantly ranging from primary to senior high school. This indicates that most farmers still possessed adequate physical capacity and experience to conduct farming activities, although relatively low to moderate educational attainment may affect their ability to access, understand, and use new information and technologies. At the same time, farming experience exceeding 10 years among most respondents indicates strong practical knowledge of rice cultivation management. Consequently, farm decisions were more often based on empirical experience than on the use of digitally enabled innovations.

From an economic perspective, most respondents cultivated small to medium-sized landholdings and continued to depend primarily on income from rice farming. These conditions reflect the characteristics of small-scale agriculture commonly found in rural areas, where limited productive

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assets may constrain farmers' ability to invest in technology and digital facilities. The high dependence on farming income also suggests that improvements in productivity and efficiency through digital technologies could have a substantial effect on farm-household welfare. These socio-economic characteristics therefore provide an important context for understanding farmers' levels of digital literacy and variations in their digital economic participation, as examined in the following section.

After describing respondents' socio-economic characteristics, the analysis turns to farmers' digital literacy as the principal variable in this study. Descriptive analysis was conducted to portray farmers' ability to access, understand, evaluate, and use digital technologies in support of agricultural activities and other information needs. This presentation provides a basis for identifying farmers' readiness for the digital transformation of agriculture and for analyzing the relationships of digital literacy with digital economic participation, expectations regarding agricultural digitalization, and socio-economic characteristics in the subsequent sections.

Table 3. Descriptive Overview of Farmers' Digital Literacy (B1-B5)

Digital Literacy Indicator	Dominant Category	Interpretation
Digital understanding	Low–moderate	Digital concepts are not yet fully understood
Self-confidence	Moderate	Still hesitant to use technology
Digital training	Low	Limited access and participation
Digital information sources	Limited	Reliance on informal sources
Application use	Low	Not yet optimized for farming

Source: Primary data (processed, 2026).

The descriptive results show that rice farmers' digital literacy remained in the low to moderate category. Understanding of digital concepts and the use of digital technologies had not fully developed, as reflected in farmers' limited ability to access and use technology to support farming activities. Although self-confidence in using technology was moderate, most farmers remained hesitant to operate digital devices and applications independently.

Low participation in digital training and limited access to information sources further indicate that efforts to strengthen farmers' digital capacity had not yet been optimal. Farmers continued to obtain much of their digital information from informal sources, while the use of digital applications for farming activities also remained relatively low. This condition suggests that farmers' digital literacy was not supported by adequate access to learning and assistance, potentially constraining the adoption of digital technologies in agriculture.

Farmers' participation in the digital economy also remained limited. The internet had not been used optimally for farm decision-making or the marketing of agricultural products. Nevertheless, the findings indicate an initial readiness to participate in training and use digital technologies when support and assistance are available. This suggests potential for expanding digital economic participation at a later stage.

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Table 4. Descriptive Overview of Digital Economic Participation (C1-D5)

Participation Aspect	Dominant Category	Description
Digital-based decision-making	Low	Still relies on experience
Digital marketing	Very low	Markets remain conventional
Readiness to participate in training	Moderate	Potential for future adoption

Source: Primary data (processed, 2026).

In contrast to their current levels of literacy and participation, farmers' expectations regarding agricultural digitalization were relatively high. Most farmers believed that digital technologies could improve market access, farm efficiency, and income. The gap between expectations and current practices indicates that the principal barriers to digitalization lie not in farmers' attitudes but in their capacity and the availability of structural support.

Table 5. Descriptive Overview of Farmers' Expectations Regarding Digitalization (E1-E5)

Expectation Dimension	Dominant Category	Meaning
Economic benefits	High	Expectation of increased income
Market access	High	Digital technology is perceived as opening markets
Business sustainability	Moderate-high	Medium-term optimism

Source: Primary data (processed, 2026).

Note: The table of results presented here is the author's synthesis of questions (E1-E5)

The socio-economic conditions of rice-farming households in Kluet Utara and Kluet Selatan Sub-districts remained dominated by small-scale farming characteristics and limited access to digital facilities. Device ownership and internet access were relatively low and unevenly distributed among farmers. Farmers' digital literacy was in the low to moderate category, characterized by limited understanding of digital concepts, weak self-confidence, and minimal experience in technology-based training. These conditions indicate that farmers' digital capacity had not been developed systematically and continued to depend on individual experience.

At the same time, farmers' digital economic participation remained very limited, particularly in the use of farm-support applications and the online marketing of agricultural products. Nevertheless, expectations regarding agricultural digitalization were relatively high, especially concerning the potential for higher income and broader market access. The gap between low literacy and actual participation on the one hand and high expectations on the other shows that the main barriers to agricultural digitalization are not farmers' attitudes, but limited access, training, and institutional support. These findings underscore the importance of policy interventions that strengthen digital literacy as a prerequisite for digital economic transformation in agriculture.

Table 6 presents the results of the validity, reliability, and data normality tests conducted to assess the quality and suitability of the measurement instrument prior to hypothesis testing. Validity analysis was performed to ensure that each indicator accurately measured its intended construct, while reliability testing evaluated the internal consistency of the measurement scales. In addition, the normality test was conducted to verify whether the data distribution met the assumptions required for subsequent statistical analyses. Collectively, these diagnostic tests provide evidence regarding

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the robustness of the measurement model and the appropriateness of the dataset for further empirical analysis.

Table 6. Validity, Reliability, and Data Normality Tests

Testing Aspect	Test Method	Criterion	Main Result	Conclusion
Validity	Item–total correlation	$r > \text{critical } r\text{-value}$	All items met the criterion	Valid instrument
Reliability	Internal reliability (α)	$\alpha \geq 0.70$	The α value was adequate	Reliable instrument
Normality	Nonparametric normality test	Sig. > 0.05 (normal)	Sig. < 0.05	Data were non-normal

Source: Primary data (processed, 2026).

The test results show that all indicators met the validity and reliability criteria, indicating that the instrument measured the constructs accurately and consistently. The normality test indicated that the data were not normally distributed ($p < 0.05$); therefore, relationships among variables were analyzed using Spearman's rank correlation, which is appropriate for ordinal and nonparametric data.

Correlation Between Digital Literacy and Related Variables

The correlation results show that socio-economic attributes continued to shape farmers' participation and attitudes toward digitalization. Most indicators of digital economic participation and technological expectations were negatively correlated with farming experience and age. This finding suggests that older farmers with extensive experience in conventional farming systems tend to be more cautious and less receptive to the use of digital technologies. In contrast, farm size and education were positively correlated with digital participation and expectations, indicating that cognitive capacity and business scale facilitate the acceptance of innovation. This pattern is consistent with technology adoption theory, as David et al. (2025) and Trinugroho et al. (2022) emphasize the importance of resources and perceived risk in adoption decisions.

Table 7. Correlation Between Digital Literacy and Digital Economic Participation

Digital Literacy Variable	Participation / Perception Variable	ρ Spearman	Sig.	Description
B.1	D.1–D.4 (combined)	0.332 – 0.606	< 0.01	Positive, moderate–strong
B.2	D.1–D.4 (combined)	0.305	< 0.01	Positive, moderate
B.3	D.1–D.4 (combined)	(0.520) – (0.751)	< 0.01	Negative, strong
B.4	D.1–D.4 (combined)	0.305 – 0.606	< 0.01	Positive, moderate–strong

Source: Primary data (processed, 2026).

Note: Values in parentheses indicate negative coefficients (–); B.1–B.4 = indicators of digital literacy and use; D = digital economic participation and farmers' perceptions. Source: Primary data (processed, 2026).

*)The statistical results shown are only the significant variables.

Digital literacy emerged as the key factor most consistently associated with the other variables. Understanding of digital terminology and self-confidence in using technology showed positive and

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significant correlations with perceptions of the internet's influence on farm decisions and with expectations regarding the benefits of digitalization. These findings confirm that digital literacy functions as a cognitive and psychological prerequisite for agricultural digitalization. Farmers with stronger digital literacy are more likely to interpret technology as an opportunity rather than a threat and consequently hold more optimistic views of the future of digitally enabled agriculture.

Nevertheless, the findings also reveal a gap between literacy and practice. Although digital literacy and technological self-confidence were strongly correlated with perceptions and expectations, their correlations with actual digital economic participation—such as the online sale of agricultural products—were relatively weak and inconsistent. This indicates that greater knowledge and positive attitudes do not automatically lead farmers to participate in digital economic activities. Digitalization remained predominantly informational rather than transactional. This condition points to structural barriers, including limited access to digital markets, low trust in online platforms, and the absence of a well-developed supporting ecosystem at the local level.

The subsequent analysis examined the relationships of these two variables with farmers' expectations regarding agricultural digitalization. Correlation analysis was conducted to determine whether levels of digital literacy and technology use were associated with farmers' expectations concerning the benefits, opportunities, and development of digitalization in agriculture. The results were expected to clarify the relationship between farmers' digital capacity and their perceptions of the prospects for agricultural digital transformation.

Table 8. Correlation of Digital Literacy and Use With Farmers' Expectations

Digital Literacy Variable ^{*)}	Farmers' Expectations (E.1–E.8)	ρ Spearman	Sig.	Strength
B.1	Total expectations	0.219 – 0.426	<0.05–0.01	Moderate
B.2	Total expectations	0.204 – 0.341	<0.05–0.01	Weak–moderate
B.3	Total expectations	–0.214 – –0.318	<0.05–0.01	Negative, moderate
B.4	Total expectations	0.306 – 0.446	<0.01	Moderate
B.4	D.1–D.4 (combined)	0.305 – 0.606	<0.01	Positive, moderate–strong

Source: Primary data (processed, 2026).

Note: ^{*)}The statistical results shown are only the significant variables.

The use of digital applications and access to digital information sources were positively correlated with farmers' expectations, although their contribution to digital economic participation remained limited. This indicates that farmers used applications primarily for communication and information seeking rather than for productive economic activities. In other words, digital technologies had entered farmers' daily lives but had not yet been fully integrated into farming systems and the marketing of agricultural products.

The role of digital training constituted another important finding. Experience in digital training was strongly correlated with willingness to attend further training and motivation to continue learning. This finding indicates that training not only develops skills but also fosters reflective attitudes and long-

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term motivation for technological learning. However, the weak relationship between training and digital economic participation suggests that training not accompanied by practical assistance and market access may increase expectations without generating actual participation.

Table 9. Strong and Significant Correlations (Key Findings)

Main Relationship	ρ	Sig.	Substantive Interpretation
B.1 ↔ E.6 (actively searches for information online)	0.426	0.000	Literacy encourages information seeking
B.4 ↔ E.6	0.446	0.000	Digital use is associated with economic readiness
B.3 ↔ E.1	-0.297	0.003	Limited training → lower expectations
B.1 ↔ D (farm decision-making)	0.606	0.000	Digital technology influences economic decisions

Source: Primary data (processed, 2026).

Note: *)The statistical results shown are only the significant variables.

The analysis of farmers' expectations shows that digital literacy was the most influential factor in shaping positive views of the benefits of agricultural digitalization. Farmers who understood technology and were confident in using it tended to believe that digitalization could increase production, income, and marketing efficiency. These high expectations represent psychological and social capital that is important to the success of digitalization programs. Without adequate policy and infrastructure support, however, these expectations may not be converted into actual practices.

These findings indicate that agricultural digitalization in the study area was in a transitional phase, in which literacy and expectations developed more rapidly than actual digital economic participation. Agricultural digitalization therefore cannot be understood merely as a matter of technology adoption; rather, it is a process of socio-economic transformation that requires an integrated approach. Improvements in digital literacy must be accompanied by stronger market ecosystems, continuous assistance, and policies capable of bridging the gap among farmers' knowledge, attitudes, and digital economic practices.

Discussion

The correlation results show that digital literacy had a consistent and significant relationship with the formation of positive expectations regarding agricultural digitalization, although this relationship was relatively weaker when associated with actual digital economic participation. This finding indicates a structural gap between farmers' cognitive capabilities and attitudes and their actual digital economic practices. In other words, stronger digital literacy successfully fostered optimistic perceptions and expectations toward technology but had not been fully converted into active participation in digitally enabled economic activities. This pattern confirms that agricultural digitalization among rural farmers remained in transition from cognitive readiness to economic implementation.

These findings have important policy implications. Digital literacy should be positioned as the principal foundation of agricultural digitalization strategies, but it cannot operate independently of an adequate supporting ecosystem. Existing digital literacy programs tend to focus on introducing technologies, whereas the correlation results show that this approach alone is not sufficient to promote digital economic participation. This interpretation is consistent with Burhanuddin et al. (2018), Zahra et al. (2024), and Alif et al. (2025), despite differences in study area, analytical

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perspective, and commodity. Policies should therefore strengthen farmers' practical capacity through contextual training based on farm needs and accompanied by continuous assistance. Digital literacy must extend beyond conceptual understanding toward applied skills relevant to production, marketing, and farm decision-making.

The analysis further shows that digital training was strongly related to farmers' expectations and learning attitudes, while its relationship with digital economic participation remained limited. This suggests that training not integrated with concrete economic opportunities may stop at the level of improved attitudes without producing changes in economic behavior. Consequently, digital training programs should be directly linked to access to digital marketing platforms, digital cooperatives, and agribusiness partnership schemes. Such integration enables farmers to observe tangible economic benefits and promotes the transition from expectations to participation.

Socio-economic characteristics served as significant differentiating factors in agricultural digitalization. Age and farming experience tended to be negatively correlated with digital literacy and participation, whereas education and farm size showed positive relationships. This pattern is consistent with Trinugroho et al. (2022), who found that digital technology adoption is influenced by human capital and learning capacity, with older groups facing adaptation constraints because of low digital self-confidence and high learning costs. Adesiji et al. (2024), Miao et al. (2025), and Sargani et al. (2025) also show that farmers operating larger farms and possessing better access to resources are more likely to use digital technologies productively because they face clearer economic incentives. In addition, Yang et al. (2025) emphasize the importance of intermediary actors in bridging the gap between digital literacy and practice, particularly in socially heterogeneous communities. These studies reinforce the implication that agricultural digitalization policies cannot be designed uniformly but require segmented approaches that are sensitive to farmers' age, business scale, and educational background. In this context, extension agents, pioneering farmers, and local intermediaries play strategic roles in facilitating knowledge transfer, reducing adoption risks, and accelerating the integration of small-scale and older farmers into the digital agricultural ecosystem.

Furthermore, the weak relationship between the use of digital applications and digital economic participation indicates that the central problem lies not merely in the ability to use technology, but also in the availability and credibility of the agricultural digital market ecosystem. Without platforms that are accessible, trustworthy, and suited to local characteristics, technology use may become an administrative activity with little economic value added. Policies should therefore promote the integration of digital technologies with farmers' economic institutions, such as cooperatives and joint business groups, to reduce individual risk and strengthen trust in digital transactions.

The high expectations that farmers placed on the benefits of agricultural digitalization—as reflected in the correlation results—must also be managed strategically to prevent future disappointment and resistance to innovation. Fahmi and Sari (2020) show that digitalization can improve the subjective well-being of rural communities only when supported by real economic opportunities and an adequate enabling environment. Farmers' positive expectations will therefore be difficult to convert into welfare improvements without digital infrastructure, network access, and supportive regulation. Liu et al. (2025) similarly emphasize that farmers' participation in the digital economy generates productive and sustainable behavioral change only when supported by a strong local digital

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ecosystem, including market services and agribusiness institutions. These studies reinforce the present finding that synchronizing farmer capacity development, rural digital infrastructure, and stronger market access is essential for converting digital expectations into sustainable economic practices. Under an integrated approach, farmers' positive expectations can develop beyond cognitive attitudes into digital economic participation that directly improves the welfare of rural rice farmers.

The findings of this study show that digital literacy and use played significant roles in shaping farmers' positive expectations regarding agricultural digitalization, although their relationships with actual digital economic participation were relatively weaker. This pattern indicates a gap between cognitive readiness and economic implementation, with digitalization operating more strongly in the domains of perception and access to information than in the transformation of farming practices. This finding is consistent with Fahmi and Mendrofa (2023), who argue that the development of digital technologies in rural areas tends to follow—rather than directly drive—ongoing economic transformation, causing technology to function more as a complementary element than as the principal engine of change.

This argument is reinforced by Fahmi and Mendrofa (2023), Fharaz et al. (2022), and Fahmi and Sari (2020), who show that rural digitalization produces tangible welfare effects only when integrated with structural changes in local economic systems and spatial arrangements. These studies emphasize that, without physical infrastructure, market access, and inclusive economic institutions, digitalization tends to improve access to information without increasing income or quality of life. This perspective is consistent with the present findings, in which farmers' expectations regarding the benefits of digitalization developed more rapidly than their actual digital economic participation, reflecting limitations in the local supporting ecosystem.

Fahmi and Sari (2020) further highlight that the rural digital divide is not only technological but also social and spatial. This is reflected in the present finding that socio-economic characteristics served as significant differentiating factors. The positive correlations of education and farm size with digital literacy and participation indicate that farmers with stronger human and economic capital were better able to use digital opportunities. In contrast, the negative correlations of age and farming experience indicate that older farmers and those operating on a small scale faced greater structural barriers to converting digital literacy into economic practices. This pattern is consistent with Kartiasih et al. (2023), who emphasize that digitalization may widen inequality when it is not accompanied by policy interventions that are sensitive to local socio-economic contexts.

The findings of this study, together with those of David et al. (2025) and Thann et al. (2020), clarify that farmers' high expectations regarding agricultural digitalization must be managed strategically. Expectations not matched by stronger infrastructure, network access, and economic institutions may generate disappointment and resistance to innovation. Agricultural digitalization policies should therefore adopt a holistic and gradual approach in which digital literacy serves as the initial foundation, expectations constitute a transitional phase, and digital economic participation becomes the ultimate objective supported by local market and institutional ecosystems.

In the context of South Aceh, these policy implications require an agricultural digitalization strategy that adapts to farmers' socio-economic and spatial characteristics. Strengthening cooperatives and farmer groups, integrating digital marketing platforms with local value chains, and expanding the

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active roles of extension agents and pioneering farmers are essential for bridging the gap among literacy, expectations, and digital economic practices. Through such an approach, agricultural digitalization can become an instrument of inclusive and sustainable rural economic transformation rather than merely a symbol of technological modernization.

The success of agricultural digitalization depends on a holistic and gradual approach in which digital literacy functions as the starting point, expectations as a transitional bridge, and digital economic participation as the ultimate objective. This framework is consistent with David et al. (2025) and Fahmi and Mendrofa (2023), who emphasize that digital transformation is not automatic but is a social process influenced by individual capacity, institutional context, and available economic incentives. Without a connection between digital capabilities and real economic opportunities, digitalization may stop at the level of cognitive readiness. Fahmi and Sari (2020) likewise show that rural digitalization improves welfare only when integrated with changes in the local economic structure and supported by an inclusive social ecosystem. In South Aceh, these findings strengthen the argument that agricultural digitalization strategies must adapt to farmers' socio-economic characteristics, focus on directly observable economic benefits, and receive support from local market and institutional ecosystems. Such an approach is a primary prerequisite for ensuring that digitalization not only builds expectations but genuinely promotes sustainable and inclusive agricultural transformation.

5. CONCLUSION

This study confirms that digital literacy and use play important roles in shaping rice farmers' perceptions of and expectations toward agricultural digitalization. The correlation results show positive and significant relationships between digital literacy—particularly understanding of digital concepts and self-confidence in using technology—and farmers' expectations regarding the benefits of digitalization, such as improved farm efficiency and access to market information. However, the relationship between digital literacy and actual digital economic participation was relatively weaker, indicating a structural gap between farmers' cognitive readiness and attitudes and their actual digital economic practices. These findings show that agricultural digitalization among rural farmers remained in a transitional stage, in which expectations developed more rapidly than substantive digital economic engagement.

Socio-economic characteristics also proved to be significant differentiating factors in the dynamics of agricultural digitalization. Age and farming experience were negatively correlated with digital literacy and participation, whereas education and farm size showed positive relationships. Digital training contributed to stronger expectations and learning readiness but was not sufficient to promote digital economic participation without an adequate market ecosystem. Overall, the findings confirm that improvements in digital literacy and technology use, although crucial, do not automatically generate sustainable digital economic transformation among rural farmers.

6. RECOMMENDATIONS

Based on the findings, agricultural digitalization strategies should be designed in an integrated and gradual manner. Digital literacy should be positioned as the initial foundation but must be followed by applied training focused on tangible economic benefits and directly connected to production, marketing, and farm decision-making. Farmer capacity-building programs should include continuous

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assistance and access to credible digital marketing platforms suited to the local context so that positive expectations can be converted into actual digital economic participation.

Agricultural digitalization policies should also account for farmers' socio-economic heterogeneity through segmented approaches, particularly for older and small-scale farmers who face greater barriers to technological adaptation. Strengthening the roles of extension agents, pioneering farmers, and local intermediaries is strategic for bridging the gap between digital literacy and practice. Local economic institutions, including cooperatives and digitally enabled farmer groups, should also be prioritized to create an inclusive and sustainable market ecosystem. Future research should examine more deeply the institutional mechanisms and market factors capable of accelerating the conversion of digital literacy and expectations into productive digital economic participation that improves farmers' welfare.

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