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Research Article

Climate Change Adaptation Strategies and Their Determinants: Insights from Smallholder Farmers in Ethiopia

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Abstract

Climate change poses a significant threat to smallholder farmers by altering rainfall patterns, increasing temperatures, and intensifying extreme weather events. These changes result in reduced crop yields, water scarcity, and greater vulnerability to pests, threatening food security and livelihoods. In Ethiopia, particularly in the Haramaya District, the livelihoods of people are predominantly reliant on subsistence rain-fed agriculture, rendering smallholder farmers highly vulnerable to the impacts of climate change. The resilience of smallholder farmers is closely tied to their ability to adapt to changing climatic conditions. In the Haramaya District, severe climate change poses significant challenges for smallholder farmers in maintaining their agricultural livelihoods. Therefore, this study was conducted to examine the climate change adaptation strategies adopted by smallholder farmers in Haramaya District, Oromia National Regional State, Ethiopia. Both primary and secondary data sources were utilized. Primary data were gathered through household surveys involving 189 randomly selected smallholder farmers, as well as Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). Secondary data were obtained from prior studies and relevant institutional reports. The data were analyzed using descriptive statistics and a multinomial probit model. The findings of the study show that farmers adopted a variety of climate change adaptation strategies. The most commonly reported strategy was changing livestock type (22.75%), while changing the planting period was the least adopted (16.40%). Other notable strategies included soil and water conservation (22.22%), income diversification (20.63%), and the cultivation of drought-tolerant crops (17.99%). he multinomial probit model identified several factors that significantly influence smallholder farmers' decisions in selecting adaptation strategies in response to climate change in the study area, such as age, access to climate information, livestock holdings, irrigation access, education level, frequency of extension visits, active labor size, and access to credit. The findings emphasize the urgent need for governmental and non-governmental organizations to strengthen support for smallholder farmers by improving access to credit, raising awareness about effective climate change adaptation strategies, and providing comprehensive extension services. Additionally, efforts should focus on enhancing educational opportunities, particularly in climate resilience, and investing in long-term climate mitigation initiatives. These measures are essential to enhance the adaptive capacities of farmers and ensure their sustainable livelihoods in the face of climate change.

Keywords

Adaptation Strategies, Climate Change, Ethiopia, Multinomial Probit Model, Smallholder Farmers

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1. Introduction

Agriculture is the backbone of many least developed countries, providing a vital source of employment, income, and food security. In Sub-Saharan Africa (SSA), the agricultural sector is particularly important, with a large share of the population, especially smallholder farmers, depending on it for their livelihoods [1]. In Ethiopia, agriculture accounts for over one-third of the country's GDP and remains the foundation of national economic development. Smallholder farmers, who cultivate less than one hectare of land and rely heavily on family labor, are central to this economy. Despite their importance, these farmers face substantial socio-economic and environmental constraints, including poverty, limited access to markets, and low levels of technological input [2].

Climate change has emerged as one of the most pressing challenges to agricultural systems globally. Shifts in rainfall patterns, increasing temperatures, and the growing frequency of extreme weather events are severely disrupting agricultural productivity, particularly in rain-fed farming systems [3, 4]. Although Africa contributes only a small portion of global emissions, it is disproportionately affected by climate change. Ethiopia is especially vulnerable due to its reliance on natural resources and limited adaptive capacity [5]. In regions such as Haramaya Woreda, recurrent droughts, erratic rainfall, and land degradation are exacerbating rural vulnerability, leading to food insecurity and income losses [6]

In response to these risks, smallholder farmers across SSA, including Ethiopia, have begun adopting various adaptation strategies, many of which are autonomously implemented. These include changing planting dates, using drought-tolerant crop varieties, diversifying crops, engaging in soil and water conservation, and practicing mixed or mono-cropping systems [7, 8]. While some of these practices are informed by traditional knowledge and local experience, others are influenced by external interventions and information dissemination. Nonetheless, the adoption and effectiveness of these strategies vary significantly across households and regions, shaped by a range of factors including access to resources, institutional support, education, and agro-ecological conditions [9, 10]. Without adaptation measures, climate change poses significant threats to agriculture; however, with effective adaptation strategies, these vulnerabilities can be substantially reduced [11].

Understanding smallholder farmers' perceptions of climate change and the determinants of their adaptive responses is critical for the formulation of effective, context-specific policy and programmatic interventions. A substantial body of literature has investigated climate change adaptation and its driving factors across diverse agroecological systems globally, including empirical studies by Kabir et al. [12], Ojo et al. [13], and Kumar et al. [14]. In the Ethiopian context, considerable scholarly attention has been devoted to examining climate-induced vulnerabilities and the utilization of indigenous knowledge systems in adaptation processes, as documented by Deressa et al. [15], Belay et al. [16], and Dessalegn et al. [17]. Despite the valuable insights generated, particularly from the Nile Basin and other ecologically sensitive regions of Ethiopia, the heterogeneity of local biophysical, socioeconomic, and institutional contexts underscores the inadequacy of universal adaptation models. Adaptation strategies must therefore be spatially differentiated and informed by localized realities. Effective climate adaptation necessitates a comprehensive understanding not only of the adaptation measures employed but also of the multifaceted factors, such as resource endowments, institutional support, and socio-cultural dynamics, that mediate their uptake and efficacy.

Therefore, this study aims to explore the climate change adaptation strategies employed by smallholder farmers in Ethiopia and examine the determinants influencing their decision regarding the choice of adaptation strategies. By focusing on the local context and farmer-level decision-making, the research seeks to contribute to the broader discourse on climate resilience in agriculture. The findings are expected to inform development practitioners, policymakers, and researchers seeking to enhance the adaptive capacity of rural communities and support sustainable agricultural transformation in the face of an evolving climate landscape.

2. Research Methodology

2.1. Description of the Study Area

The study was conducted in the rural kebeles of Haramaya District, located in the eastern part of Ethiopia, approximately 505 km from Addis Ababa, the capital city. Haramaya is bordered by Kurfa Chele to the south, Kersa to the west, Dire Dawa to the north, Kombolcha to the east, and the Harari Region to the southeast. Geographically, the district lies at coordinates 41°59'58" N latitude and 09°24'10" E longitude. Haramaya Woreda is subdivided into 34 rural kebeles and 2 urban kebeles. The district's altitude ranges from 1,900 to 2,450 meters above sea level, encompassing three agro-ecological zones: *Dega* (highland), *Woinadega* (midland), and *Kola* (lowland). The mean annual rainfall is 74.1 mm, with a mean annual temperature of 16.9°C. The dry season, characterized by less than 30 mm of rainfall per month, extends from October to February, while the main autumn rains occur between September and November, and the smaller spring rains take place from March to May [18].

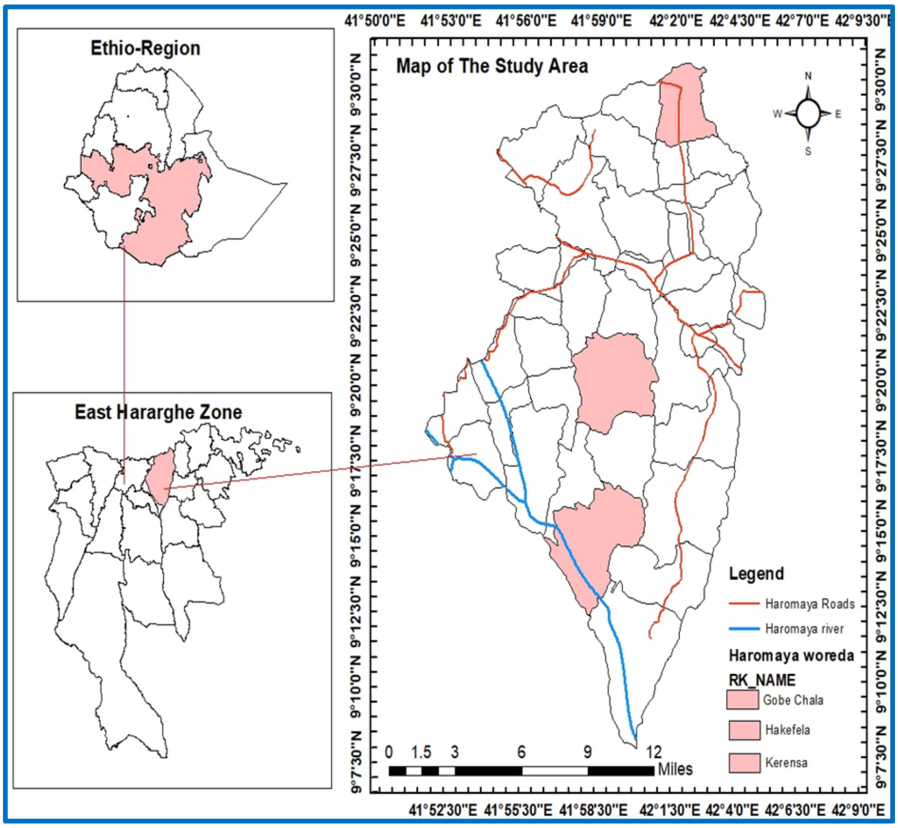

Figure 1. Location Map of Haramaya District.

2.2. Sampling Technique and Sample Size

Haramaya District, comprising 34 kebeles and two towns, served as the study area for this research. To ensure a representative sample, the researchers employed a stratified random sampling technique, dividing the 34 kebeles into three distinct agro-climatic zones: highland (*Dega*), midland (*Woinadega*), and lowland (*Kola*). One kebele was selected from each zone: *Haqa Fila* from the lowland, *Gobe Chala* from the highland, and *Kerensa Sharif Kalid* from the midland. From these selected kebeles, 7% of households were randomly chosen from the household lists, with the sample size allocated proportionally based on the number of households in each kebele. Specifically, *Gobe Chala* had 800 households, *Haqa Fila* had 978, and *Kerensa Sharif Kalid* had 673. To determine the required sample size, the study utilized Yamane's (1967) simplified formula, applying a precision level of 7%. This calculation yielded a final sample size of 189 households, ensuring a robust and statistically reliable representation of the district's diverse agricultural contexts.

$$n = \frac{N}{1+N\,(e)^2}$$

$$\mathrm{n} = \frac{2451}{1+2451(0.07)^2}$$

$$\mathrm{n} = 189$$

Where n is the sample size, N is the population size (total household), and e is the level of precision. The above formula requires a minimum of 189 sampled households, as the total number of households is 2451.

Table 1. Distribution of sampled households by sample kebeles.

Kebeles	Sample households	Sample size	Percentage
Gobe Chala	800	62	32.5%
Haqa fila	978	75	40%
Kerensa sherif kelid	673	52	27.5%
Total	2451	189	100%

2.3. Data Type and Methods of Data Collection

Both qualitative and quantitative data were collected from primary and secondary sources to explore smallholder farmers' adaptation strategies to climate change in Haramaya District. Primary data were gathered using four main methods: household surveys, focus group discussions, and key informant interviews. The household survey, conducted with 189 randomly selected respondents, was translated into *Afan Oromo* to ensure effective communication with participants. Focus group discussions were held in the selected kebeles, with eight participants in each group representing different age groups, genders, and socio-economic statuses. These discussions focused on farmers' perceptions of climate change, particularly changes in rainfall patterns, temperature, and extreme weather events, as well as coping mechanisms and adaptation strategies.

Key informant interviews involved sixteen individuals, including ten community key informants (five male and five female farmers) and three development agents at the kebele level, as well as three experts from the Woreda level, specializing in agriculture, natural resource conservation, and disaster risk management. Secondary data were obtained from various sources, including previous research, official websites, unpublished documents, and publications from government offices, such as regional, zonal, and district agricultural offices. This multi-method approach enabled a comprehensive understanding of both the context and the factors influencing adaptation strategies.

2.4. Analytical Methods

The data collected from both primary and secondary sources were analyzed using a combination of qualitative and quantitative methods, including descriptive analysis and the econometric multinomial probit model. Qualitative data gathered through focus group discussions and key informant interviews were analyzed using a content analysis method to extract in-depth insights. For the quantitative analysis, descriptive statistics—such as means, percentages, and frequencies—were employed to assess farmers' adaptation strategies and to examine the socio-economic characteristics of the sample households. This comprehensive approach allowed for a thorough understanding of both the numerical patterns and the underlying qualitative factors influencing adaptation strategies.

2.5. Multinomial Probit Model Specification

Farmers are more likely to adopt a combination of adaptation strategies to cope with the diverse risks and challenges induced by climate change, rather than relying on a single approach. Analytical methods commonly used to study adaptation decisions with multiple choices include the multinomial logit (MNL) and multinomial probit (MNP) models. However, many existing studies on climate change adaptation strategies fail to account for the potential interrelationships between different strategies. For example, Nhemachena and Hassan [19] used the multinomial probit model to analyze factors influencing adaptation choices in Southern Africa.

In response to adverse climatic changes, farmers tend to adopt a mix of strategies to maximize mitigation efforts, leveraging the complementary benefits of various options. Adaptation is also path-dependent, with earlier strategies influencing future decisions. To accurately estimate the impact of external factors on the adoption of adaptation strategies, it is crucial to use a model that accounts for the simultaneous influence of these factors while allowing for the correlation of error terms across strategies. Failure to do so can lead to biased estimates. Therefore, this study employs a multinomial probit model to identify the factors influencing smallholder farmers' choice of adaptation strategies in response to climate change. The model includes one categorical dependent variable representing the chosen adaptation strategy, with five distinct outcome categories: y1 (changing planting period), y2 (soil and water conservation practice), y3 (changing livestock type), y4 (income source diversification), and y5 (Growing drought-tolerant crops). This modeling approach allows for the simultaneous examination of multiple, non-ordered adaptation choices, capturing the complexity and interdependence of smallholder adaptation behavior under climate stress. The model is specified as follows:

$$yi=1\ if\ \beta ix'+\varepsilon i>0, \text{ and}$$

$$yi=0\ if\ \beta ix'+\varepsilon i\leq 0$$

Where i=1, 2,3,4…,189; x is a vector of the explanatory variables; $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, and $\beta 5$ are conformable parameter vectors and $\varepsilon 1$, $\varepsilon 2$, $\varepsilon 3$, $\varepsilon 4$ and $\varepsilon 5$ are random errors distributed as a multivariate normal distribution with zero mean, unitary variance and correlation matrix. Thus, the dependent variable in the empirical estimation for this study is the choice of an adaptation decision(s) from the set of adaptation measures such as soil and water conservation practices, income source diversification, changing livestock type, growing drought-tolerant crops as major climate change adaptation strategies, and changing planting period. But, choice of an adaptation decision(s) was determined by several factors. This model was also used to examine the trade-offs and complementarities that existed between the strategies adopted by farmers. This technique simultaneously models the influence of the set of explanatory variables on each of the different strategies while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the strategies of different practices.

2.6. Definition of Variables and Working Hypothesis

Dependent variable

For this study, the dependent variable is the choice of adaptation mechanisms most pursued by smallholder farmers in the study district. The choice of adaptation options is assumed to be made among completely mutually exclusive alternatives based on the assumption of the multinomial probit model. It is a categorical variable and includes the following adaptation strategies: Changing planting period, Soil and water conservation practice, Changing livestock type, Income source diversification, and Growing drought-tolerant crops.

Explanatory variables

Based on the findings of past studies on climate change adaptation strategies, the following variables were hypothesized to affect climate change adaptation strategies of smallholder farmers in the study area.

Table 2. *Summary of Variables, Definition, and Measurement.*

Variables	Type	Definition	Measurement
Dependent variable			
Adaptation strategies to climate change	Categorical		
Explanatory variables			
Age	Continuous	Age of household head	Year
Education level	Continuous	Education level of household head	Class completed
Access to credit	Dummy	Access to credit	1 if access; 0 otherwise
Sex	Dummy	Sex of household head	1 if access; 0 otherwise
Distance to market	Continuous	Distance from home to the nearest market	Kilometer (km)
Climate information	Dummy	Access to climate information	1 if access; 0 otherwise
Cultivated land size	Continuous	Cultivated land size	Hectare (ha.)
Household farm income	Continuous	Annual on-farm income	Birr
Active labor size	Continuous	Household member whose age is between 15 and 65	Number
Livestock holding	Continuous	Total livestock holding	Tropical Livestock Unit (TLU)
Irrigation access	Dummy	Access to irrigation water	1 if access; 0 otherwise
Extension visit	Continuous	Extension visit	Number

3. Results and Discussion

This chapter presents the results of the study on climate change adaptation strategies and attitudes of farmers using data obtained from 189 sample households, focus group discussions, and interviews with key informants. It has two parts. The first segment describes the adaptation strategies adopted by smallholder farmers in the study area. The second section presents econometric outcomes of the determinants of the climate change adaptation strategies of smallholder farmers in the study area.

3.1. Households' Adaptation Strategies to Climate Change

Smallholder farmers are on the frontline of climate change impacts, particularly in developing countries where agriculture is predominantly rain-fed and highly sensitive to climatic variations. Changes in rainfall patterns, prolonged droughts, increased temperature, and soil degradation are among the critical challenges affecting agricultural productivity. In response, farmers are not passive victims but active agents who adopt various adaptation strategies to sustain their livelihoods. Identifying and analyzing these adaptation responses is vital to informing agricultural policy, guiding climate-resilient development planning, and ensuring that interventions are responsive to the realities faced by rural communities.

In the study area, a large proportion of farmers have experienced the effects of climate change in recent years and have adopted various strategies to mitigate its impact. The sampled smallholder farmers were asked whether they had taken any adaptive measures in response to these challenges. In their responses, farmers indicated that they are actively implementing a range of adaptation strategies to reduce the negative effects of climate change on their agricultural activities and livelihoods.

Among the strategies identified, changing livestock type was the most frequently used adaptation, with 43 farmers (22.75%) reporting a shift toward more resilient or drought-tolerant livestock breeds. This decision reflects an effort to adapt to declining feed and water availability. Likewise, 42 farmers (22.22%) reported adopting soil and water conservation (SWC) practices, such as terracing, mulching, and water harvesting. These measures reflect a strong understanding of the need to prevent soil erosion, retain moisture, and improve soil fertility—key factors in maintaining agricultural productivity under increasingly variable climate conditions.

Additionally, 39 respondents (20.63%) diversified their income sources through off-farm work, small businesses, or seasonal migration, as a way to reduce dependency on climate-sensitive agriculture. These findings highlight that farmers are not only aware of the risks posed by climate change but are also actively making strategic decisions to safeguard their livelihoods. Other commonly adopted strategies include growing drought-tolerant crops (17.99%) and adjusting the planting period (16.40%). Farmers noted that drought-resistant crop varieties offered greater reliability under dry conditions and shorter growing seasons. Adjusting planting dates was seen as a necessary response to the increasingly erratic onset of rainy seasons, as traditional planting calendars have become less dependable. Overall, these adaptation efforts illustrate a high level of responsiveness among smallholder farmers in the study area. Their choices are shaped by both necessity and experience, and they provide valuable insights for designing locally appropriate support systems and agricultural policies that enhance resilience to climate change.

Table 3. *The widely used adaptation strategies to climate change by smallholder farmers.*

Strategies	Frequency	Percentage
Changing planting period	31	16.40
Soil and water conservation	42	22.22
Change livestock type	43	22.75
Income source diversification	39	20.63
Growing drought-tolerant crops	34	17.99

3.2. Econometric Model Results

3.2.1. Regression Diagnostics

Before estimating the multinomial probit model, it was necessary to check for outliers and whether multicollinearity exists among the explanatory variables considered for analysis. The reason for this is that the existence of multicollinearity will seriously affect the parameter estimates. If multicollinearity turns out to be significant, the simultaneous presence of the two variables will attenuate or reinforce the individual effects of these variables. In short, the coefficients of the interaction of the variables indicate whether or not one of the two associated variables should be eliminated from model analysis [20].

Thus, before estimating the parameters of the model, the regression diagnostics were done to check whether it follows the assumption of regression or not. Variance Inflation Factor (VIF) was checked for the existence of multicollinearity between all the explanatory variables included in the model using SPSS version 20. The variance inflation factor for all explanatory variables was less than 10, which indicates that multicollinearity is not a serious problem in the model (Table 4).

Table 4. *Variance Inflation Factor (VIF) for continuous variables.*

Variable	VIF	TOL
Education level	1.80	0.554831
Extension visit	1.51	0.664000
Household farm income	1.33	0.753762
Active labor size	1.31	0.765100
Cultivated land size	1.19	0.843022
Age	1.18	0.843921
Livestock holding	1.10	0.910464
Distance to market	1.09	0.917724
Mean VIF	1.31	

In addition, there may be interaction between dummy variables, which can lead to the problem of multicollinearity. To detect this problem, the coefficients of contingency were computed from the survey data. The contingency coefficients (CC) were done on SPSS version 20, and the result showed the absence of a strong association between the different discrete explanatory variables, since the respective coefficients were very low (less than 0.75) (Table 5).

Table 5. *Contingency Coefficients (CC) for Dummy Variables.*

Variable	Contingency Coefficient (CC)
Irrigation access	0.196
Access to credit	0.107
Climate information	0.180
Sex	0.043

3.2.2. Determinants of Farmers' Choice of Adaptation Strategies to Climate Change

The multinomial probit model was employed to estimate the parameters of the explanatory variables expected to determine farmers' choice of adaptation strategies to climate change, and the model result is presented in Table 6. The goodness-of-fit was tested by the Log likelihood ratio (LR) test. The result showed that Wald chi2 is 423.21 and prob > chi2 = 0.00. This means that χ^2 is statistically significant and the model displays a good fit. The Pseudo R^2 of the model is 0.73, implying that 73% of the variation in the choice of adaptation strategies to climate change was explained by the 12 explanatory variables included in the model. This verifies that the model has a good fit to the data and explains significant non-zero variations in factors influencing households' adaptation strategies to climate change.

The multinomial probit model was employed to identify the determinants of farmers' choice of adaptation strategies to climate change in the study area using the cross-sectional data from 189 sample households. Accordingly, variables hypothesized to influence the farmer's choice of adaptation strategies to climate change were fitted into the model. To act in response to climate change and decrease its negative effects, changing planting period, soil and water conservation practice, changing livestock type, income source diversification, and growing drought-tolerant crops were adaptation strategies used by farmers in the study to mitigate the adverse impact of climate change. However, many factors influence households' choice to prefer a particular adaptation option.

The results of the multinomial probit model showed that the decision to choose a certain adaptation strategy to climate change and variability depends on several factors. Out of 12 variables included in the model, eight variables were statistically significant. Namely, access to climate information and formal extension services, household education level, the age of the household head, household farm size, and household income the study areas were reported as some of the factors that affect adaptation strategies to climate change in the study area. We reported here only those factors that significantly affected the choice of adaptation options to be implemented (Table 6).

Age of the household head: The survey result indicated that the age of the household head had positively impacted the decision to practice change in crop type, change livestock type, and income source diversification as an adaptation strategy to climate change in the study area and significant at 5%, 5% and 1% probability level, respectively (Table 6). The positive sign showed that the age of the household head increases the probability of taking up adaptation measures. This is because older farmers have long years of experience to notice changes in their environment and take up adaptation measures. This means that as the age of the household head increases by a year, the probability of changing the planting period, changing livestock type, and income source diversification as a climate change adaptation option will increase by probability of 0.2%, 0.15%, and 0.12%. The result of the study is in line with Nhemachena and Hassen [19]. Thus, it can be inferred from the result that the age of the farm households was one of the factors in the choice of adaptation strategies to climate change.

Educational level: It was a significant determinant in adopting livestock type change as an adaptation strategy to climate change at 5% probability level. Household education level and changing livestock type as an adaptation strategy to climate change were positively correlated, implying that educated farmers are expected to adopt new livestock breeds based on their awareness of the potential benefits of the proposed climate change adaptation measures (Table 6). A year increase in the school level of education of the farm household leads to an increase in the probability of changing livestock type as an adaptation option by 1.5%. The survey result is in line with the findings of Hassan and Nhemachena [21].

Active labor size: As expected, active labor size had a positive and significant relationship with changing the planting period and income source diversification as an adaptation strategy to climate change in the study area at 5% probability level. The positive sign showed that the probability of changing planting period and income source diversification was high for households where active (productive) members are greater than inactive (unproductive) members (Table 6). Other variables remaining constant, as the active labor size (15-65 years) increases by a unit, the probability that the household uses changing planting period and income source diversification as an adaptation strategy to climate change increases by 3.2% and 4.6%, respectively.

Access to formal extension services: It had a positive and significant influence on the probability of growing drought-tolerant crops as climate change adaptation measures at 5% significance level (Table 6). The post estimation result of the marginal effect implied that an increase in extension visits by one leads to an increase in the probability of smallholder farmers to adopt growing of drought-tolerant crops as an adaptive strategy in response to climate change by 3.4%. This result agrees with Alemayehu and Bewket [22].

The finding of the study suggests that extension services are an important source of information on climate change impacts and adaptation strategies, and improved provision of extension services for modern farming practices should be encouraged. Ifeanyi-obi et al. [23] suggested that extension agents need to be well-groomed in climate change adaptation strategies that are relevant to the farmers' particular environment.

Access to climate information: It is one of the most important variables that affect the decision of smallholder farmers to choose certain adaptation options to climate change in the study district. Smallholder farmers who had access to climate information had a higher probability of implementing climate change adaptation options. Access to climate information had a positive effect on farmers' decisions to use changing of livestock type and income source diversification as an adaptation strategy to climate change, and was significant at 5% probability level (Table 6). The marginal effect result indicated that the probability of farm households who had access to climate information to practice changing of livestock type and income source diversification was higher than their counterparts by 0.08% and 0.2%, respectively, considering other factors remaining constant. The findings of the study are in line with Alemayehu and Bewket [22]

Access to climate information, provided by the national meteorological agency, significantly increased farmers' choice of adaptation options. This indicates that a household that had better access to weather information was better informed about adaptation decisions. Households with regular access to official weather information are more likely to change the crop selection for the upcoming growing season as an adaptation option. This implies that the provision of weather information and services at the local level will increase the adaptive capacity of the agricultural communities. Hence, the information on agricultural practices needs to be complemented with seasonal weather forecasts and should be supported by extension agents' advice. This can help farmers adjust to the seasonal variation in the onset and cessation of rainfall by changing their planting dates, crop choices, and timely agricultural planning. Apart from the national meteorological services, it is also important to develop and increase the availability of localized forecasts to improve the reliability and spatial-temporal resolution of the services to smallholder farmers.

Access to irrigation: It had a negative relationship with soil and water conservation adaptation strategy to climate change, and was significant at 10% probability level. This implies that the probability of using soil and water conservation adaptation strategies to climate change decreased with access to irrigation. However, access to irrigation had a positive impact on smallholder farmers' decision to grow drought-tolerant crops in response to climate change (Table 6). The marginal effects analysis reveals that households with access to irrigation were 3.2% less likely to adopt soil and water conservation measures but 12.7% more likely to cultivate drought-tolerant crops as part of their climate change adaptation strategies, compared to those without irrigation access.

Irrigation, as one of the technology options available, enables smallholder farmers to directly produce consumable food grains and/or diversify their cropping and supplement moisture deficiency in agriculture, and helps to increase production and food consumption without being affected by climate change.

Table 6. *Determinants of adaptation choice to climate change: Multinomial probit model.*

Explanatory Variables	Changing planting period		Soil and water conservation		Change livestock type		Income source diversification		Growing drought-tolerant crops	
	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
Sex	-0.136	0.841	-0.201	0.526	0.210	0.528	-0.003	0.999	0.041	0.904
Age	0.054	0.014**	0.0188	0.366	0.041	0.036**	0.059	0.005*	-0.030	0.183
Educational level	-0.048	0.407	-0.096	0.103	0.118	0.042**	-0.022	0.695	0.090	0.131
Active labor size	0.337	0.019**	-0.069	0.610	-0.219	0.107	0.288	0.042**	0.209	0.121
Frequency of extension visit	0.012	0.949	0.175	0.343	-0.202	0.084	0.027	0.884	0.372	0.048**
Access to credit	0.629	0.308	0.887	0.112	-1.00	0.084*	0.114	0.839	-0.436	0.424
Distance from market	-0.005	0.841	0.014	0.540	0.011	0.603	-0.026	0.262	-0.001	0.956
Cultivated land size	-0.341	0.534	-0.229	0.644	-0.375	0.444	0.605	0.233	-0.477	0.361

Explanatory Variables	Changing planting period		Soil and water conservation		Change livestock type		Income source diversification		Growing drought-tolerant crops	
	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
Household farm income	0.02	0.225	-0.001	0.354	0.000	0.715	0.002	0.196	0.000	0.567
Livestock holding in TLU	-0.323	0.627	0.039	0.542	0.068	0.275	-0.107	0.091*	0.0137	0.833
Access to climate info	-0.136	0.373	0.124	0.710	0.682	0.047**	-0.806	0.021**	0.235	0.490
Access to irrigation	-0.529	0.337	-0.917	0.072*	0.386	0.460	0.531	0.292	0.919	0.083*
Constant	0.721	0.45	0.069	0.941	-1.29	0.157	1.23	0.191	-0.102	0.917
Number of observations	189									
Log likelihood	-32.33									
LR chi2 (19)	423.21									
Prob > chi2	0.00									
Pseudo R^2	0.73									

Note: ***, ** and* significant at 1%, 5%, and 10% probability level of significance

The result of the post estimation (marginal effect and the likelihood probability) showed that the likelihood of households to use changing planting period, soil and water conservation practices, diversification of their income sources, change livestock type, and growing drought tolerant crops were 16.69%, 22.32%, 15.25%, 28.92% and 16.82%, respectively.

***Table 7**. The probability of using different adaptation strategies to climate change.*

Adaptation strategies	Likelihood
Changing planting period	16.69%
Soil and water conservation practices	22.32%
Diversification of their income sources	15.25%
Change livestock type	28.92%
Growing drought-tolerant crops	16.82%

4. Summary, Conclusion, and Recommendation

4.1. Summary and Conclusion

Ethiopia remains highly vulnerable to the impacts of climate change due to its heavy reliance on rain-fed agriculture, frequent drought occurrences, and limited adaptive capacity. These climatic challenges disrupt planting and harvesting cycles, lower crop yields, and heighten the risk of crop failure, posing a direct threat to the livelihoods of rural households. This study investigates the factors influencing smallholder farmers' adaptation strategies to climate change in the Haramaya District, Eastern Ethiopia.

Cross-sectional data were collected through a survey of 189 randomly selected households across three rural Kebeles using a structured questionnaire, focus group discussions, and key informant interviews. The data were analyzed using descriptive statistics and a multinomial probit econometric model. Descriptive statistics provided insights into the types of adaptation strategies employed, while the multinomial probit model was used to identify key determinants influencing farmers' decisions to adopt specific adaptation practices.

The descriptive results revealed that the most commonly employed adaptation strategy was changing livestock type (22.75%), followed closely by soil and water conservation practices (22.22%). Income diversification was adopted by 20.63% of the respondents, while 17.99% of households reported growing drought-tolerant crops. Changing the planting period was the least commonly used strategy, cited by 16.40% of respondents. These findings indicate a diverse array of adaptation responses, with a notable emphasis on livestock and natural resource management.

The multinomial probit analysis identified several significant factors influencing adaptation choices, including access to climate information, availability of formal extension services, educational attainment of the household head, age, farm size, and household income. The predicted probabilities of households adopting each respective strategy were 16.69% for changing planting periods, 22.32% for implementing soil and water conservation, 15.25% for diversifying income sources, 28.92% for changing livestock types, and 16.82% for growing drought-tolerant crops.

These results underscore the importance of enhancing access to climate information, strengthening extension services, and promoting educational initiatives to improve the adaptive capacity of smallholder farmers. The findings offer important implications for policymakers and development practitioners aiming to strengthen rural resilience to climate change in Ethiopia.

4.2. Recommendations

Based on the findings of this study, the following recommendations have been made for local policymakers and stakeholders in the study district.

The findings of this study underscore the critical role of farmers' perceptions in shaping their adaptation strategies in response to climate change. Farmers who recognize climate change are significantly more likely to adopt strategies that mitigate its impacts. However, a considerable number of farmers still do not perceive these changes. Therefore, raising awareness about the realities and risks of climate change is vital. Policies should focus on awareness creation through diverse channels, including media platforms, extension services, and community engagement.

Strengthening the adaptive capacity of smallholder farmers requires a multifaceted approach. Enhancing the provision and quality of agricultural extension services, promoting farmer-to-farmer knowledge sharing, and facilitating access to timely and accurate climate information are all essential. Encouraging the use of local networks and community-based discussions enables farmers to share experiences and identify appropriate adaptation strategies. Access to climate information via radios, extension agents, village leaders, and elders can also play a transformative role in decision-making and preparedness.

Policy measures must also be tailored to local agro-ecological settings and should incorporate gender-sensitive approaches to ensure inclusivity and effectiveness. The promotion of adaptation strategies, such as planting drought-tolerant crops, changing planting periods, practicing soil and water conservation, diversifying income sources, and adjusting livestock types, should be context-specific. Recognizing gender-based differences in resource access, labor roles, and decision-making power is essential for achieving equitable outcomes.

Education plays a foundational role in enhancing farmers' resilience. Literate farmers are better equipped to access, interpret, and apply information related to climate change and its management. Expanding adult education programs and designing flexible learning systems that accommodate farmers' schedules will empower them to make informed choices and adopt suitable farming practices. Education also supports the long-term sustainability of climate adaptation interventions.

Improving household income through diversified livelihood opportunities is another key area of intervention. Increased income enhances farmers' purchasing power, enabling them to afford critical agricultural inputs such as drought-resistant seeds, irrigation equipment, and fertilizers. To facilitate this, the government and stakeholders must ensure the availability and affordability of farm inputs and invest in the development of off-farm income-generating activities.

Landholding size also influences the ability of farmers to adapt effectively. Farmers with larger plots should be guided through targeted extension services to adopt sustainable and climate-smart practices. Meanwhile, those with limited land should be supported to use their plots more efficiently. Moreover, transitioning from traditional livestock systems to modern, sustainable practices can help reduce resource strain and improve productivity.

Access to credit is a critical enabler for adopting and sustaining adaptation strategies. Affordable and accessible credit allows farmers to invest in inputs and infrastructure necessary for implementing adaptive measures. Expanding the outreach of formal financial institutions and offering loans with favorable terms will significantly improve farmers' capacity to respond to climate challenges.

Finally, further research is needed to evaluate the effectiveness and long-term impacts of various adaptation strategies on household welfare and agricultural productivity. Evidence-based insights will help refine policy design and ensure that interventions are both targeted and sustainable in addressing the impacts of climate change in the Haramaya District.

Abbreviations

FAO	Food and Agriculture Organization of the United Nations
FGDs	Focus Group Discussions
HWADPFSO	Haramaya Woreda Administration Disaster Preparedness and Food Security Office
HWAEPA	Haramaya Woreda Administration Environmental Protection Authority
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KIIs	Key Informant Interviews
MNP	Multinomial Probit
NBE	National Bank of Ethiopia

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Conflicts of Interest

The authors declare no conflicts of interest.

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