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Adoption of Climate Change Adaptation Practices and Farm Income among Crop Farmers in Hue City, Vietnam

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HIGHLIGHTS

- 65.9% of farmers adopted climate change adaptation practices.
- Climate knowledge, farm size, and distance significantly influence adoption decisions.
- Adoption increases farm income by approximately 35%.
- Knowledge-based extension systems are crucial for effective and inclusive adaptation.

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Keywords: Climate change adaptation, Crop income, Smallholder farmers, Climate knowledge, Adoption behavior, Vietnam.

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ABSTRACT

Climate change poses significant challenges to crop production and rural livelihoods in developing countries. This study examines the determinants of climate change adaptation and its association with crop income among farming households in Hue City, Vietnam. Primary data were collected from 337 households in 2025. A binary logit model was applied to analyze adaptation decisions, while an Ordinary Least Squares (OLS) model with robust standard errors was applied to examine income outcomes. The results show that 65.9% of households adopted at least one climate change adaptation practice. Climate knowledge, agricultural land size, and age positively influenced adaptation adoption, whereas distance to economic centers reduced the likelihood of adoption. Adaptation adoption was positively associated with crop income per hectare, with adopters tending to achieve higher income than non-adopters. In addition, skilled labor, community participation, and climate knowledge were positively associated with income outcomes, whereas remoteness showed a negative relationship with income. The findings suggest that climate knowledge, resource endowments, and accessibility conditions are important factors shaping both adaptation behavior and economic outcomes among farming households. The study highlights the importance of strengthening knowledge-based agricultural extension and improving access to information and rural services to support effective climate change adaptation.

INTRODUCTION

The increasing frequency and intensity of extreme weather events, including droughts, erratic rainfall, and heatwaves, have significantly reduced crop productivity, disrupted farming systems, and threatened rural incomes. Empirical evidence consistently shows that climate change not only lowers agricultural yields but also intensifies farmers' vulnerability to environmental and economic shocks (Acevedo et al., 2020; Grigorieva et al., 2023; Islam & Farjana, 2024; Xian-Kang et al., 2024). In response, the adoption of climate change adaptation practices has been widely promoted as a key strategy to enhance resilience and sustain agricultural production. These practices, commonly framed under Climate-Smart Agriculture (CSA), include drought-tolerant crop varieties, adjusted planting calendars, water-saving irrigation, and sustainable land management. Previous studies demonstrate that such practices can mitigate climate risks while improving productivity and farm income (Ma & Rahut, 2024). However, their

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adoption critically depends on farmers' access to relevant information, technical knowledge, and institutional support.

Through extension services, farmers can access climate information, receive technical guidance, and improve their ability to implement appropriate adaptation strategies. However, previous studies suggest that extension access alone does not necessarily result in effective adaptation, particularly when information dissemination is not sufficiently relevant, localized, or responsive to farmers' needs (Davis et al., 2021). In this context, climate knowledge plays a critical role in shaping farmers' perceptions and adaptive behavior. Farmers with better understanding of climate risks and adaptation options are more likely to evaluate the potential benefits of adaptation practices and implement appropriate responses. In this study, extension access is measured as a binary variable indicating whether a household has received extension services, while climate knowledge is measured as a composite index reflecting farmers' understanding of climate change and adaptation practices. Both variables are included in the empirical model to capture their roles in influencing adaptation behavior and crop income outcomes.

The adoption of climate change adaptation practices can be explained using established theoretical frameworks. The Diffusion of Innovations theory (Rogers, 2003) highlights the role of information, perception, and social learning in shaping adoption behavior, while the Random Utility Theory (McFadden, 1972) suggests that farmers adopt new practices when expected benefits outweigh associated costs and risks. Empirical studies consistently identify key determinants of adoption, including education, farm size, access to extension services, and climate information (Finizola e Silva et al., 2024; Shitu et al., 2024; Gashure, 2024; Lamichhane et al., 2022). However, existing research has largely focused on identifying adoption determinants, with relatively limited attention to the mechanisms linking extension systems, knowledge dissemination, and economic outcomes. Evidence indicates that constraints such as limited access to climate information and institutional support continue to hinder effective adaptation among smallholder farmers (Incoom et al., 2025).

In Vietnam, empirical evidence on climate change adaptation at the household level remains limited and fragmented. Existing studies mainly examine factors affecting adoption, while the role of extension systems and climate knowledge in shaping income outcomes remains underexplored (Bien et al., 2022; Ferrer et al., 2023; Nhuong et al., 2025). This gap is particularly relevant in Central Vietnam, where agricultural systems are highly exposed to climate risks and rural livelihoods depend heavily on crop production.

METHODOLOGY

The study was conducted in Hue City, Vietnam, covering both lowland and mountainous agro-ecological zones. These areas are characterized by smallholder-based farming systems that are highly vulnerable to climate variability, particularly droughts and heavy rainfall. Differences in agro-ecological conditions also reflect variations in farmers' access to markets, infrastructure, and agricultural extension services.

Primary data were collected through a structured household survey conducted in 2025 in both lowland and mountainous areas of Hue City, Central Vietnam. A stratified random sampling approach was employed to ensure representation across different agro-ecological conditions. Specifically, the sample was stratified by agro-ecological zones, including lowland and mountainous areas. The sample size was determined using the Yamane (1967) formula at a 95% confidence level and a 5% margin of error, resulting in a target sample of approximately 350 households. A total of 350 households were surveyed, and after data cleaning, 337 valid observations were retained for analysis.

Among the surveyed households, 191 were selected from lowland areas and 146 from mountainous areas. In the lowland zone, 171 households were adopters and 20 were non-adopters of climate change adaptation practices, while in the mountainous zone, 51 households were adopters and 95 were non-adopters. This stratification approach was used to capture differences in agro-ecological conditions and adaptation behavior among farming households. Data were collected through face-to-face interviews with household heads using a structured questionnaire. The questionnaire gathered information on household socio-economic characteristics, production conditions, access to extension services, climate knowledge, adaptation practices, and crop income. Prior to the official survey, the questionnaire was pre-tested with 15 households to assess clarity, reliability, and contextual relevance. Feedback from the pre-test was used to refine and improve the survey instrument before field implementation.

Two dependent variables were defined. First, adaptation adoption (Adapt) is a binary variable equal to 1 if a household adopts at least one adaptation practice, and 0 otherwise. Second, crop income (Income) is measured as annual income from crop production (VND per hectare). Due to skewness, the natural logarithm of income is used in the regression analysis.

The selection of explanatory variables is guided by the Diffusion of Innovations theory (Rogers, 2003) and Random Utility Theory (McFadden, 1972). Accordingly, variables are grouped into four categories: (i) household characteristics (ii) economic resources (iii) institutional and market factors and (iv) perception-related factors.

Household characteristics include age (years), education (years of schooling), labor (number of working household members), and skilled labor (number of members with technical or vocational training). Economic resources are represented by agricultural land (hectares) and distance to economic centers (kilometers), capturing production capacity and accessibility constraints.

Institutional and market factors include extension access, measured as a binary variable (1 = household has received extension services; 0 = otherwise), community participation (1 = participation in local organizations; 0 = otherwise), and market linkage (1 = household has established market connections; 0 = otherwise).

Perception-related factors are captured by climate knowledge, which is constructed as a composite index based on farmers' self-reported understanding of climate change and adaptation practices using a Likert scale. This variable reflects the extent to which farmers internalize and utilize information relevant to adaptation decisions.

Climate knowledge was measured using a composite index constructed from five Likert-scale items capturing farmers' understanding of climate change, awareness of climate-related risks, perceived changes in temperature and rainfall patterns, knowledge of adaptation practices, and confidence in applying adaptation measures. Each item was rated on a five-point scale ranging from 1 (very low) to 5 (very high).

The climate knowledge index was calculated as the average score across all items, with higher values indicating greater climate knowledge. The reliability of the scale was assessed using Cronbach's alpha, yielding a value of 0.94, indicating good internal consistency. These variables are expected to influence both adoption decisions and income outcomes.

To examine the determinants of adaptation adoption, a binary logistic regression model is employed:

$$P\ (\text{Adaptation}_i = 1) = F(ZiY)$$

Where, Adaptation_i denotes the adoption decision of household_i; Zi is a vector of explanatory variables; Y is a vector of parameters to be estimated; and F(·) represents the logistic cumulative distribution function.

To estimate the impact of adaptation on farm income, the study applies an Ordinary Least Squares (OLS) model:

$$\text{Ln}(\text{Income}_i) = \beta_0 + \beta_1\ \text{Adaptation}_i + \beta_2 X_i + \varepsilon_i$$

Where Income_i represents crop income per hectare of household i; Adaption_i is a binary variable indicating adoption; X_i is a vector of control variables; β denotes parameters to be estimated; and ε_i is the error term. The coefficient β_1 captures the income difference between adopters and non-adopters. Robust standard errors are used to address heteroscedasticity.

RESULTS

The descriptive statistics in Table 1 indicate that farming households are characterized by small-scale production systems and moderate human capital, which are likely to influence both adaptation behavior and crop income outcomes. The average agricultural landholding is relatively small (0.5 ha), confirming the dominance of smallholder farming in the study area. Although limited land size may constrain production capacity, households with relatively larger landholdings may possess greater resources and incentives to invest in adaptation practices.

Education levels remain modest, averaging 7.9 years of schooling, while the number of skilled laborers is relatively low (0.7 persons per household). These characteristics suggest limited technical and managerial capacity, which may reduce farmers' ability to adopt and effectively implement knowledge-intensive adaptation practices. In addition, households are located an average of 7.7 km from commune centers, implying potential difficulties in accessing markets, agricultural inputs, climate information, and extension services. Such accessibility constraints may negatively affect both adaptation adoption and farm income.

Table 1. Socio-economic characteristics of surveyed households

Variables	Mean	Std. Dev.
Age (years)	50.4	10.7
Education (years)	7.9	3.9
Labor (persons)	2.5	0.9
Skilled labor (persons)	0.7	0.7
Agricultural land (ha)	0.5	0.6
Distance to center (km)	7.7	10.2
Credit access (yes=1)	0.7	0.5
Extension access (yes=1)	0.6	0.5
Community participation (yes=1)	0.3	0.4
Market linkage (yes=1)	0.4	0.5
Climate knowledge (Likert 1-5)	2.2	1.2
Crop income per hectare (million VND)	58.1	40.4

Access to institutional support appears moderate, with 70% of households having access to credit and 60% reporting access to extension services. However, participation in community organizations (30%) and market linkages (40%) remains relatively limited, indicating weak social and market integration that may constrain information exchange and economic opportunities. Climate knowledge is also modest, with an average score of 2.2 on a five-point scale, reflecting limited awareness and understanding of climate change and adaptation practices.

Crop income per hectare shows considerable variation across households, with an average of 58.1 million VND per hectare, suggesting substantial heterogeneity in production performance. Overall, the descriptive statistics highlight that resource availability, human capital, climate knowledge, and accessibility conditions are likely to play important roles in shaping households' adaptation decisions and income outcomes.

Adoption of climate change adaptation practices

Figure 1 shows that 65.9% of households adopt at least one climate change adaptation practice, indicating a moderate level of engagement. However, adoption is uneven across practices. Farmers mainly adopt simple and low-cost measures, particularly drought-tolerant varieties (57.6%) and adjustments in planting calendars (40.6%).

In contrast, the uptake of more technical practices remains limited, including soil conservation (23.6%), water-saving irrigation (8.3%), and integrated pest management (6.2%). The adoption of sustainable practices, such as VietGAP and organic farming, is also relatively low (5.9%). Overall, adaptation is concentrated in accessible and less resource-intensive strategies, while more advanced practices are less widely implemented.

Comparison of crop income between adopters and non-adopters

The comparison results in Table 2 reveal a clear and statistically significant difference in crop income between adopters and non-adopters. Households adopting adaptation practices achieve a higher average income (67.5 million VND/ha) than non-adopters (40.1 million VND/ha), with a mean difference of 27.4 million VND/ha.

The independent samples t-test confirms that this difference is statistically significant at the 1% level ($t = 6.21$, $p < 0.01$). This provides strong descriptive evidence that adaptation is associated with improved economic outcomes.

Determinants of adoption of climate change adaptation practices

The logit results (Table 3) indicate that the model is statistically significant (LR $\chi^2 = 221.48$, $p < 0.01$) with strong explanatory power (Pseudo $R^2 = 0.512$). Among variables, climate knowledge, agricultural land size, age, and distance to economic centers are identified as key determinants of adaptation adoption.

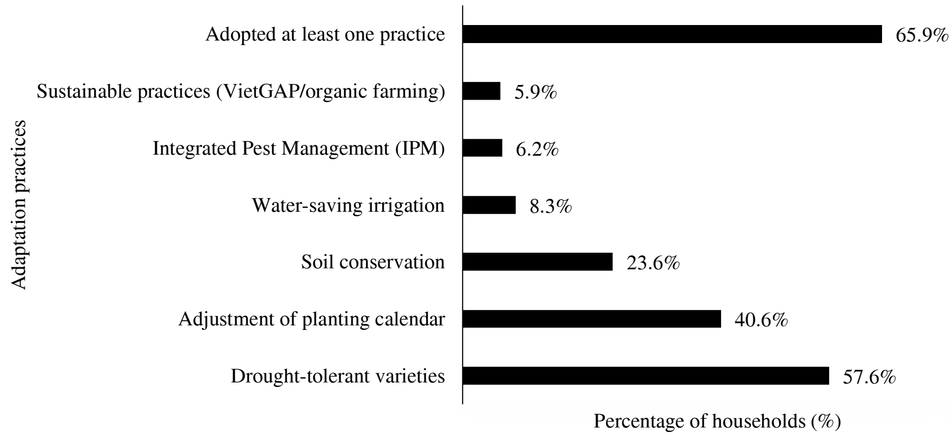

Figure 1. Adoption of climate change adaptation practices among surveyed households
Note: Multiple responses were allowed; therefore, percentages do not sum to 100%.

Table 2. Comparison of Crop Income between Adopters and Non-adopters

Group	Observations	Mean (million VND/ha)	Std. Dev.
Non-adopters	115	40.1	43.5
Adopters	222	67.5	35.5
Difference		27.4***	

t-value = 6.21; p-value = 0.000
Note: *** denotes significance at 1% level.

Climate knowledge is the most influential factor, increasing the probability of adoption by approximately 14.6 percentage points. Agricultural land also has a strong positive effect, raising adoption likelihood by about 26.9 percentage points. Age shows a positive and significant effect, suggesting that more experienced farmers are more likely to adopt adaptation practices.

In contrast, distance to economic centers negatively affects adoption, reducing the probability by approximately 0.96 percentage points per kilometer. Other variables, including education, labor, skilled labor, credit access, extension access, community participation, and market linkage, are not statistically significant among variables.

Impact of climate change adaptation on crop income

The OLS results with robust standard errors presented in Table 4 indicate that the model is statistically significant ($F = 16.73$, $p < 0.01$) and explains a substantial proportion of the variation in crop income per hectare ($R^2 = 0.468$). The relatively low mean VIF value (1.59) further suggests that multicollinearity is not a concern in the model.

Among variables, adoption is positively and significantly associated with crop income ($\beta = 0.350$, $p < 0.01$), suggesting that households adopting at least one climate change adaptation practice tend to achieve approximately 35% higher income per hectare than non-adopters, holding other factors constant. However, this relationship should be interpreted cautiously as an association rather than a strict causal effect due to the cross-sectional nature of the data and the potential presence of selection bias.

Several household and institutional characteristics are also significantly associated with income outcomes. Skilled labor, community participation, and climate knowledge exhibit positive and statistically significant relationships with crop income, highlighting the importance of technical capacity, social networks, and farmers' awareness in improving farm performance. Age is also positively associated with income, suggesting that farming experience contributes to better production outcomes.

In contrast, labor, agricultural land size, and distance to economic centers are negatively associated with crop income per hectare. The negative coefficient of agricultural land ($\beta = -0.411$, $p < 0.01$) indicates that households with larger landholdings tend to obtain lower income per unit of land. Since the dependent variable

Table 3. Determinants of Climate Change Adaptation (Logit Model)

Variables	Coefficient	Std. Error	Marginal Effect	Std. Error
Age	0.062***	0.016	0.006***	0.001
Education	0.067	0.048	0.007	0.005
Labor	-0.016	0.212	-0.002	0.021
Skilled labor	-0.352	0.242	-0.035	0.024
Agricultural land	2.713***	0.817	0.269***	0.076
Distance to center	-0.096***	0.022	-0.010***	0.002
Credit access	-0.153	0.391	-0.015	0.039
Extension access	-0.091	0.386	-0.009	0.038
Community participation	-0.379	0.736	-0.038	0.073
Market linkage	0.735	0.526	0.073	0.051
Climate knowledge	1.476***	0.297	0.146***	0.025
Constant	-5.612***	1.247		

Observations = 337, LR $\chi^2 = 221.48$*** , Prob > $\chi^2 = 0.000$, Pseudo $R^2 = 0.512$
Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
Marginal effects are reported as average marginal effects.

Table 4. Impact of Climate Change Adaptation on Crop Income (OLS with Robust Standard Errors)

Variables	Coefficient	Robust Std. Error
Adoption (1 = yes)	0.350***	0.108
Age	0.010**	0.004
Education	0.014	0.010
Labor	-0.089**	0.041
Skilled labor	0.179***	0.038
Agricultural land	-0.411***	0.123
Distance to center	-0.027***	0.005
Credit access	0.123*	0.075
Extension access	0.093	0.092
Community participation	0.323***	0.120
Market linkage	-0.048	0.111
Climate knowledge	0.110***	0.034
Constant	3.055***	0.250

Observations = 337, $R^2 = 0.468$
F-statistic = 16.73*** Root MSE = 0.606Mean VIF = 1.59
*Note: *** p < 0.01; ** p < 0.05; * p < 0.10.*
Dependent variable is the natural logarithm of crop income per hectare.

is measured as income per hectare rather than total household income, this result may reflect differences in land-use intensity and management efficiency across farm sizes. Larger farms may face constraints related to labor allocation, supervision, and input intensity, resulting in lower productivity per hectare compared to smaller and more intensively managed farms.

Distance to economic centers is also negatively associated with income, implying that remoteness limits access to markets, information, and production inputs. Credit access shows a weak positive association at the 10% significance level, while education, extension access, and market linkage are not statistically significant in the model. Overall, the findings suggest that adaptation behavior, human capital, climate knowledge, and accessibility conditions are closely associated with crop income outcomes among farming households.

DISSCUSION

The findings provide consistent evidence that climate knowledge, resource endowments, and accessibility jointly shape both adaptation behavior and income outcomes. Among these factors, climate knowledge emerges as the most influential determinant of adoption, highlighting the critical role of farmers' awareness and understanding of climate risks and adaptation options in decision-making. This result is consistent with previous studies emphasizing the importance of information and learning in promoting climate-smart agriculture (Ma & Rahut, 2024; Mishra et al., 2025).

Importantly, access to extension services alone does not show a significant effect on adoption. This suggests that the effectiveness of extension systems depends less on coverage and more on the quality and relevance of knowledge dissemination. In this context, climate knowledge can be interpreted as a key transmission channel through which extension services influence farmers' behavior (Ghanghas et al., 2015). This interpretation aligns with Patra et al. (2023) and is further supported by Davis et al. (2021), who argue that extension services are most effective when they enhance farmers' knowledge and technical capacity rather than merely expanding access.

Resource endowments also play a key role. The positive effect of agricultural land on adoption indicates that households with greater resources are better positioned to invest in adaptation practices. At the same time, the strong positive impact of skilled labor on income highlights the importance of technical capacity in improving farm performance. This finding is consistent with Abate et al. (2023) and Davis et al. (2021), who emphasize that farmers with higher technical skills are more capable of effectively implementing improved agricultural practices. In contrast, the negative effect of labor suggests diminishing returns or inefficiencies in labor use, implying that labor quality may be more important than quantity.

Accessibility constraints further shape both adoption and income outcomes. The negative effect of distance to economic centers confirms that remoteness limits access to markets, inputs, and information, thereby reducing both the likelihood of adoption and economic performance. This result is consistent with studies highlighting the importance of infrastructure and market access in facilitating technology uptake and improving livelihoods (Finizola e Silva et al., 2024).

The positive association between adaptation adoption and crop income suggests that climate change adaptation practices may contribute to improved farm performance among farming households. Households adopting adaptation practices tend to achieve higher income per hectare, implying that adaptation may help enhance production efficiency and reduce climate-related production risks. This finding is consistent with previous studies showing that climate-smart agricultural practices can generate both economic and environmental benefits for smallholder farmers (Bello et al., 2024; Xian-Kang et al., 2024). However, given the cross-sectional nature of the data, the observed relationship should be interpreted as an.

The negative relationship between agricultural land size and crop income per hectare appears counterintuitive at first; however, it is consistent with the characteristics of smallholder farming systems in developing countries. Because the dependent variable is measured as income per hectare, larger landholdings do not necessarily generate higher land productivity. In many cases, small-scale farmers intensify production through closer supervision, higher labor input, and more efficient use of resources, thereby achieving higher returns per unit of land. In contrast, households with larger farms may face difficulties in maintaining the same level of management intensity and input application across all plots, resulting in lower productivity per hectare.

This finding is consistent with the inverse farm size-productivity relationship widely documented in agricultural economics. Amartya Sen argued that small farms often achieve higher land productivity due to more intensive labor use and closer management (Sen, 1966). Similar evidence has been reported in empirical studies on smallholder agriculture in developing countries, where land expansion is not always accompanied by proportional increases in productivity or income efficiency (Barrett et al., 2010; Larson et al., 2014). The result therefore highlights that improving technical efficiency and resource management may be more important than farm expansion in enhancing crop income performance.

Finally, the positive effects of community participation and climate knowledge on income highlight the role of social capital and learning in enhancing farm performance. Social networks facilitate information exchange, collective action, and access to resources, thereby improving economic outcomes. Overall, the results suggest a coherent mechanism in which extension systems, through knowledge dissemination, influence adoption behavior, which in turn contributes to improved income outcomes.

The findings suggest several important policy implications. First, improving the quality of agricultural extension services is essential, with greater emphasis on strengthening farmers' climate knowledge rather than simply expanding service coverage. Extension programs should prioritize practical, location-specific, and demand-driven training. Second, targeted support should be directed toward resource-constrained households, particularly those with limited land and technical capacity, to reduce barriers to adopting advanced practices. Third, improving rural infrastructure and market connectivity is critical to mitigate the negative effects of remoteness. Finally, promoting community-based approaches and farmer organizations can enhance knowledge sharing and collective action, thereby strengthening both adaptation capacity and income outcomes. Together, these measures can support more effective and inclusive climate change adaptation in agriculture.

CONCLUSION

The findings reveal that climate knowledge, agricultural land size, age, and distance to economic centers are important factors associated with adaptation adoption. Among these variables, climate knowledge emerged as the strongest predictor, highlighting the critical role of awareness and information in shaping farmers' adaptation decisions. The results also show that households adopting at least one adaptation practice tend to achieve significantly higher crop income per hectare than non-adopters. In addition, skilled labor, community participation, and climate knowledge are positively associated with income outcomes, while remoteness negatively affects both adaptation and farm performance. Policies should focus not only on expanding extension coverage but also on improving the quality, relevance, and accessibility of climate-related information and technical support. Greater attention should also be given to improving rural infrastructure, market access, and support for resource-constrained households, particularly in mountainous areas.

DECLARATIONS

Ethical approval and consent to participate: This study was conducted in accordance with ethical standards. Informed consent was obtained from all respondents prior to data collection.

Conflict of interest: The authors declare that they have no conflict of interest.

Data availability: The data used in this study are available from the corresponding author upon reasonable request.

Author contributions: All authors contributed to the study conception and design. Data collection and analysis were performed by the authors. All authors read and approved the final manuscript.

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