

Farmers' Acceptance of Drone-Based Crop Monitoring Systems for Climate-Resilient Rice Production

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ABSTRACT

Climate change increases the risks of drought, shifting rainfall patterns, and crop growth disturbances that threaten the sustainability of rice production. Drone-based crop monitoring systems offer timely information to support more adaptive agricultural management. This study aims to analyze the factors influencing farmers' acceptance of drone use in supporting climate-resilient rice production. A quantitative approach with a cross-sectional survey design was employed involving 200 rice farmers in Grobogan Regency, Central Java, Indonesia. Data were collected through a structured questionnaire and analyzed using multiple linear regression. The results indicate that perceived usefulness, ease of use, trust in technology, facilitating conditions, and climate change awareness positively influence farmers' acceptance, while perceived cost remains a major barrier. These findings support the development of precision agriculture adoption strategies to strengthen the climate resilience of rice production.

INTRODUCTION

Climate change is increasingly disrupting rice production through rising temperatures, rainfall variability, drought, and other environmental stresses, creating greater uncertainty for agricultural management and food security. Evidence from Indonesia indicates that changing temperature and rainfall patterns can substantially affect rice production, highlighting the need for more adaptive production strategies (Ansari et al., 2023). Rice farmers have also reported water shortages, increasing temperatures, and pest outbreaks as important climate-related challenges affecting farming activities and adaptation decisions (Arifah et al., 2022). At the local level, Grobogan Regency holds a strategic position in Central Java's rice sector, as it is recognized as one of the major rice-producing areas contributing substantially to regional food security. This condition highlights the importance of strengthening the sustainability and resilience of rice production in the region, particularly in response to increasing climatic and agricultural risks (Nurjati, 2023).

Digital agricultural technologies provide new opportunities to respond to these challenges by improving the availability, accuracy, and timeliness of information used in farm management. Drone-based crop monitoring can provide detailed aerial information on crop growth, field conditions, vegetation health, water availability, and spatial variations that may be difficult to observe through conventional field inspection. Sari et al. (2021) demonstrated that drone imagery can support the monitoring of rice crop development and paddy field conditions, indicating its potential to improve field-level crop management. Similarly, Karmakar et al. (2024) emphasized that multimodal remote sensing can improve crop monitoring by integrating complementary information for detecting changes in plant conditions, while Guebsi et al. (2024) identified crop health assessment, mapping, and resource management as important applications of drones in precision agriculture. Thus, drone-based monitoring has considerable potential to provide farmers with timely information required for more adaptive and climate-resilient rice management.

Despite these technological advantages, the availability of drone technology does not automatically lead to its adoption by farmers. Farmers' acceptance is influenced by their perceptions of technological usefulness, ease of operation, confidence in the technology, economic value, and the availability of supporting resources. Michels et al. (2021) found that perceived usefulness, perceived ease of use, confidence, and job relevance contributed to explaining farmers' intentions to adopt drones, demonstrating the relevance of the Technology Acceptance Model in agricultural technology adoption. Bai et al. (2022) further revealed that drone adoption among Hungarian precision farmers occurs through different stages and is associated with farmer and farm characteristics, while Suvittawat (2024) showed that expectations, perceived product quality, and perceived value significantly shape farmers' attitudes toward agricultural drones. These findings indicate that farmers' acceptance should be understood as a multidimensional process involving technological, economic, behavioral, and enabling conditions.

However, existing research remains fragmented between studies of drone performance, agricultural technology adoption, and climate-change adaptation. Studies conducted by Sari et al. (2021) and Karmakar et al. (2024) primarily emphasize the technical ability of drone imagery and remote sensing to monitor crops, but they do not explain whether rice farmers are willing to accept such technologies under actual farming conditions. Conversely, Michels et al. (2021), Bai et al. (2022), and Suvittawat (2024) examine farmers' acceptance or adoption of drones, but their empirical evidence originates mainly from European and Thai agricultural contexts and is not specifically oriented toward climate-resilient rice production. Indonesian studies have highlighted the importance of climate-smart agriculture and technological adaptation strategies in strengthening rice production resilience under changing climatic conditions. However, existing research has primarily focused on the adoption of climate-smart practices and farmers' adaptive capacity, while limited attention has been given to farmers' acceptance of advanced digital technologies, such as drone-based crop monitoring systems, as tools for climate adaptation (Wandayantolis et al., 2024). Consequently, limited empirical evidence exists regarding the factors determining Indonesian rice farmers' acceptance of drone-based monitoring as a technological tool for strengthening climate resilience.

To address this gap, this study focuses on rice farmers in Grobogan Regency, Central Java, Indonesia, where rice production has substantial regional importance and adaptive agricultural management is increasingly relevant. The study explicitly aims to analyze the influence of perceived usefulness, perceived ease of use, trust in technology, perceived cost, facilitating conditions, and climate change awareness on farmers' acceptance of drone-based crop monitoring systems. It also seeks to identify which factors have the strongest influence on farmers' willingness to accept such technology for supporting rice production. By focusing on farmers rather than solely on the technical performance of drones, this research positions technology acceptance as an essential condition for translating digital monitoring capabilities into practical climate-adaptation measures.

Theoretically, this study contributes to agricultural technology-acceptance research by extending its application to the specific context of climate-resilient rice production and integrating technological perceptions with economic, institutional, and climate-related considerations. It also provides empirical evidence from an important rice-producing region in Indonesia, a context that remains comparatively underrepresented in international studies of agricultural drone adoption. Practically, the findings are expected to assist agricultural extension services, local governments, technology providers, and farmer organizations in developing appropriate training, financing, demonstration, and shared-service strategies that respond to farmers' actual barriers and expectations. Such evidence can support more targeted introduction of drone-based crop monitoring systems and strengthen farmers' capacity to make timely and adaptive production decisions under increasing climate variability.

THEORETICAL REVIEW

Climate Change and the Need for Climate-Resilient Rice Production

Climate change has become a major challenge for agricultural sustainability, particularly for rice production systems that are highly sensitive to temperature fluctuations, rainfall variability, drought, and water availability. These environmental changes increase production uncertainty and require farmers to adopt adaptive management strategies that improve resilience while maintaining productivity. Climate-resilient agriculture emphasizes the integration of technological innovation, efficient resource management, and improved decision-making processes to reduce climate-related risks. Digital agricultural technologies have increasingly been recognized as important tools for supporting climate adaptation because they provide accurate and timely information for managing agricultural resources (Maddikunta et al., 2020). In rice production systems, access to real-time crop information is essential to enable farmers to respond more effectively to environmental changes and maintain sustainable production under uncertain climatic conditions.

Drone-Based Crop Monitoring for Precision Rice Farming

Drone-based crop monitoring systems represent an important innovation within precision agriculture by enabling farmers to obtain high-resolution information regarding crop conditions, vegetation health, water stress, and field variability. Agricultural drones equipped with imaging sensors can support more efficient crop management through early detection of plant stress, improved input management, and better spatial decision-making. Recent studies have shown that drone technology has expanded beyond aerial imaging into integrated agricultural monitoring systems that support productivity improvement and resource optimization (Guebsi et al., 2024). In Indonesia, the implementation of unmanned aerial vehicles in agriculture has demonstrated potential benefits for crop monitoring and precision farming, although challenges remain regarding technical capability, operational costs, and farmer readiness (Fikri et al., 2023). Therefore, the effectiveness of drone-based monitoring systems depends not only on technological performance but also on farmers' willingness to accept and utilize the technology.

Farmers' Acceptance and Adoption of Agricultural Drone Technology

Farmers' acceptance is a critical factor determining whether agricultural innovations can be successfully implemented in real farming environments. The Technology Acceptance Model explains that adoption decisions are strongly influenced by perceived usefulness and perceived ease of use, where individuals are more likely to adopt technologies that provide clear benefits and are considered manageable. Michels et al. (2021) found that farmers' intention to adopt drone technology was influenced by perceived usefulness, technological confidence, and the relevance of drones to farming activities. Similarly, Bai et al. (2022) demonstrated that drone adoption among farmers is associated with individual characteristics, farming experience, and perceptions of technological advantages. These findings indicate that agricultural drone adoption is not solely

a technical issue but also involves behavioral, economic, and social considerations among farmers.

Determinants of Farmers' Acceptance of Drone-Based Crop Monitoring Systems

Previous research indicates that farmers' acceptance of digital agricultural technologies is influenced by multiple factors, including perceived benefits, economic feasibility, trust, supporting infrastructure, and technological literacy. Farmers may hesitate to adopt drone-based monitoring systems due to high investment costs, limited knowledge, lack of technical assistance, and uncertainty regarding practical benefits. Suvittawat (2024) reported that perceived value, expectations, and product quality significantly influence farmers' attitudes toward agricultural drone technology, demonstrating the importance of farmers' perceptions in technology adoption processes. However, existing studies have primarily examined drone adoption from a general precision agriculture perspective, while limited research has specifically investigated farmers' acceptance of drone-based crop monitoring systems as a strategy for climate-resilient rice production. Therefore, further empirical research is needed to understand how technological, economic, and climate-related factors influence farmers' acceptance of drone monitoring systems, particularly in rice-producing regions such as Grobogan Regency, Indonesia.

METHODOLOGY

Research Design and Approach

This study employed a quantitative research approach using a cross-sectional survey design to examine the factors influencing farmers' acceptance of drone-based crop monitoring systems for climate-resilient rice production. A quantitative approach was selected because the research aims to measure relationships among variables and statistically evaluate the influence of technological, economic, and environmental perceptions on farmers' acceptance behavior. The cross-sectional design allows data collection from respondents at a specific period to capture farmers' current perceptions and willingness to adopt drone-based agricultural technologies. This approach has been widely applied in agricultural technology adoption studies because it enables researchers to identify behavioral patterns and determinants affecting technology acceptance among farmers (Kumar et al., 2021). The research model focuses on farmers' acceptance of drone-based crop monitoring systems as the dependent variable, while perceived usefulness, perceived ease of use, perceived cost, trust in technology, facilitating conditions, and climate change awareness are examined as independent variables.

Research Location, Population, and Sampling Technique

The research was conducted in Grobogan Regency, Central Java, Indonesia, which was selected because the region represents an important rice-producing area with increasing challenges related to climate variability and agricultural sustainability. The population of this study consisted of rice farmers operating in Grobogan Regency who have experience in rice cultivation activities

and are potential users of digital agricultural technologies. A total of 200 rice farmers were selected as research respondents. The sample size was considered adequate for quantitative analysis involving multiple predictor variables and regression-based statistical testing. The respondents were selected using purposive sampling, considering that not all farmers have sufficient knowledge or exposure to agricultural technology, particularly drone-based monitoring systems. Purposive sampling is appropriate when researchers require participants with specific characteristics relevant to the research objectives (Campbell et al., 2020).

Data Collection Instrument and Measurement

Data were collected using a structured questionnaire developed based on previous technology acceptance and agricultural innovation adoption studies. The questionnaire consisted of two main sections: respondent characteristics and measurement items related to research variables. Each construct was measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The measurement indicators for perceived usefulness and perceived ease of use were adapted from the Technology Acceptance Model framework, while trust, facilitating conditions, perceived cost, and climate change awareness indicators were developed based on previous agricultural technology adoption studies (Venkatesh et al., 2022). Before conducting the main survey, the questionnaire was reviewed by agricultural experts and tested on a small group of respondents to ensure clarity, relevance, and suitability for the local farming context. Instrument quality was evaluated through validity testing using item-total correlation and reliability testing using Cronbach's alpha coefficient, where values above the acceptable threshold indicated internal consistency among measurement items (Hair et al., 2021).

Research Procedure

The research procedure was conducted systematically through several stages. The first stage involved identifying research problems, reviewing relevant literature, and developing the conceptual framework related to farmers' acceptance of drone-based crop monitoring systems. The second stage consisted of questionnaire preparation, adaptation of measurement indicators, expert evaluation, and preliminary instrument testing. The third stage involved field data collection through direct distribution of structured questionnaires to selected rice farmers in Grobogan Regency. After data collection, the responses were examined, coded, and organized into a dataset for statistical analysis. The final stage involved interpretation of statistical findings, evaluation of relationships among variables, and formulation of conclusions regarding factors influencing farmers' acceptance of drone-based crop monitoring systems for climate-resilient rice production.

Data Analysis Technique

The collected data were analyzed using descriptive and inferential statistical approaches. Descriptive statistics were applied to describe respondents' demographic characteristics and the general perception of farmers

toward drone-based crop monitoring systems. Prior to hypothesis testing, validity and reliability analyses were conducted to ensure that the measurement instruments accurately represented the studied constructs. Classical assumption tests, including normality, multicollinearity, and heteroscedasticity tests, were performed to ensure that the regression model met statistical requirements. Multiple linear regression analysis was subsequently applied to examine the influence of perceived usefulness, perceived ease of use, perceived cost, trust in technology, facilitating conditions, and climate change awareness on farmers' acceptance of drone-based crop monitoring systems. Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) software, which is commonly used for quantitative analysis in social and agricultural research (Pallant, 2020).

RESULTS

Characteristics of Respondents

The demographic characteristics of respondents were analyzed to provide an overview of the background of rice farmers involved in this study. Understanding respondent characteristics is important because farmers' experiences, educational backgrounds, age, and farming scale may influence their perceptions and readiness toward adopting drone-based crop monitoring systems. A total of 200 rice farmers from Grobogan Regency participated in this study, and the distribution of respondent characteristics is presented in Table 1.

Table 1. Characteristics of Respondents (n = 200)

Characteristics	Category	Frequency	Percentage (%)
Age	< 30 years	18	9.0
	31–45 years	82	41.0
	46–60 years	76	38.0
	>60 years	24	12.0
Education	Elementary school	56	28.0
	Junior high school	54	27.0
	Senior high school	72	36.0
	University	18	9.0
Farming experience	<10 years	34	17.0
	10–20 years	92	46.0
	>20 years	74	37.0
Land size	<1 ha	118	59.0
	1–2 ha	64	32.0
	>2 ha	18	9.0

Based on Table 1, the majority of respondents were within the productive age group, with farmers aged 31–45 years representing the largest proportion (41.0%), followed by farmers aged 46–60 years (38.0%). In terms of education

level, most respondents had completed senior high school education (36.0%), while only a small proportion had university education (9.0%). Regarding farming experience, most respondents had 10–20 years of experience in rice cultivation (46.0%), indicating that respondents had considerable involvement in agricultural activities. Furthermore, the majority of farmers managed relatively small agricultural areas, with 59.0% cultivating less than one hectare of rice fields.

Descriptive Statistics of Research Variables

Descriptive statistical analysis was conducted to identify the general perceptions of respondents toward drone-based crop monitoring systems. This analysis presents the mean and standard deviation values of each research variable, including perceived usefulness, perceived ease of use, perceived cost, trust in technology, facilitating conditions, climate change awareness, and farmers' acceptance. The results of descriptive analysis are presented in Table 2.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Standard Deviation	Category
Perceived Usefulness (X1)	4.12	0.56	High
Perceived Ease of Use (X2)	3.98	0.61	High
Perceived Cost (X3)	3.21	0.74	Moderate
Trust in Technology (X4)	3.87	0.63	High
Facilitating Conditions (X5)	3.95	0.60	High
Climate Change Awareness (X6)	4.18	0.52	High
Farmers' Acceptance (Y)	4.05	0.58	High

Table 2 shows that all research variables obtained relatively high average scores, indicating positive perceptions among farmers regarding drone-based crop monitoring systems. Climate change awareness recorded the highest mean value (4.18), followed by perceived usefulness (4.12) and farmers' acceptance (4.05). Meanwhile, perceived cost obtained the lowest mean score (3.21), indicating that economic considerations received relatively lower evaluations compared with other variables. The results indicate that respondents generally recognized the potential value of drone technology while still considering cost-related aspects in the adoption process.

Validity and Reliability Testing

Before conducting further statistical analysis, the research instrument was evaluated to ensure that all measurement indicators were valid and reliable. Validity testing was performed to determine whether each questionnaire item accurately measured the intended construct, while reliability testing was conducted to assess the internal consistency of each variable. The results of validity and reliability testing are presented in Table 3.

Table 3. Validity and Reliability Test Results

Variable	Number of Items	Item Correlation Range	Cronbach Alpha	Decision
Perceived Usefulness	4	0.612–0.821	0.842	Reliable
Perceived Ease of Use	4	0.588–0.796	0.817	Reliable
Perceived Cost	3	0.601–0.774	0.793	Reliable
Trust in Technology	4	0.623–0.834	0.861	Reliable
Facilitating Conditions	4	0.595–0.809	0.829	Reliable
Climate Change Awareness	4	0.640–0.847	0.872	Reliable
Farmers' Acceptance	4	0.615–0.838	0.866	Reliable

The results presented in Table 3 indicate that all measurement items achieved acceptable validity values, with item correlation coefficients exceeding the minimum required criteria. Furthermore, Cronbach's alpha values for all variables ranged from 0.793 to 0.872, exceeding the acceptable reliability threshold. These results confirm that the questionnaire instrument had adequate consistency and was suitable for analyzing farmers' acceptance of drone-based crop monitoring systems.

Classical Assumption Testing

Prior to regression analysis, classical assumption tests were conducted to verify whether the dataset met the statistical requirements for multiple linear regression analysis. The tests included normality testing, multicollinearity testing, and heteroscedasticity testing. The results of these assessments are summarized in Table 4.

Table 4. Classical Assumption Test Results

Test	Indicator	Result	Decision
Normality	Kolmogorov-Smirnov Sig.	0.087	Normal
Multicollinearity	VIF range	1.214–2.486	No problem
Heteroscedasticity	Sig. range	0.214–0.672	No problem

As shown in Table 4, the regression model fulfilled all classical assumption requirements. The normality test produced a significance value of 0.087, indicating that the residual data followed a normal distribution. The VIF values ranged from 1.214 to 2.486, demonstrating that the independent variables did not experience multicollinearity problems. In addition, the heteroscedasticity

test results showed acceptable significance values, confirming that the regression model was appropriate for further analysis.

Multiple Linear Regression Analysis and Model Fit Statistics

Multiple linear regression analysis was conducted to examine the influence of perceived usefulness, perceived ease of use, perceived cost, trust in technology, facilitating conditions, and climate change awareness on farmers' acceptance of drone-based crop monitoring systems. The regression analysis was used to identify the contribution of each independent variable and to evaluate the overall explanatory capability of the proposed research model. The results of regression coefficients and model fit statistics are presented in Table 5 and Table 6.

Table 5. Multiple Linear Regression Analysis Results

Variable	Regression Coefficient (β)	t-value	Sig.	Result
Perceived Usefulness	0.284	5.214	0.000	Significant Positive
Perceived Ease of Use	0.176	3.421	0.001	Significant Positive
Perceived Cost	-0.143	-2.876	0.005	Significant Negative
Trust in Technology	0.219	4.118	0.000	Significant Positive
Facilitating Conditions	0.192	3.764	0.000	Significant Positive
Climate Change Awareness	0.231	4.506	0.000	Significant Positive

Table 6. Model Fit Statistics

Indicator	Value
R	0.782
R Square	0.612
Adjusted R Square	0.599
F-value	50.842
Sig.	0.000

Based on Table 5, the regression analysis shows that perceived usefulness, perceived ease of use, trust in technology, facilitating conditions, and climate change awareness have a positive and significant influence on farmers' acceptance of drone-based crop monitoring systems. Among these variables, perceived usefulness recorded the highest regression coefficient ($\beta = 0.284$), followed by climate change awareness ($\beta = 0.231$) and trust in technology ($\beta = 0.219$). This indicates that these factors contributed substantially to explaining variations in farmers' acceptance levels. In contrast, perceived cost showed a

negative and significant coefficient ($\beta = -0.143$), indicating that higher perceived economic barriers were associated with lower acceptance of drone-based crop monitoring systems.

The model fit statistics presented in Table 6 indicate that the regression model has adequate explanatory capability. The correlation coefficient (R) value of 0.782 demonstrates a strong relationship between the independent variables and farmers' acceptance. The coefficient of determination (R Square) value of 0.612 indicates that the six independent variables collectively explain 61.2% of the variation in farmers' acceptance, while the remaining 38.8% is influenced by other factors outside the research model. The adjusted R Square value of 0.599 confirms that the model maintains a consistent explanatory capacity after considering the number of predictors included. Furthermore, the F-value of 50.842 with a significance value of 0.000 confirms that the regression model is statistically significant and suitable for explaining factors influencing farmers' acceptance of drone-based crop monitoring systems for climate-resilient rice production.

DISCUSSION

The findings of this study demonstrate that farmers' acceptance of drone-based crop monitoring systems is influenced by a combination of technological perceptions, economic considerations, supporting conditions, and climate-related awareness. The results confirm that the adoption of agricultural drone technology is not determined solely by the availability of advanced technological tools but also by how farmers perceive the usefulness, accessibility, reliability, and relevance of the technology to their farming needs. This finding supports the Technology Acceptance Model (TAM), which explains that perceived usefulness and perceived ease of use are fundamental factors shaping individuals' intention to adopt new technologies. In the context of climate-resilient rice production, farmers' acceptance becomes an important initial stage in ensuring that digital agricultural innovations can be transformed into practical adaptation strategies.

Perceived usefulness emerged as the most influential factor affecting farmers' acceptance of drone-based crop monitoring systems. This finding indicates that farmers are more willing to accept drone technology when they perceive that it can provide practical benefits, such as improving crop monitoring accuracy, identifying field conditions, and supporting better agricultural decision-making. Drone technology provides information that is difficult to obtain through conventional observation methods, allowing farmers to respond more effectively to variations in crop conditions and environmental risks. This result is consistent with the concept of digital agriculture, where the value of technology depends on its ability to generate useful information for improving farm management rather than merely introducing technological innovation. Walter et al. (2023) emphasized that digital agricultural technologies can create meaningful impacts when farmers recognize their contribution to improving productivity, efficiency, and risk management. Therefore, increasing farmers' awareness of the practical benefits of drone monitoring is essential for accelerating adoption.

Perceived ease of use also significantly influenced farmers' acceptance, demonstrating that technological complexity remains an important consideration in agricultural digitalization. Although drone-based monitoring systems offer advanced capabilities, farmers may hesitate to adopt them if the technology is perceived as difficult to operate or requires specialized technical knowledge. This finding highlights the importance of digital literacy and user-friendly technology design in supporting agricultural transformation. Rose et al. (2021) explained that the successful adoption of digital agriculture depends on farmers' ability to understand, access, and integrate technology into existing farming practices. Therefore, training programs, field demonstrations, and support from agricultural extension services are necessary to reduce technological barriers and increase farmers' confidence in using drone-based systems.

Trust in technology was also found to influence farmers' acceptance of drone-based crop monitoring systems. Farmers' willingness to rely on drone-generated information depends on their confidence regarding the accuracy, reliability, and usefulness of the technology. In agricultural decision-making, uncertainty can create significant risks because incorrect information may affect production outcomes and economic returns. Therefore, trust becomes a critical factor in determining whether farmers are willing to incorporate drone information into their cultivation decisions. Klerkx et al. (2022) highlighted that trust, transparency, and institutional support are important elements in the adoption of digital agricultural innovations because farmers often evaluate not only technological performance but also the reliability of the entire innovation system. Strengthening trust through demonstration projects, technical assistance, and credible information sources can therefore improve farmers' acceptance.

Facilitating conditions showed a positive influence on farmers' acceptance, indicating that technology adoption requires supportive environments beyond individual willingness. Farmers may recognize the advantages of drone-based monitoring but still face difficulties adopting the technology due to limited infrastructure, lack of technical assistance, and restricted access to service providers. This finding supports the innovation diffusion perspective, which emphasizes that adoption is influenced by the interaction between individuals and their surrounding social and institutional systems. Barnard et al. (2023) stated that digital agricultural transformation requires collaboration among farmers, extension institutions, technology developers, and policymakers to create an enabling ecosystem. In Grobogan Regency, strengthening facilitating conditions through training, shared drone services, and institutional support may become an important approach for translating positive acceptance into actual utilization.

Climate change awareness was another significant factor influencing farmers' acceptance of drone-based crop monitoring systems. Farmers who recognize climate-related risks, including irregular rainfall, drought, and crop stress, tend to show greater interest in technologies that can support adaptation and improve decision-making. This finding indicates that technology acceptance is not only driven by productivity considerations but also by farmers' perceptions of environmental challenges. Zhang et al. (2024) explained that climate-smart agricultural technologies are more likely to be adopted when farmers understand

their contribution to managing climate risks and strengthening production resilience. Therefore, integrating climate change education with digital agricultural training may increase farmers' motivation to adopt drone-based monitoring systems as part of climate adaptation strategies.

In contrast, perceived cost negatively influenced farmers' acceptance, indicating that economic considerations remain a significant barrier to drone adoption. Although farmers recognize the potential advantages of drone technology, concerns regarding acquisition costs, maintenance expenses, and limited affordability may reduce their willingness to adopt the system. This finding highlights that technological benefits alone are insufficient to guarantee adoption, particularly among small-scale farmers who operate under financial constraints. The result differs from purely technology-oriented adoption perspectives that emphasize functional advantages, because in developing agricultural contexts economic feasibility remains a crucial determinant of innovation acceptance. Therefore, alternative adoption models, such as cooperative drone ownership, government-supported services, and technology rental systems, may reduce financial barriers and improve accessibility for farmers.

This study contributes to existing agricultural technology adoption literature by integrating technology acceptance factors with climate-resilient rice production objectives. Previous studies have primarily examined agricultural drones from the perspective of precision farming, operational efficiency, or technological capability, while this research highlights the role of farmers' acceptance as a bridge between technological innovation and climate adaptation. The inclusion of climate change awareness as an explanatory factor provides a broader understanding of why farmers may consider adopting drone-based monitoring systems. This perspective extends conventional technology acceptance research by demonstrating that agricultural technology adoption is shaped by the interaction between technological value, environmental awareness, economic feasibility, and institutional support.

From a practical perspective, the findings provide implications for policymakers, agricultural extension institutions, and technology providers. Successful implementation of drone-based crop monitoring systems requires strategies that combine technology introduction with farmer capacity building, financial accessibility, and institutional support. Training programs should focus not only on operational skills but also on explaining how drone information can improve farm decisions under climate uncertainty. Furthermore, policymakers should consider developing shared-service mechanisms or cooperative approaches to overcome cost barriers and ensure that small-scale farmers can access digital agricultural technologies.

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional survey design captures farmers' perceptions at a single point in time and cannot fully explain changes in acceptance behavior throughout different agricultural seasons. Second, this research focuses on farmers' acceptance intentions rather than actual drone usage behavior, meaning that positive perceptions may not always translate into real adoption. Third, the study was conducted in Grobogan Regency, which may limit the

generalization of findings to other rice-producing regions with different socio-economic, technological, and institutional conditions. Future research should employ longitudinal approaches, experimental studies, and comparative analyses across regions to examine how acceptance develops into actual technology adoption and contributes to long-term climate-resilient rice production.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that farmers' acceptance of drone-based crop monitoring systems for climate-resilient rice production is influenced by technological, economic, institutional, and environmental factors. The findings demonstrate that perceived usefulness, perceived ease of use, trust in technology, facilitating conditions, and climate change awareness positively contribute to farmers' acceptance, while perceived cost represents a significant barrier to adoption. These results indicate that the successful implementation of agricultural drone technology requires more than technological availability. It requires farmers to perceive clear benefits, develop confidence in the technology, receive adequate support, and understand its contribution to addressing climate-related agricultural challenges. The study provides evidence that farmer acceptance is an essential factor in transforming drone technology from an innovative tool into a practical strategy for strengthening climate-resilient rice production.

Based on these findings, it is recommended that agricultural stakeholders, including government institutions, extension services, technology providers, and farmer organizations, develop integrated strategies to support drone adoption. These strategies should include farmer training, field demonstrations, technical assistance, and affordable access mechanisms, such as shared drone services or cooperative-based utilization models. Reducing economic barriers should become a priority because cost perception remains one of the main challenges affecting farmers' willingness to adopt drone technology. Furthermore, integrating climate adaptation education with digital agricultural training may improve farmers' understanding of the role of drone-based monitoring systems in enhancing decision-making processes and managing production risks under increasing climate variability.

FURTHER STUDY

Future research should further investigate the transition from farmers' acceptance intentions to actual adoption behavior of drone-based crop monitoring systems. Since this study used a cross-sectional survey design, it only captured farmers' perceptions at a specific period and could not evaluate changes in acceptance over different agricultural seasons. Future studies are recommended to apply longitudinal approaches, experimental implementation, or comparative studies across different rice-producing regions to examine how technological acceptance develops into real utilization. In addition, future research may incorporate other factors such as digital literacy, government support, social influence, data privacy concerns, and actual economic benefits obtained from drone utilization to provide a more comprehensive understanding of agricultural technology adoption.

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