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ADAPTATION STRATEGIES AND CONSTRAINTS TO CLIMATE CHANGE AMONG CLOVE FARMERS IN EAST KOLAKA

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Abstract

Background: Climate change has become a major challenge for agriculture in tropical regions, particularly in East Kolaka, Southeast Sulawesi, where cloves are a vital economic crop. Gaining insight into how farmers respond to and adapt to these climatic shifts is essential for formulating effective and sustainable climate resilience policies.
Purpose: This study explores the range of adaptation strategies employed by clove farmers, identifies the socioeconomic factors shaping their strategic choices, analyzes the interconnections among different adaptation measures, and evaluates the primary barriers that constrain adaptation in East Kolaka.
Design/Methodology/Approach: Primary data were obtained from 138 clove farmers in Anggaloosi Village, East Kolaka Regency, Indonesia. Descriptive statistical techniques were applied to describe the adaptation strategies used. The multivariate probit model was utilized to determine the influencing factors and interrelations among the strategies, while the Constraint Facing Index (CFI) method was used to assess the dominant obstacles faced by farmers in adapting to climate change.
Findings/Results: Findings revealed that 80.43% of farmers participated in training and extension programs, 73.19% utilized climate information, 71.01% implemented irrigation improvements, and 65.94% diversified their income sources. Access to extension services emerged as the most significant determinant of adaptation behavior. Several adaptation strategies were found to be complementary or substitutive. The main challenge faced by clove farmers at the research location is environmental obstacles, namely, unpredictable changes in weather patterns, with a score of 305 at a very high level of obstacles.
Conclusion: The study highlights that successful adaptation among clove farmers largely relies on increased access to agricultural extension, climate-related information, and financial assistance.
Originality/value (State of the art): This study adds to the scarce body of empirical evidence concerning climate change adaptation in perennial crops such as cloves in Indonesia. By combining the Multivariate Probit and Constraint Facing Index (CFI) approaches, this study provides an integrated analysis of both the determinants and barriers to adaptation, generating valuable implications for policymakers and practitioners in designing localized and inclusive climate adaptation strategies.

Keywords: adaptation strategies, climate change, multivariate probit, cloves, southeast Sulawesi

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INTRODUCTION

Currently, climate change is a global threat that is important for people around the world to pay attention to (Sekiyama, 2022). The causes of climate change are very varied, and are also supported by various interesting things, where low-income countries and those with very little involvement in climate change are the countries that feel the impact of climate change the most, (Dhakal et al.2022) and has the potential to threaten various sectors, especially the agricultural and fisheries sectors. The Intergovernmental Panel on Climate Change (IPCC) reported that Asian countries are vulnerable to climate change, particularly in South Asia and Southeast Asia. (IPCC, 2023). In Indonesia, farmers increasingly face multiple challenges, such as rising temperatures, erratic rainfall, and sea level rise. A study by the Asian Development Bank showed a productivity decline of approximately 25% in Indonesia's agricultural sector due to climate change. Agricultural commodities, particularly cloves, are highly dependent on a stable climate, and this commodity is one of the most affected (Onyeneke et al.2023).

Clove (Syzygium aromaticum) is one of Indonesia's key export commodities that depends heavily on stable temperature, rainfall, and humidity levels. However, recent climate variability has begun to threaten clove productivity, particularly in East Kolaka Regency, one of the country's main clove-producing regions (BPS, 2024; Onyeneke et al.2023). Extreme weather disrupts flowering and post-harvest processes, thereby reducing essential oil content and overall yield (Ardiansa et al.2025; Duru and Chidiebere, 2024). The success of these strategies largely depends on socioeconomic characteristics, such as education, age, land ownership, access to information, and institutional support (Ackerl et al.2023). The form of climate change adaptation strategy was explained using descriptive statistical analysis. A multivariate probit model was used to analyze the factors influencing the choice of climate change adaptation strategies and the relationships between each strategy. Nonetheless, farmers continue to face numerous constraints, such as economic, social, technological, and environmental constraints, that hinder their adaptive capacity. The combination of both yields a powerful analytical framework for understanding and enhancing farmers' adaptive responses to climate change effects. Therefore, analyzing how clove farmers respond to climate change and identifying the key factors and constraints affecting their adaptation are vital steps toward enhancing resilience in East Kolaka's clove farming sector.

Although numerous studies have examined agricultural adaptation to climate change, research specifically addressing clove farmers in Indonesia, particularly in East Kolaka, is scarce. This area experiences increasingly erratic rainfall, higher temperatures, and humidity fluctuations, which threaten clove productivity and farmers' income stability. However, limited empirical evidence exists on how socioeconomic and institutional factors influence adaptation decisions, as well as on the interactions and barriers among different strategies. Most previous research has focused on short-term crops such as rice, maize, and cassava (Mossie and Chanie, 2024; Dawid and Boka, 2025; Ndiwa et al.2024climate change adaptation strategies have the potential to address the challenges faced by crop farmers. Despite this, there is limited literature to inform policy on the best interventions to help farmers deal with climate issues. This study assessed the determinants of climate change adaptation strategies and the intensity of their use among 723 crop farmers in Busia County, Kenya, selected through a multistage sampling technique. Data were collected using a structured questionnaire and analyzed using principal component analysis (PCA), while studies on perennial crops like cloves are rare, especially those employing the Multivariate Probit (MVP) model to capture simultaneous adaptation decisions. Moreover, few studies have integrated the analysis of both adaptation determinants and constraints through a combined Multivariate Probit and Constraint Facing Index (CFI) approach.

To address these gaps, this study employs three approaches: descriptive statistics, multivariate probit (MVP), and Constraint Facing Index (CFI). The Multivariate Probit model is used to analyze the factors that influence the choice of adaptation strategies adopted by farmers and is also used to analyze the relationship between each strategy adopted by clove farmers in Anggaloosi village. The CFI was used to analyze the obstacles faced by farmers in dealing with the impacts of climate change (Mossie and Chanie, 2024). This combination provides a comprehensive understanding of both adaptive behavior and constraints.

This study aimed to determine the adaptation strategies adopted by clove farmers in East Kolaka, determine the factors that influence the choice of adaptation strategies by clove farmers, analyze the relationship between each adaptation strategy adopted by clove farmers, and analyze the obstacles faced by farmers in adopting climate change adaptation strategies in East Kolaka.

METHODS

This study used primary and secondary data. Primary data were collected from 138 clove farmers in Anggaloosi Village using structured questionnaires and survey, while secondary data were obtained from journals, books, and BPS Website. The sampling technique for the farmers uses a saturated sampling technique, where the entire population is used as a sample/research respondent. This approach was chosen because the total number of active clove farmers in the area was relatively small and manageable for complete data collection purposes.

Data for this study were gathered through direct interviews conducted between May and June 2025. A census sampling method was applied to cover the entire population of 138 clove farmers. The location of this research was chosen considering that East Kolaka Regency is one of the largest clove-producing regencies, with a productivity contribution of 0.31 tons ha-1 from 17 regencies in Southeast Sulawesi, and around 50% of the population in East Kolaka Regency, Southeast Sulawesi, work as clove farmers.

The data analysis methods used in this study were descriptive statistics, multivariate probit analysis, and constraint-facing index analysis. Descriptive statistics were used to analyze the adaptation strategies adopted by clove farmers in response to the impact of climate change (Schipper et al.2024). Frequencies and percentages were used to describe the frequency of the implementation of a particular strategy.

Multivariate probit regression analysis was used to analyze the factors influencing farmers' decisions in selecting climate change adaptation strategies (Mossie and Chanie, 2024) (income diversification, utilization of climate information, extension, and improvement of irrigation systems). A multivariate probit analysis was also used for the simultaneous analysis of adaptation strategies and to identify relationships between them. The model equation for the multivariate probit is presented in Equation 1.

$$Yj^* = \beta_0 j + \beta_1 jX_1 + \beta_2 jX_2 + \beta_3 jX_3 + \beta_4 jX_4 + \beta_5 jX_5 + \beta_6 jX_6 + \beta_7 jX_7 + \beta_8 jX_8 + \beta_9 jX_9 + j \text{ ...... (1)}$$

Note: Yj^* (binary outcome for adaptation strategy j (1=adopted, 0=not adopted)); X_1-X_9 (socio-economic variables including education, age, land size, income, farming experience, access to credit, access to agricultural inputs, access to climate information, and access to extension services); j (error term assumed to follow multivariate normal distribution).

Constraint Facing Index (CFI) analysis was used to identify the barriers faced by farmers in responding to the impacts of climate change (Mossie and Chanie, 2024). Respondents were asked to rate the level of barriers faced by farmers using a Likert scale (1-5). The index value was then calculated using the CFI formula to determine the ranking of obstacles. From the results of this ranking of obstacles, the most dominant obstacles for farmers in adopting adaptation strategies can be identified as follows. The CFI value can be calculated as see in equation 2:

$$\text{CFI} = \frac{\sum_{i=1}^{n} w_i \cdot f_i}{\sum_{i=1}^{n} f_i}$$

$$\text{CFI} = \frac{(F_1 \cdot 1) + (F_2 \cdot 2) + (F_3 \cdot 3) + (F_4 \cdot 4) + (F_5 \cdot 5)}{N}$$

Notes: Fi (number of respondents with score *I);*Wi (weight/constraint level (score 1:no constraint; score 2:minor constraint; score 3: moderate constraint; score 4:major constraint; score 5:very severe constraint));N (total number of repondents).

Operational definitions of variables are used to provide a clear and objective definition of the research variables so that they can be measured clearly and objectively. This study includes two groups of variables: (1) dependent variables, namely, farmers' adaptation strategies to climate change, and (2) independent variables, namely, socioeconomic and institutional factors influencing adaptation decisions. Operational definition of variables we can see in the Table 1.

Table 1. Operational definition of variables

Variable	Operational Definition	Indicators/ Measurements	Data Scale	Supporting Literature
Income Diversification (Y1)	Farmers' efforts to increase income sources outside of clove farming as a form of adaptation to the risks of climate change.	1=diversified income; 0=did not diversify income	Nominal (dummy)	(Asfaw Eshetu & Mekonen, 2024)
Utilizing Climat Information (Y2)	Utilization of weather data or information from various sources to support agricultural decisions (planting, harvesting, fertilization).	1=utilized climate information; 0=did not utilize climate information	Nominal (dummy)	(Atta-Aidoo & Antwi-Agyei, 2025)
Extension and Training (Y3)	Farmers' participation in extension activities, training, or outreach related to agriculture and climate change.	1=attended training activities; 0=did not participate	Nominal (dummy)	(Hassan et al.2024)
Improving Irrigation Sytems (Y4)	Farmers' efforts to improve, maintain, or optimize irrigation systems to address climate uncertainty.	1=improved irrigation systems; 0=did not improved irrigation systems	Nominal (dummy)	(Mahaarcha & Sirisunhirun, 2023)
Level of education (X1)	The length of formal education the respondent has completed.	Number of years of formal education	Ratio	(Mossie & Chanie, 2024)
Age (X2)	The respondent's lifespan, from birth to the time of the study, indicates their level of maturity and experience in farming.	Year	Ratio	(Ndiwa et al.2024)
Land area (X3)	The total area of land used for clove farming by the respondent.	Hectares (ha)	Ratio	(Mossie & Chanie, 2024)
Income (X4)	The total annual income of the farmer's household from all sources (on-farm and off-farm).	Rupiah per year (Rp/year)	Ratio	(Mossie & Chanie, 2024)
Farm experience (X5)	The length of time the farmer has been running the clove farming business.	Year	Ratio	(Mossie & Chanie, 2024)
Access to Credit (X6)	The ease with which farmers can obtain loans or business capital from financial institutions.	1=has access to credit; 0=does not have access to credit	Nominal (dummy)	(Mossie & Chanie, 2024)
Access to Agricultural Input (X7)	The ease with which farmers can obtain production inputs such as fertilizers, pesticides, and agricultural tools.	1=easy; 0=not easy	Nominal (dummy)	(Mossie & Chanie, 2024)
Access to Climate Information (X8)	The ease with which farmers can obtain climate information from extension workers, social media, the (BMKG), or farmer groups.	1=easy; 0=not easy	Nominal (dummy)	(Mossie & Chanie, 2024)
Access to Extension Service (X9)	The intensity and ease with which farmers can participate in agricultural extension activities related to climate change.	1=easy; 0=not easy	Nominal (dummy)	(Ferdousi et al.2024)

As shown in Figure 1, climate change is a complex phenomenon that has a wide impact on various sectors, including agriculture and plantations, through increasing extreme temperatures, changing rainfall patterns, and pest and disease attacks that reduce productivity by 5–20% and farmer incomes (Cipriani et al.2024; Jiliberto et al.2024). Clove plants, a plantation commodity with high economic value that plays a vital role in the Indonesian economy, are also impacted by climate change, affecting production, prices, and quality (Bandara & Senevirathne, 2023; Silva et al.2024; Jamshidi Alashti et al.2024). In East Kolaka Regency, Southeast Sulawesi, increased rainfall intensity and pest attacks threaten the sustainability of clove production (Michel et al.2021). Therefore, adaptation is a crucial step in reducing vulnerability and increasing farmer resilience through income diversification, utilization of climate information, participation in extension services, and improved irrigation systems (Parra-López et al.2024; Dangi et al.2024). Internal factors such as education, age, income, and farming experience, as well as external factors such as access to credit, information, and institutional support, influence the adoption of adaptation strategies (Mossie & Chanie, 2024). The relationships between strategies were analyzed using a Multivariate Probit, while economic, social, technological, and environmental barriers were analyzed using the Constraint Facing Index (CFI) to identify key constraints in implementing climate change adaptation. These findings emphasize the need for targeted policies to address key constraints and enhance farmers' capacity to adopt multiple complementary adaptation strategies.

The hypotheses of this study are as follows: It is suspected that education level (X_1), age (X_2), land area (X_3), income (X_4), farming experience (X_5), access to credit (X_6), access to agricultural inputs (X_7), access to climate information (X_8), and access to extension services (X_9) significantly influence income diversification strategies (Y_1), utilization of climate information (Y_2), extension services and training (Y_3), and irrigation system improvement (Y_4). It is suspected that there is a significant positive relationship between income diversification strategies, utilization of climate information, extension services and training, and irrigation system improvement in response to climate change.

RESULTS

Adaptation strategy analysis

Climate change adaptation strategies are a process of adjustment in response to the impact of climate conditions. Adaptation strategies aim to increase resilience and reduce vulnerability to climate change (IPCC, 2023). The adaptation strategies adopted by clove farmers in Anggaloosi Village include (1) diversifying income, (2) utilizing climate information from various sources, (3) participating in outreach and training, and (4) improving irrigation systems. Clove farmers in Anggaloosi Village do not only adopt one type of adaptation strategy, but most farmers adopt multiple adaptation strategies. The forms of adaptation strategies can be seen in Table 2.

Table 2 indicates that extension and training represent the most commonly implemented adaptation strategies among clove farmers (80.43%), supporting the conclusions of Hassan et al. (2024) and Mossie and Chanie (2024), who observed that participation in agricultural extension enhances farmers' knowledge and promotes the adoption of adaptive practices. Although extension is necessary, its effectiveness often depends on enabling conditions, such as institutional backing and access to finance (Ma and Rahut, 2024). In Anggaloosi, however, extension appears to have produced tangible adaptation actions (income diversification, irrigation upgrades). The use of climate information (73.19%) is consistent with Onyeneke et al. (2023), who emphasized that access to data-based decision-making improves productivity and resilience, yet differs from Onyeneke et al. (2023), who reported that farmers in Ghana still depend primarily on informal information sources.

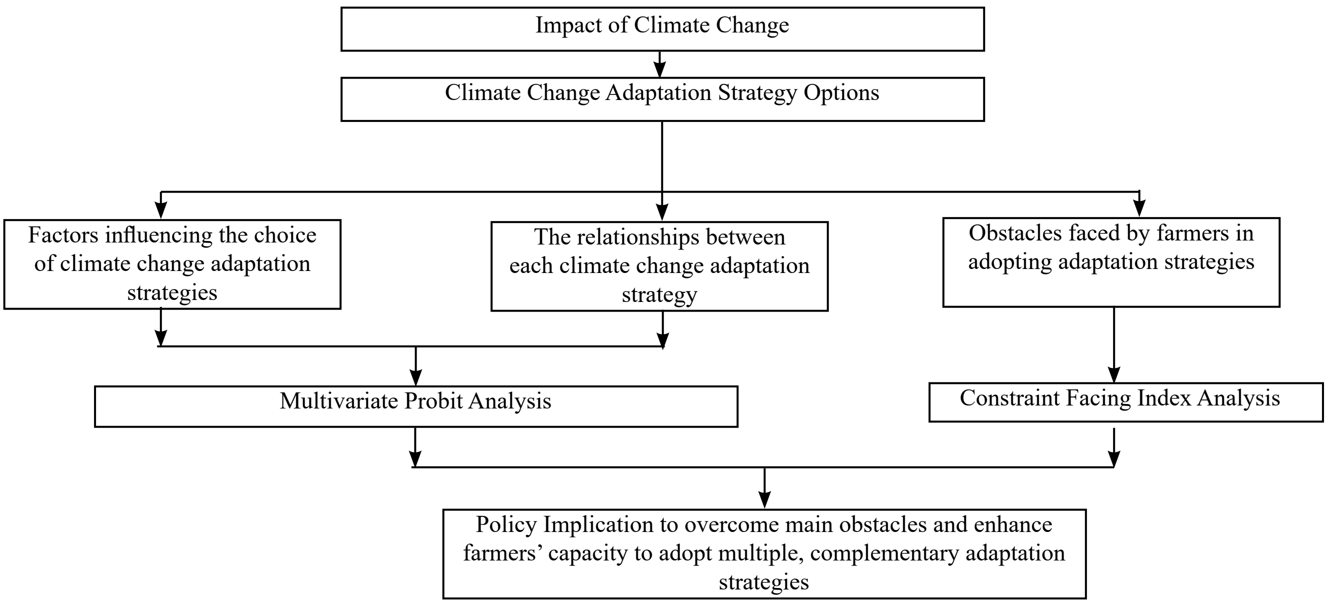

Figure 1. Framework for climate change adaptation strategies among farmers

Table 2. Types of adaptation strategies adopted by clove farmers in Anggaloosi Village

Forms of Adaptation Strategies	Number of Farmers	Percentage (%)
Income Diversification	91	65.94
Utilizing Climate Information	101	73.19
Extension and Training	111	80.43
Improving Irrigation Systems	98	71.01

Similarly, the adoption of irrigation system improvements (71.01%) aligns with Dawid Mume et al. (2023) and Jagadeesh et al. (2024), although the present study underscores small-scale, farmer-driven efforts rather than the large-scale infrastructure projects typically emphasized in arid regions. Income diversification (65.94%) corroborates the findings of Prommawin et al. (2024), who found that such strategies reduce vulnerability, but contrasts with Shitaye et al. (2024), who contended that diversification alone cannot guarantee resilience without adequate institutional and financial support. Overall, these results reinforce the recent evidence of Parra-López et al. (2024), suggesting that farmers adopt multiple interrelated behavioral, technological, and livelihood strategies to cope with climate risks while contributing new empirical insights into the adaptive practices of perennial crop farmers in East Kolaka.

Factors influencing the choice of adaptation strategies in facing the impacts of climate change

Factors influencing clove farmers' choice of adaptation strategies to address the impacts of climate change were analyzed using multivariate probit analysis. The variables used in this study included age, education, land area, income, farming experience, access to credit, access to agricultural inputs, access to climate information, and access to extension services. Table 3 presents the results of the multivariate probit analysis for each adaptation strategy.

Based on Table 3, income diversification is positively influenced by income, farming experience, and access to extension, but negatively influenced by age and land area. Climate information utilization increases with higher education and access to climate data but declines with age, limited credit, and extension access. Extension participation is positively affected by land area, credit, input access and extension contact. Meanwhile, irrigation improvement is driven by income and extension access but is constrained by older age, larger land size, and limited agricultural inputs.

1. Income diversification adaptation strategy

Table 3 indicates that income diversification among clove farmers is negatively influenced by age and land size but positively affected by income, farming experience, and access to extension services. The negative effect of age ($\beta = -0.0425$, $p = 0.017$) suggests that as farmers get older, their farming ability and physical capacity decline, while their knowledge becomes less updated, leading to reduced income and limited capacity to engage in off-farm activities. This supports the findings of Ndiwa et al. (2024), who found that younger farmers are more inclined toward off-farm activities due to greater flexibility and risk-taking behavior.

Production, as a result of productivity multiplied by land area, may also explain the negative relationship between land size and diversification ($\beta = -0.5006$, $p = 0.076$). When the land area increases but production and income decline, productivity becomes the main determining factor, which can be influenced by crop variety, climatic conditions, and input use, such as fertilizers and pesticides. This finding aligns with Kassegn and Abdinasir (2023), suggesting that larger landholders often focus on their main crop. However, Namdeo et al. (2023) found that large-scale farmers may diversify when driven by labor shortages or better market opportunities. The positive effects of income ($\beta = 0.0721$, $p = 0.002$) and farming experience ($\beta = 0.0714$, $p = 0.041$) confirm the findings of Habib et al. (2023), emphasizing that financial resources and accumulated knowledge enable investment in alternative income sources. Moreover, access to extension services ($\beta = 1.1068$, $p = 0.003$) plays a critical role in promoting adaptive livelihood strategies (Mwololo et al., 2019), although such programs must be supported by strong institutional and financial mechanisms to sustain behavioral change (Becerra-Encinales et al., 2024).

2. Utilizing climate information adaptation strategy

The use of climate information is a key adaptation strategy influenced by education, age, credit access, climate information, and extension services. Based on Table 3, we found that education positively affects adoption (β = 0.3003, ρ = 0.029), supporting (Becerra-Encinales et al. (2024) that educated farmers better interpret climate data, though Dawid and Boka (2025) noted its limited role in strong informal networks. Age had a negative effect (β = -0.7115, ρ = 0.002), consistent with Nyoni et al. (2024), who found that younger farmers are more open to technology, while Alam et al. (2024) emphasized institutional support for older farmers. Credit access negatively affects adoption (β = -0.6383, ρ = 0.089), aligning with Luu (2020), who found that credit often prioritizes physical over information-based adaptation, although Baffour-Ata et al. (2024) showed that integrated credit-training systems can improve adoption.

Access to climate information increases adoption (β = 0.6528, ρ = 0.085), consistent with Ndiwa et al. (2024) and Habib et al. (2023), while Shitaye et al. (2024) warned of the digital inequality. Lastly, extension access negatively affects adoption (β = -0.7875, ρ = 0.034), supporting Belay et al. (2022), who found that traditional extension focuses on inputs, but contrasting Dawid and Boka (2025), who found that climate-integrated programs boost adoption. Farming experience (β = 0.0032, ρ = 0.914) was not a factor influencing the choice of climate change adaptation strategies, as experienced farmers tended to rely more on past experience than on climate information. This finding aligns with Ziro et al. (2023) in Kenya, who found that the adoption of climate information was more influenced by institutional support and access to extension services.

3. Extension adaptation strategy

Table 3 shows that the adoption of extension-based adaptation strategies was positively influenced by land area (β = 0.9717, p = 0.001), access to credit (β = 0.9900, p = 0.011), agricultural input availability (β = 0.7451, p = 0.054), and access to extension services (β = 1.1275, p = 0.004). The positive relationship between land size and adoption supports Becerra-Encinales et al. (2024), who found that farmers with larger holdings are more capable of implementing technologies promoted through extension programs. However, Mossie and Chanie (2024) argue that well-targeted extension initiatives can effectively benefit smallholders, suggesting that program design can reduce land size disparities. The significant role of credit access aligns with Haryanto et al. (2023), who showed that financial support enables farmers to apply extension recommendations, although Prommawin et al. (2024) caution that credit unlinked to markets may not lead to sustainable adoption. Likewise, improved access to inputs encourages participation in extension activities, consistent with Shitaye et al. (2024), while Zafar et al. (2023) note that excessive subsidies may discourage complementary investments. Moreover, access to extension services strongly promotes adoption, in line with Hassan et al. (2024), who highlighted the importance of technical education and advisory contact. Nonetheless, Becerra-Encinales et al. (2024) emphasized that extension effectiveness depends on institutional support and program continuity.

Education (β = 0.0163, ρ = 0.844). This is because extension materials are often not aligned with farmers' practical needs, so formal education does not increase motivation to participate. This finding aligns with Hassan et al. (2024), who asserted that extension effectiveness is more influenced by the relevance of the material and its accessibility. Age (β = 0.0093, ρ = 0.606) was not a factor influencing clove farmers' choice of climate change adaptation strategies, because young farmers tended to obtain information through social media and applications, so the role of age was not a determining factor. These results are in line with cross-country research (Tunio et al., 2024), which emphasizes that the exchange of information between farmers (peer learning) plays a greater role in the dissemination of innovation than formal extension, where farmers of various ages can learn from each other through direct practice in the field, so that age is not a significant differentiating factor in the adoption of extension strategies.

4. Improving irrigation systems adaptation strategy

The irrigation improvement strategy serves as a key measure to enhance water efficiency and reduce farmers' vulnerability to climate extremes. As presented in Table 3, adoption is determined by age, land size, income, access to inputs, and extension services. Age has a negative and significant effect (β = -0.0379, ρ = 0.021), supporting Idahe and Solomon (2024), who noted that older farmers are less likely to adopt labor- and technology-intensive irrigation systems, although Namdeo et al. (2023) emphasized that institutional support can help overcome such constraints. Similarly, land area negatively influences adoption (β = -0.5877, ρ = 0.008), consistent with Solaja et al. (2024), who reported that larger farms face higher costs for irrigation investment, while Dawid and Boka (2025) found the opposite in collective irrigation systems where economies of scale prevail.

Income positively affects adoption (β = 0.0582, ρ = 0.002), in line with Asfaw Eshetu and Mekonen (2024), indicating that higher income enables farmers to invest in irrigation technologies, although Becerra-Encinales et al. (2024) stressed the importance of complementary technical and policy support. Access to agricultural inputs showed a negative effect (β = -0.5670, ρ = 0.095), supporting Zafar et al. (2023), who argued that subsidies may shift focus from long-term adaptation investments, whereas Habib et al. (2023) highlighted that integrated input–training programs can enhance technology uptake. Finally, access to extension services had a positive effect (β = 0.6835, ρ = 0.041), consistent with Debisa et al. (2025), who found that frequent engagement with extension agents improves farmers' adaptive capacity. However, Dawid and Boka (2025) pointed out that program quality and frequency remain decisive factors.

The education level (β = 0.336, ρ = 0.554) did not significantly influence the adoption of irrigation system improvement strategies, where highly educated farmers tended to be more cautious about long-term investments and did not always possess a technical understanding of irrigation. This finding aligns with Bedo et al. (2024), who stated that decisions to improve irrigation systems are more influenced by group dynamics than by individual education levels. Farming experience (β = 0.0387, ρ = 0.136) did not significantly influence the adoption of irrigation system improvement strategies, where experienced farmers did not necessarily possess the technical skills to build irrigation systems. This finding aligns with that of Agbenyo et al. (2022) in Ghana, who found that farming experience did not significantly influence irrigation system adoption.

Table 3. Result of multivariate probit analysis on factors influencing the choice of adaptation strategies in facing the impacts of climate change in anggaloosi village

Variable	Income Diversification Strategy	Climate Information Utilization Strategy	Participation in Extension Strategy	Irrigation System Improvement Strategy
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
Level of education	0.1012 (0.148)	0.3003 (0.029)**	0.0163 (0.844)	0.336 (0.554)
Age	-0.0425 (0.017)**	-0.7115 (0.002)***	0.0093 (0.606)	-0.0379 (0.021)**
Land area	-0.5006 (0.076)*	0.2446 (0.378)	0.9717 (0.001)***	-0.5877 (0.008)***
Income	0.0721 (0.002)***	0.0169 (0.452)	-0.0097 (0.670)	0.0582 (0.002)***
Farm experience	0.0714 (0.041)**	0.0032 (0.914)	0.0310 (0.309)	0.0387 (0.136)
Access to Credit	0.0434 (0.898)	-0.6383 (0.089)*	0.9900 (0.011)**	0.3876 (0.219)
Access to Agricultural Input	0.1761 (0.645)	-0.3792 (0.342)	0.7451 (0.054)*	-0.5670 (0.095)*
Access to Climate Information	-0.1013 (0.788)	0.6528 (0.085)*	0.0943 (0.0809)	0.2615 (0.434)
Access to Extension Service	1.1068 (0.003)***	-0.7875 (0.034)**	1.1275 (0.004)***	0.6835 (0.041)**
Total respondent	138			
Log likelihood	-45.806.569	-32.709.001	-32.435.025	-55.177.518
Wald	59.67	67.48	39.16	42.35
Prob > chi^2	0.0000	0.0000	0.0000	0.0000

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, respectively

The relationship between each adaptation strategy

Multivariate probit analysis was used to identify the determinants of farmers' adaptation strategies and examine the correlations between the strategies adopted by clove farmers in Anggaloosi Village. The results revealed both complementary and substitutive relationships among the strategies. Table 4 shows the correlation analysis data for each strategy adopted by the clove farmers in Anggaloosi Village.

The results in Table 4 reveal strong interlinkages among the adaptation strategies of clove farmers in Anggaloosi Village. Income diversification positively correlated with participation in extension programs ($\rho = 0.9722$; $p = 0.000$), consistent with Ongachi and Belinder (2025) such as climate variability, pests and policy changes, which threaten agricultural productivity and livelihood diversification. d using Stata software with the Ordered Probit model. The study found that farmers' access to agricultural information is significantly influenced by factors such as experience, exposure to electronic and printed media, farm size, access to extension services, input availability, market distance, proximity to development centers, and participation in Farmer Training Centers (FTC, who found that digital platforms complement rather than replace extension services. Climate information use and irrigation improvement were strongly and positively linked ($\rho = 0.8360$; $p = 0.000$), which is consistent with the findings of Jagadeesh et al. (2024). However, unlike Prommawin et al. (2024), this study shows that farmers in Anggaloosi adopt small-scale locally adapted irrigation measures. Other strategy combinations showed no significant correlations.

Barriers faced by farmers in adopting climate change adaptation strategies Clove

Farmers in Anggaloosi Village face various interrelated barriers in adopting climate change adaptation strategies. These barriers fall into four main categories: economic, social, technological and environmental. Table 5 presents the barriers farmers face in adopting climate-change adaptation strategies.

Based on Table 5, we can see that economic constraints are identified as the most significant barriers for clove farmers, particularly the lack of working capital (CFI = 4.01), unstable clove prices (CFI = 3.98), and marketing challenges (CFI = 3.76). These findings are consistent with Dawid and Boka (2025) and Namdeo et al. (2023), who noted that financial limitations and market fluctuations discourage farmers from adopting climate adaptation practices. However, recent studies, such as Haryanto et al. (2023), emphasize that while access to credit or subsidies can temporarily ease liquidity constraints, their effectiveness depends on being coupled with market access and long-term investment support. Social barriers, though relatively less severe (CFI 2.34–2.83), remain significant due to weak institutional support and limited access to climate information and extension services. This aligns with Baffour-Ata et al. (2024), who highlighted the importance of information accessibility for farmers' adaptive decision-making. Habib et al. (2023) observed that strong community networks can sometimes compensate for institutional shortcomings.

Table 4. Results of correlation analysis between climate change adaptation strategies adopted by clove farmers in anggaloosi village

Correlation Between Strategies	ρ (rho)	p-value
Strategy 1 and Strategy 2	-0.1665	0.351
Strategy 1 and Strategy 3	0.9722	0.000
Strategy 1 and Strategy 4	-0.1252	0.610
Strategy 2 and Strategy 3	-03227	0.046
Strategy 2 and Strategy 4	0.8360	0.000
Strategy 3 and Strategy 4	-0.2659	0.220

Technological barriers (CFI 2.99–3.63), such as inadequate training and limited awareness of agricultural innovations, also constrain adaptation efforts, consistent with Shitaye et al. (2024). Jagadeesh et al. (2024) showed that targeted extension and climate-smart technology demonstrations can mitigate these challenges when properly implemented. Environmental barriers remain the most critical, dominated by unpredictable weather (CFI = 4.29) and natural disaster risks (CFI = 4.06), supporting Chapke et al. (2024). However, Ndiwa et al. (2024) found that access to timely climate forecasts and adaptive planning can help farmers anticipate and mitigate these impacts. Overall, these findings reveal that while the constraint patterns in Anggaloosi are consistent with broader regional evidence, addressing them effectively requires an integrated approach that links financial support, extension services, technology transfer, and climate information dissemination.

Table 5. Analysis of barriers experienced by clove farmers in adopting climate change adaptation strategies in anggaloosi village

Barriers	Score x Frequency	Total Respondents	CFI Value	Level of Barriers
Economic Barriers				
Limited business capital	558	138	4.01	High
Difficulties in commodity marketing	522	138	3.76	High
Undeveloped production technology	493	138	3.55	High
Difficulties in obtaining labor	455	138	3.27	Medium
High costs of environmentally friendly fertilizers and pesticides	470	138	3.38	High
Fluctuating clove prices	549	138	3.98	High
Difficulties in accessing financial institutions to support agricultural development	520	138	3.77	High
Social Barriers				
Lack of government support	325	138	2.34	Low
Lack of cooperation among farmers in addressing climate change	333	138	2.40	Low
Lack of information related to climate change	393	138	2.83	Medium
Lack of outreach from relevant institutions	386	138	2.78	Medium
Technological Barriers				
Lack of access to modern agricultural tools and machinery	459	138	3.30	Medium
Lack of information regarding agricultural innovation	482	138	3.47	High
Lack of irrigation infrastructure	416	138	2.99	Medium
Lack of extension services regarding technological improvements	505	138	3.63	High
Lack of access to pest and disease detection technology	467	138	3.36	Medium
Environmental Barriers				
Unpredictable changes in weather patterns	597	138	4.29	Very High
Risk of natural disasters	565	138	4.06	High
Unpredictable water availability (drought or extreme rainfall)	544	138	3.91	High

Managerial Implications

The findings of this study suggest several managerial implications for strengthening clove farmers' adaptive capacity to climate change. Strengthening agricultural extension and training programs focused on climate-smart practices, along with the integration of digital information platforms, can improve farmers' knowledge and access to adaptation technologies. Expanding access to finance through flexible credit schemes and market-linked programs is crucial for addressing capital limitations and supporting long-term adaptation. Reliable climate information systems developed through collaboration among meteorological agencies, extension offices, and farmer cooperatives are essential for timely decision-making. Furthermore, promoting income diversification and supporting small-scale irrigation initiatives can enhance resilience and reduce dependence on climate-sensitive crops in the region. Coordination among local institutions, agricultural departments, and research centers is necessary to ensure that policies addressing climate change are context-specific and farmer centered. Such collaborations can align technical, financial, and informational support for more sustainable adaptation outcomes.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study found that clove farmers in Anggaloosi Village adopted four main climate change adaptation strategies: participation in training and extension programs, income diversification, utilization of climate information, and improvements in irrigation systems. Among these, participation in training and extension activities was the most commonly adopted strategy, with 111 farmers adopting it, reflecting farmers' preference for approaches that provide hands-on knowledge and alternative sources of income. The multivariate probit analysis shows that each strategy is influenced by different socioeconomic and institutional factors, with access to extension being an influential factor across all climate change adaptation strategies. Several adaptation strategies were found to be complementary or substitutive. Environmental constraints—particularly unpredictable weather patterns, disaster risk, and erratic water availability—emerged as the most critical constraints, followed by economic challenges such as limited capital and price fluctuations, whereas social and technological constraints were relatively minor. Therefore, strengthening institutional support, improving access to extension and climate information services, and expanding financial assistance should be prioritized as policy interventions to enhance farmers' adaptive capacity and promote the integration of multiple complementary adaptation strategies. These findings highlight the importance of designing integrated, context-based policies that promote the simultaneous adoption of multiple, complementary adaptation strategies among clove farmers.

Recommendations

Climate change policies should be context-specific and farmer-centered, meaning they should be tailored to the unique environmental, economic, and social contexts of each farming community, actively engaging farmers in identifying problems, needs, and feasible adaptation options. In this regard, local governments are advised to strengthen agricultural extension and microfinance initiatives focused on climate adaptation, particularly by increasing farmers' access to funding, training, and technical assistance tailored to local farming systems and resource conditions. Extension workers should integrate digital platforms that provide real-time weather, climate, and market information, enabling farmers to make timely and informed decisions based on local realities. Furthermore, research organizations are encouraged to conduct long-term, cross-regional studies to evaluate the effectiveness and sustainability of adaptation strategies implemented by clove farmers, ensuring that future policies are based on local evidence and farmer experience. Finally, farmers should be encouraged to utilize climate-related information, diversify their income sources, and adopt innovative but locally appropriate cultivation practices to increase their resilience to climate uncertainty and sustain their livelihoods.

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