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Flying into the Future: Modelling Farmers' Acceptance of Agricultural Drones in Kedah, Malaysia using TAM and Economic Factors

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Abstract

The rapid advancement of agricultural drone technology has transformed farming practices globally, offering improvements in productivity, efficiency, and sustainability. In Malaysia, particularly in Kedah, one of the nation's primary agricultural regions where the potential benefits of drone adoption are evident; however, farmers' acceptance of the technology remains influenced by usability and economic considerations. This study examines the factors affecting the acceptance of agricultural drones among farmers in Kedah by integrating the Technology Acceptance Model (TAM) with economic perspectives. A quantitative research design was employed, whereby structured questionnaires were distributed to 385 farmers through social media platforms and agricultural agency networks. The data were analyzed using descriptive statistics, Pearson correlation, reliability testing, and multiple regression analysis. The findings reveal that Perceived Usefulness, Perceived Ease of Use, and Economic Factors significantly influence farmers' acceptance of agricultural drones. Perceived Usefulness emerged as the strongest predictor ($\beta = 0.728$), indicating that farmers are more likely to adopt drones when they perceive clear improvements in crop monitoring, yield, and operational efficiency. Perceived Ease of Use also had a positive effect ($\beta = 0.519$), suggesting that simplicity of operation encourages adoption. Economic Factors, while significant, showed a negative coefficient ($\beta = -0.424$), indicating that high initial costs may hinder adoption despite long-term benefits. Overall, the model explains 73.1% of the variance in drone acceptance ($R^2 = 0.731$). These findings highlight the need for cost-sharing schemes, training support, and policy incentives to ensure wider drone adoption and sustainable agricultural modernization in Malaysia.

Keywords: Agriculture Drones; Technology Adoption; Precision Agriculture; Perceived Usefulness; Perceived ease of use; Economic factors

1. Introduction

Agriculture plays a vital role in global economic development, food security, and rural livelihood sustainability, particularly in developing countries where a large proportion of the population depends on

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farming as a primary income source (FAO, 2022). The transition toward smart and precision agriculture has accelerated due to advancements in digital technologies, automation, and data-driven decision-making tools (Basso & Antle, 2020). Among these innovations, agricultural drones have gained prominence as efficient solutions for crop monitoring, pesticide application, yield estimation, and land management, enabling farmers to improve accuracy, reduce labor intensity, and enhance productivity (Mogili & Deepak, 2021; Tripicchio et al., 2022).

In Malaysia, the adoption of drone technology has been expanding, especially in major agricultural regions such as Kedah, which is known as the nation's primary rice producer (Department of Agriculture Malaysia, 2023). Government agencies such as MADA and the Ministry of Agriculture have introduced training programs and mechanization incentives to encourage farmers to shift toward modern agricultural technologies (MADA, 2022). However, despite these initiatives, drone adoption among farmers remains inconsistent and relatively limited (Abdullah et al., 2023). Many farmers still rely on traditional manual farming practices, perceiving drones as costly, technically complex, or unnecessary for their scale of operation (Karim & Samah, 2021).

Previous studies in Malaysia have tended to focus primarily on technical performance or agricultural productivity outcomes, while empirical studies examining farmers' perceptions, decision-making behavior, and economic considerations remain limited (Yusoff et al., 2022; Rahman & Anuar, 2023). This creates a knowledge gap, as understanding the behavioral and financial determinants of drone acceptance is necessary to support effective policy design, subsidy structures, and training frameworks. Addressing this gap is crucial to enabling Malaysia's transition toward modern, sustainable, and technology-driven agriculture in line with national smart-farming aspirations.

To explain farmers' decision-making toward drone usage, this study employs the Technology Acceptance Model (TAM), which proposes that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) influence technology adoption behavior (Davis, 1989; Venkatesh & Bala, 2020). Additionally, this study incorporates Economic Factors (EF), such as affordability, operational cost, and return on investment, as these financial considerations play a significant role in technology acceptance within agricultural contexts (Wang et al., 2023).

A quantitative research method is employed, utilizing a structured questionnaire distributed to farmers across Kedah, and the data are analyzed using descriptive statistics, correlation, and regression analysis. Therefore, the aim of this study is to examine the factors influencing the acceptance of agricultural drones among farmers in Kedah, integrating behavioral and economic perspectives to provide insights that support wider and more effective drone adoption in the agricultural sector.

2. Literature Review

2.1. Precision agriculture: Drone usage among farmers

Studies have shown that factors such as raising awareness of farm-specific applications, increasing confidence in drone usage, addressing labor factors, overcoming water scarcity, and enhancing productivity and quality of crops (Noor & Noel, 2023), as well as the positive effects of technology acceptance factors on perceived benefits and behavioral intention for agricultural drone service, play crucial roles in the acceptance of drone technology in agriculture. Additionally, the association between economic, social, and personal factors with drone utilization has been highlighted as significant, indicating a positive trend towards the adoption of drones in agriculture (Sundar et al., 2023d). Furthermore, the use of drones in smart agriculture, particularly in disease detection and crop management, has been emphasized as a promising technology that can revolutionize farming practices and enhance food supply chain safety (Kazi & Jahangir, 2023). Drones are being used more and more in agriculture because farmers are becoming more aware of the benefits of using them to address labor issues, water scarcity, and crop quality, as well as economic, social, and personal factors. Drones are particularly helpful for disease detection and crop management, which improves smart farming and food safety.

2.2. Perceived Ease of Use (PEOU)

PEOU refers to the degree to which an individual believes that using a particular technology will be free of effort (Davis, 1989; Venkatesh & Bala, 2020). In other words, when a technology is intuitive, simple to learn, and does not require high technical skill, users are more likely to adopt it (Li, Wang, & Chen, 2022). According to (Gohari et al., 2023), Kedah farmers have increasingly come to accept and find agricultural drones to be easier to utilize, particularly in the context of smart farming and modernizing agricultural operations. However, drone spraying dramatically increases field efficiency and yield in paddy fields when compared to manual spraying, highlighting the advantages of using drone technology in agriculture (Zaman et al., 2023). Malaysia has demonstrated its commitment to incorporating cutting-edge technologies like drones into the agricultural sector by establishing a legal framework for UAV operations in the country that guarantees safety, risk assessment, and conformity with international standards (Sundar et al., 2023). This industry has a great impact on the use of agricultural drone technology by farmers in Malaysia. Based on the discussion above, this study formulates the following hypothesis:
H1 : Perceived Ease of Use has a significant positive influence on the acceptance of agricultural drones among farmers in Kedah.

2.3. Perceived Usefulness (PU)

PU refers to the degree to which an individual believes that using a particular technology will enhance job performance (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989; Venkatesh & Davis, 2000; Venkatesh et al., 2003; Marangunić & Granić, 2015).). In technology adoption research, PU is regarded as a key determinant of behavioral intention, as users are more likely to adopt technologies that demonstrably improve productivity, efficiency, and overall outcomes (Venkatesh et al., 2012; Marikyan, Papagiannidis, & Alamanos, 2020). In the agricultural context, PU is commonly associated with benefits such as increased crop yield, cost reduction, labor savings, and improved decision-making, particularly through the application of precision farming technologies such as drones (Barnes et al., 2019; Rejeb et al., 2022). The integration of smart agricultural tools, including drones and digital data systems, has been shown to enhance operational efficiency and support sustainable farming practices, thereby reinforcing farmers' perceptions of the practical value of such technologies (Saiz-Rubio & Rovira-Más, 2020; Eastwood, Klerkx, & Nettle, 2019). Consequently, farmers are more inclined to adopt agricultural drones when they perceive clear performance improvements and tangible benefits in their farming activities. Based on the discussion above, this study formulates the following hypothesis:

H2: Perceived Usefulness has a significant positive influence on the acceptance of agricultural drones among farmers in Kedah.

2.4 Economic Factors (EF)

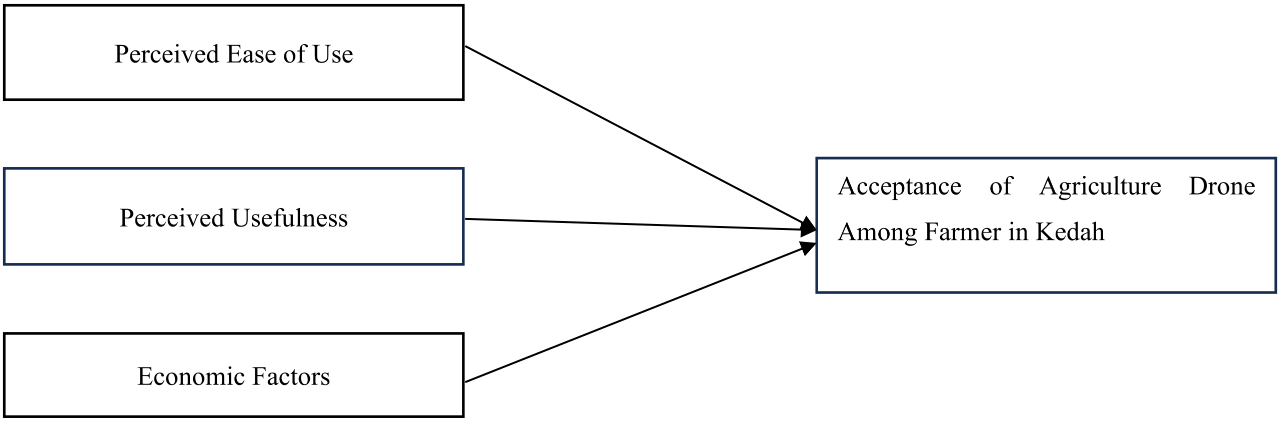
EF are widely recognized as critical determinants of technology adoption in agriculture, particularly for capital-intensive innovations such as agricultural drones. Prior research consistently shows that high initial acquisition costs, maintenance expenses, and uncertainty regarding financial returns constitute major barriers to adoption, especially among smallholder and resource-constrained farmers (Barnes et al., 2019; Rejeb et al., 2022). Farmers typically assess drone adoption through a cost benefit lens, where perceived return on investment, labor cost savings, optimized input usage, and yield improvement significantly influence adoption decisions (Ayamga, Tekinerdogan, & Kassahun, 2021; Saiz-Rubio & Rovira-Más, 2020). However, empirical studies also highlight that the presence of financial incentives such as government subsidies, shared ownership schemes, and access to affordable financing that plays a crucial role in lowering economic risk and accelerating adoption (Klerkx, Jakku, & Labarthe, 2019; Lioutas & Charatsari, 2020). Furthermore, affordability and cost-effectiveness are closely linked to farmers' risk perceptions, as adoption is more likely when economic uncertainty is mitigated through institutional support, demonstration of tangible financial benefits, and reduced compliance costs (Eastwood, Klerkx, & Nettle, 2019; Radoglou-Grammatikis et al., 2020). Collectively, prior findings suggest that economic factors extend beyond cost alone and encompass broader considerations of financial sustainability, incentives, and long-term profitability, justifying their integration with the Technology Acceptance Model to better explain agricultural drone adoption among farmers. Based on the discussion above, this study formulates the following hypothesis:

H3: Economic Factors have a significant influence on the acceptance of agricultural drones among farmers in Kedah.

2.5. Conceptual Framework

This study is based on the technology acceptance model, where PEOU refers to how easy they feel drones are to learn and operate, PU refers to farmers' belief that drones can improve their farming efficiency. In addition, EF is included to account for cost, affordability, and financial considerations that may influence adoption. Together, PEOU, PU and EF act as the independent variables that are expected to influence farmers' acceptance of agricultural drones as the dependent variable, as shown in Figure 1.

Figure 1: Conceptual framework of the study



3. Method

This study employed a quantitative research design to investigate the influence of PEOU, PU, and EF on farmers' acceptance of agricultural drones in Kedah. A structured questionnaire consisting of Likert-scale items was developed and distributed to farmers through agricultural agency networks, farmer associations, and social media channels such as WhatsApp and Telegram. 385 respondents answered the questionnaire which was structured in both English and Malay Language.

A sample of 385 respondents was determined using the Krejcie and Morgan (1970) sampling table to ensure adequate representativeness for statistical analysis. The collected data were analyzed using SPSS, which included reliability testing using Cronbach's Alpha, Pearson correlation analysis to examine relationships among variables, and multiple regression analysis to determine the predictive significance of the independent variables on drone acceptance.

4. Results and Discussion

4.1. Descriptive Analysis

This section presents the demographic profile of respondents and their perceptions regarding agricultural drone adoption in Kedah. A total of 385 farmers participated in the survey. Descriptive statistics were used to analyze demographic variables and responses to key constructs: PEOU, PU, and EF, and Acceptance of Agricultural Drones.

4.1.1 Demographic Analysis

Table 1 : Demographic Profile of Respondents

Demographic Profile of Respondents (N = 385)

Category	Subgroup	Frequency	Percentage (%)
Gender	Male	205	53.2
	Female	180	46.8
Age Group	18–25 years	97	25.2
	26–35 years	97	25.2
	36–45 years	143	37.1
	46 years and above	48	12.5
Ethnicity	Chinese	124	32.2
	Malay	113	29.4
	Indian	101	26.2
	Others (e.g., Bidayuh, Siam, Dusun)	47	11.4
Education Level	SPM	82	21.3
	Diploma / Matriculation / STPM / ASASI	93	24.2
	Degree	115	29.9
	Master's	65	16.9
	PhD	30	7.8

The demographic profile of the 385 respondents as in Table 1 reveals a diverse yet balanced representation of farmers in Kedah. A slight majority were male (53.2%), and the largest age group was 36–45 years (37.1%), indicating a mature and experienced farming population. Ethnically, Chinese respondents formed the largest group (32.2%), followed by Malays (29.4%) and Indians (26.2%), with a smaller proportion from other ethnic backgrounds (11.4%). In terms of education, most respondents held a degree (29.9%), while others had qualifications ranging from SPM (21.3%) to postgraduate levels, including Master's (16.9%) and PhD (7.8%). This demographic composition suggests a relatively educated and diverse farming community, well-positioned to engage with emerging agricultural technologies like drones.

4.1.2 Descriptive Analysis

The descriptive analysis as in Table 2 reveals that farmers in Kedah generally hold favorable perceptions of agricultural drones across all measured dimensions. PU received the highest average ratings, particularly for enhancing crop yield and monitoring crop conditions, with mean scores approaching 4.0. PEOU also scored positively, indicating that drones are seen as manageable and user-friendly. EF such as labor cost reduction and time savings were viewed as beneficial, though cost reasonableness scored slightly lower. Acceptance indicators showed consistent agreement on drones' effectiveness in boosting farm productivity. Overall, the data suggest strong potential for drone adoption, driven by perceived practicality, efficiency, and usefulness.

Table 2: Descriptive Analysis

Descriptive Analysis Table

No.	Variable	Statement	N	Min	Max	Mean	Std. Deviation
1	PEOU	I find agricultural drones easy to use in my farming activities.	385	1.0	5.0	3.7675	1.38920
2	PEOU	I find agricultural drones useful in my farming activities.	385	1.0	5.0	3.8052	1.09019
3	PEOU	I find agricultural drones easy to learn.	385	1.0	5.0	3.7662	1.17610
4	PEOU	I find agricultural drones flexible to interact with.	385	1.0	5.0	3.7662	1.17610
5	PEOU	I find agricultural drones easy to operate.	385	1.0	5.0	3.7922	1.17422
6	PEOU	I find agricultural drones clear and understandable to use.	385	1.0	5.0	3.7922	1.17422
7	PU	Agricultural drones increase my crop yield.	385	1.0	5.0	4.0000	1.11337
8	PU	Agricultural drones help improve crop yield.	385	1.0	5.0	3.9610	1.29055
9	PU	Agricultural drones are useful for monitoring crop health status.	385	1.0	5.0	3.6286	1.27087
10	PU	Agricultural drones are useful for monitoring crop health conditions.	385	1.0	5.0	3.6883	1.26505
11	PU	Agricultural drones are useful for monitoring crop condition.	385	1.0	5.0	3.8442	1.23918
12	PU	Agricultural drones are useful for observing crop condition.	385	1.0	5.0	3.8442	1.23918
13	PU	Agricultural drones are useful for tracking crop condition.	385	1.0	5.0	3.6449	1.23918
14	EF	The cost of using agricultural drone services is reasonable for my farm.	385	1.0	5.0	3.5606	1.32804
15	EF	Agricultural drone services can save time.	385	1.0	5.0	3.6649	1.05245
16	EF	Agricultural drone services can increase crop yields.	385	1.0	5.0	3.8052	1.05903
17	EF	Agricultural drone services can reduce labor cost.	385	1.0	5.0	3.8052	1.05903
18	Acceptance	I use agricultural drone services to increase agricultural productivity.	385	1.0	5.0	3.6442	1.16200
19	Acceptance	Agricultural drones are effective in increasing farm productivity.	385	1.0	5.0	3.6831	1.05245
20	Acceptance	Agricultural drone services are effective in increasing farm productivity.	385	1.0	5.0	3.8052	1.12236
21	Acceptance	Agricultural drone services are effective in increasing farm productivity.	385	1.0	5.0	3.7254	1.14421

4.2 Reliability Analysis

Table 3 : Correlations

Correlations	SC	SB1	SB2	SB3
Pearson Correlation				
SC	1.000	.756	.795	.565
SB1	.756	1.000	.782	.783
SB2	.795	.782	1.000	.800
SB3	.565	.783	.800	1.000
Sig. (1-tailed)				
SC	.	<.001	<.001	<.001
SB1	.000	.	.000	.000
SB2	.000	.000	.	.000
SB3	.000	.000	.000	.
N				
SC	385	385	385	385
SB1	385	385	385	385
SB2	385	385	385	385
SB3	385	385	385	385

Based on Table 3, the correlations were significant at the 0.000 level (1-tailed). All the independent variables showed significant 1-tailed correlations with the dependent variable. First, the dependent variable, Acceptance of Agriculture Drones Among Farmers in Kedah, demonstrated a strong correlation with PU, with a value of 0.795. This indicates a strong relationship. Secondly, PEOU showed a moderate correlation with the dependent variable, with a value of 0.756. Lastly, EF also displayed a strong correlation with the dependent variable, with a value of 0.565.

4.3 Multiple Regression Analysis

Table 4: Multiple Linear Regression of all variable

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	.855	.731	.729	.44948	.731

a. Predictors: (Constant), SB3, SB1, SB2

b. Dependent Variable: SC

According to the results of the Multiple Regression Analysis (Table 4), the correlation coefficient (R) value is 0.855, indicating that the three independent variables (IVs), PEOU, PU, and EF , are highly correlated with the dependent variable. This suggests that the respondents have a positive perception of the acceptance of agriculture drones among farmers in Kedah. The R-Square value of 0.731 indicates that 73.1% of the variance in the acceptance of agriculture drones among farmers in Kedah is explained by these independent variables.

4.4 Coefficient

Table 5: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
1 (Constant)	.427	.123		3.475	<.001
SB1	.609	.055	.519	11.052	<.001
SB2	.683	.046	.728	14.956	<.001
SB3	-.392	.045	-.424	-8.698	<.001

Based on Model 1 in the table above, the coefficients reveal significant relationships between the independent variables and the dependent variable, which is the acceptance of agricultural drones among farmers in Kedah.

The regression analysis revealed that all three independent variables i.e. PEOU, PU, and EF significantly influence the acceptance of agricultural drones among farmers in Kedah. PEOU showed a positive and significant relationship (p = 0.001), indicating that farmers are more likely to adopt drones when they find them easy to use. Similarly, PU demonstrated a strong positive effect (p = 0.001), emphasizing that the perceived benefits and practicality of drones play a crucial role in encouraging adoption. Although EF exhibited a negative coefficient, it remained statistically significant (p = 0.001), suggesting that economic considerations, such as cost and affordability, also impact acceptance. Overall, these results confirm that ease of use, PEOU, PU and EF are key determinants of farmers' acceptance of agricultural drones.

4.5 Hypothesis Testing

Regression analysis was conducted to examine the influence of PEOU, PU and EF on the acceptance of agricultural drones among farmers in Kedah. The analysis determined the significance of these relationships using p-values, where a p-value below 0.05 indicates a significant effect. The results show that all three independent variables significantly influence the acceptance of agricultural drones. Specifically, PEOU (p = 0.001), PU (p = 0.001), and EF (p = 0.001) each demonstrated significant positive relationships with drone acceptance. Hence, all alternative hypotheses (H1, H2, and H3) were supported. These findings highlight that technological and economic considerations play a crucial role in determining farmers' willingness to adopt drone technology in agricultural practices.

Table 6: Summary of Hypothesis Testing Results

Hypothesis	Statement	p-value	Result
H1	Perceived Ease of Use has a significant positive influence on the acceptance of agricultural drones among farmers in Kedah.	0.001	Supported
H2	Perceived Usefulness has a significant positive influence on the acceptance of agricultural drones among farmers in Kedah.	0.001	Supported
H3	Economic Factors have a significant influence on the acceptance of agricultural drones among farmers in Kedah.	0.001	Supported

5.0 Discussion of findings

This study aimed to examine the key factors influencing the acceptance and adoption of agricultural drones among farmers in Kedah, focusing on three primary constructs derived from the Technology Acceptance Model (TAM) i.e. PEOU, PU and an additional variable, EF. The results of the descriptive, correlation, and regression analyses provide strong empirical support for the hypothesized relationships between these variables and the acceptance of agricultural drones.

The findings reveal that all three independent variables PEOU, PU, and EF have significant effects on the acceptance of agricultural drones, as indicated by their p-values ($p = 0.001$). Among them, PU emerged as the most influential factor, demonstrating the strongest standardized coefficient ($\beta = 0.728$). This suggests that farmers' decision to adopt drone technology is primarily motivated by their perception of its practical benefits, such as improving crop yield, enhancing monitoring efficiency, and reducing manual labor. These findings are consistent with previous research by Davis (1989), Davis, Bagozzi, & Warshaw, (1989), Venkatesh & Davis (2000) and Venkatesh et al. (2003). Furthermore, recent agricultural and digital innovation studies similarly report that farmers are more inclined to adopt advanced technologies when clear economic and operational benefits are evident (Barnes et al., 2019; Rejeb et al., 2022; Saiz-Rubio & Rovira-Más, 2020).

PEOU also showed a significant positive relationship with drone acceptance ($\beta = 0.519$), indicating that farmers are more likely to adopt technologies they find simple and user-friendly. This aligns with the core assumption of TAM that ease of use enhances PU and adoption intention (Gohari et al., 2023). In this study, farmers expressed favorable views toward the usability of drones, particularly regarding their operation, flexibility, and ability to simplify farming processes. The result suggests that simplifying drone interfaces, providing hands-on training, and offering user support can further strengthen acceptance among farmers.

Interestingly, EF exhibited a negative but statistically significant relationship with drone acceptance ($\beta = -0.424$), indicating that cost-related concerns remain a substantial barrier despite the acknowledged usefulness and usability of drones. While farmers recognize the long-term economic advantages of drone adoption such as labor cost savings, optimized input usage, and yield improvement, the high initial investment and associated financial risks discourage immediate uptake. This finding is consistent with prior research showing that affordability, access to capital, and perceived return on investment play decisive roles in agricultural technology adoption (Barnes et al., 2019; Rejeb et al., 2022). Recent studies further emphasize that financial incentives, including subsidies, cooperative ownership models, and access to low-interest financing, are crucial in mitigating economic risks and accelerating adoption (Klerkx, Jakku, & Labarthe, 2019; Lioutas & Charatsari, 2020; Eastwood, Klerkx, & Nettle, 2019). Without such economic support mechanisms, even highly beneficial technologies may face resistance among small and medium scale farmers.

Overall, the regression model demonstrated strong explanatory power ($R^2 = 0.731$), indicating that 73.1% of the variance in the acceptance of agricultural drones can be explained by the three predictor variables. This supports the robustness of the proposed framework, integrating technological and economic perspectives in explaining technology adoption behavior among farmers. The strong inter-correlations among variables ($r = 0.756$ to 0.795) further underscore the interconnectedness of PEOU, PU, and EF in shaping farmers' attitudes toward drones.

In summary, this study confirms that PU is the most dominant predictor of agricultural drone acceptance in Kedah, followed by PEOU and EF. The findings contribute to both theoretical and practical understanding of technology acceptance in agriculture, reinforcing the relevance of TAM in the context of emerging economies while highlighting the need for supportive economic policies and user-centered technological design to ensure sustainable adoption of drone technology in farming.

6.0 Implications

This study offers both theoretical and managerial contributions to the understanding of agricultural drone adoption among farmers in Kedah. Theoretically, it validates the influence of PEOU, PU, and EF as key determinants, thereby extending technology acceptance models within the agricultural innovation context. Managerially, the findings provide actionable insights for stakeholders such as policymakers, agricultural agencies, and drone providers, highlighting the need for user-friendly drone designs, targeted training initiatives, and financial support mechanisms like subsidies or affordable service packages to enhance adoption and reduce economic barriers.

7.0 Conclusion

In conclusion, this study successfully explored the factors influencing the acceptance and adoption of agricultural drones among farmers in Kedah. Drawing on data from 385 respondents, the findings revealed that PEOU, PU, and EF significantly affect farmers' acceptance, with PU emerging as the strongest determinant. Theoretically, the study enhances existing technology acceptance models by providing empirical evidence on agricultural innovation adoption, while managerially, it offers valuable insights for policymakers, agricultural agencies, and drone developers to design user-friendly, cost-effective, and training-supported drone solutions. Although the study faced certain limitations such as time constraints, limited geographical scope, and respondent diversity, it contributes meaningfully to the understanding of technology adoption in agriculture. Future research should expand the scope to other regions, integrate emerging technologies, and adopt longitudinal and qualitative approaches to gain a deeper, more comprehensive understanding of drone adoption dynamics and their potential to drive sustainable agricultural transformation.

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