

Research Article

Choices of Adaptation Strategies to Climate Variability and Its Determinants: Evidence from Farm Households of Benishangul Gumuz Regional State, Western Ethiopia

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Abstract

Climate variability and change is a serious threat to the livelihoods of rural communities because they are very sensitive to such changes. This study identified farmers' choice of and factors determining adaptation strategies to climate variability and change in Benishangul Gumuz regional state, western Ethiopia which is harshly affected by climate change stresses. Both primary and secondary data were used for the study. Primary data were collected from a randomly selected 395 sample households through interviewed using field-based questionnaires and focus group discussions. Relevant secondary data were also obtained from Benishangul Gumuz region Agriculture and Natural resource Bureau, national meteorological agency and different reports. Descriptive statistics were used to describe farmers' adaptation strategies to climate change. Multivariate probit model was estimated to identify the factors determining households' choice of adaptation strategies to climate change. The results of the model pointed out that the likelihood of households to adopt soil and water conservation practice, crop diversity, small scale irrigation, improved crop varieties, agrochemical applications and adjusting planting date were 64.7%, 70.4%, 65.5%, 64.2%, 63.6% and 58.9% respectively. The results also indicated that the joint likelihood of using all adaptation strategies was only 2.13% and the joint likelihood of failure to adopt all of the adaptation strategies was 2.82%. Moreover, Multivariate probit model confirmed that age, sex, education status, family size, dependency ratio, total land holding, farming experience, credit access, frequency of extension contacts, distance to the market, total livestock holding, farm income and off/non-farm income have a statistically significant impact on climate adaptation strategies. Therefore, policy makers should focus on towards supporting improved extension service, facilitating the availability of credit especially to adaptation technologies, improving farmers farm income earning opportunities, improving their literacy status, and improving their access to markets.

Keywords

Determinates, Adaptation Strategies, Climate Change, Multivariate Probit Model

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1. Introduction

Climate change is one of the swiftly spread phenomena across the globe since last century and livelihood of residents of the planet is at risk [16]. One-third of the world population is directly or indirectly facing the heat of the climate change variations [25]. Evidence points to the fact that climate-induced shocks have significant negative effect on crop yield, food security and the economy [3, 7].

Developing countries with large rural economies that rely on agriculture and those who directly depend on the production of the agricultural commodity for their income may suffer as a result, as earnings may be threatened to anticipated climate change impacts [4]. Ethiopia is one the developing country in which agriculture accounts about 42 percent of the GDP, employs about 85 percent of the labor force and contributes around 90 percent of the total export earnings which shows that the overall economy of the country and the food security of the majority of the population depend on small holder agriculture is suffering from variability and extremes of climate [10].

Climate change is therefore a threat to the Ethiopian economy and livelihoods of millions of the poor. The available option for Ethiopia to reduce the wide-ranging impacts of climate change is to adapt to changing climate. Addressing long-term climate change is thus required to reduce the impacts on livelihoods in general and major economic sectors such as agriculture, which is the mainstay of the country. However, adaptation strategies used during the events of climate variability shocks are influenced by many factors. Available empirical literature showed that farmers' socio-economic characteristics, farm-level and institutional factors influence their response to climate change events [5, 6, 29] which is area or country specific.

According to different authors, in Benishangul Gumuz region, the temperature is increasing and rainfall is decreasing from time to time [26]. Population growth, increased settlements and expansion of cropping land, thus changing the environment into hot and dry conditions, deforestation resulting from charcoal burning and other uses, increasing livestock pressure on grazing lands and the traditional grazing land management system are the characteristics of the region [26].

Identifying and understanding the determinants of adaptation to climate change at local scale by engaging farmers are absolutely imperative and will undoubtedly assist decision-makers in understanding local climate issues and thus ensuring relevant policy interventions [18]. Thus, Farmers in the study area are trying to adapt different mechanisms to reduce the negative influences of climate change. Conversely, in the study area, the socio-economic determinants on climate change adaptation and choice of adaptation strategies on a

larger spatial scale have not been deliberated in previous studies.

Therefore, the objective of this study is to analyze the factors affecting the choice of adaptation methods in crop production systems by taking the case of farmers in the Benishangul Gumuz regional state of Western Ethiopia to bridge this gap of knowledge in order to guide policymakers and other stakeholders on ways to promote adaptation.

2. Materials and Methods

2.1. Study Area

The study area, Benishangul Gumuz Regional State is located in the Western part of Ethiopia. According to the projected population of Ethiopian of 2019, the total population of the region is 1,125,999 of which 571,000 (50.7%) are male [10]. The total area of the Region is estimated to be about 50,380Km². Mixed farming (crop production and livestock rearing) is the predominant sources of livelihood for the majority of the population in the area. The crop production is dominated by rain fed agriculture while irrigation is practiced on small-scale level [26].

The climate of the region is characterized by a mono-modal rainfall pattern (i.e., a single rainfall maximum per year). The duration of the rainy season decreases from south to north. Agro-ecologically, the study area can be classified into three major climatic zones. Lowland or kola with an altitude below 1500 m, Midland (woynadega) zone that has an altitude of 1500 to 2500 m; and highland (Dega) which lies at an altitude of 2500 m.

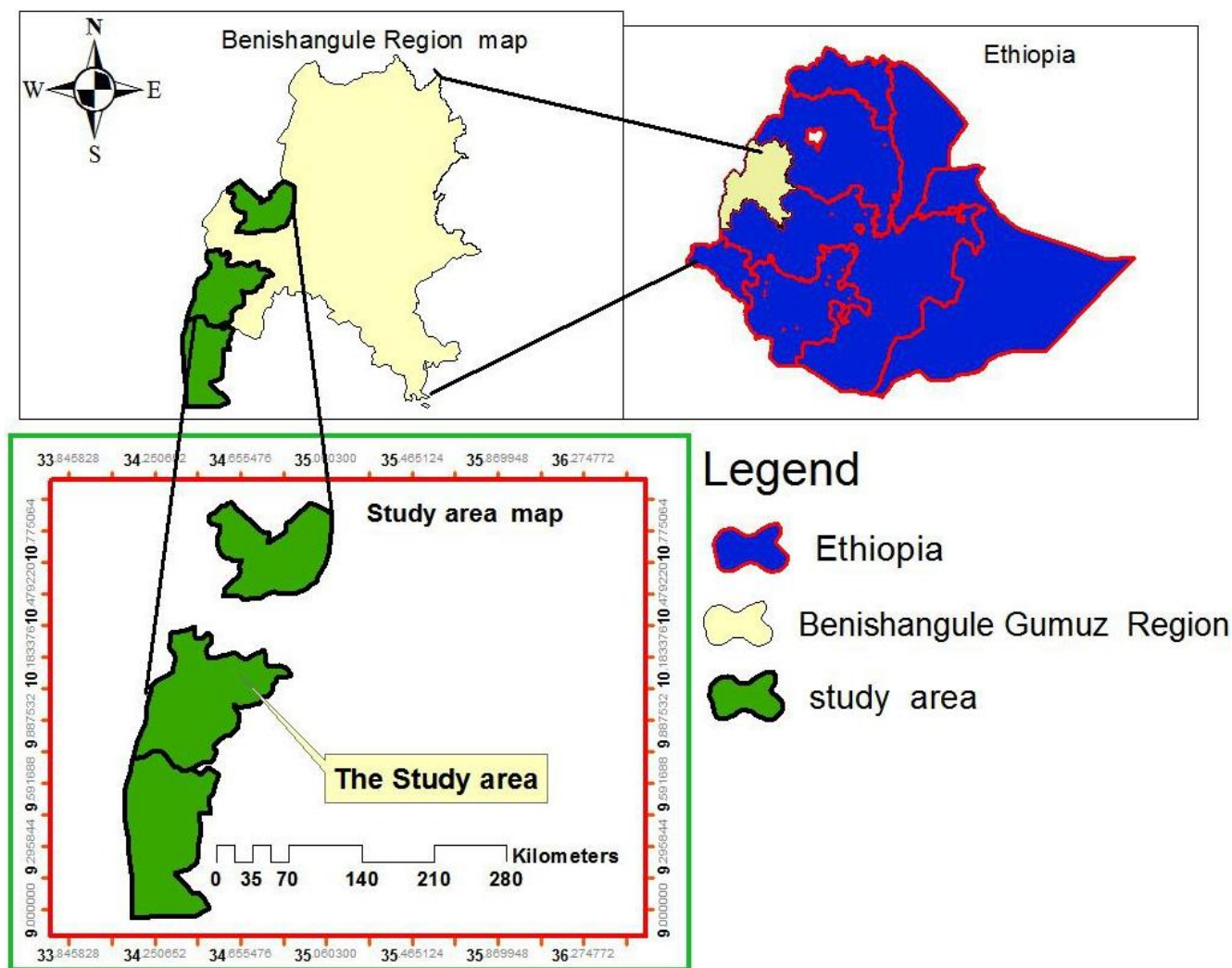
2.2. Procedure of Data Collection

The multistage sampling procedure was employed in selecting the sample households for this study. In the first stage, one zone (Assosa) and one special district (Mao Komo) were purposively selected based on main farming practices and socio-economic status. In the second stage, the districts were categorized based on agroecology and three districts (Mao Komo special district from the highland; Assosa district from midland and Sherkolle district from the low land climate zone were taken purposively based agroecology of the districts. In the third stage, two kebeles were randomly selected to make a total of six kebeles. In the last stage, sample size of households at kebele level was determined based on probability proportion to size and the households were identified using simple random sampling technique.

For the household survey, sample size of respondents is determined following [20] formula given as:

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

$$= \frac{(1.96)^2(0.5)(0.5)226,966}{(0.05)^2(226,966-1) + (1.96)^2(0.5)(0.5)} = \frac{217,978.1464}{568.3729} = 383.5126 \approx 384 + 10\% \text{ compensate for more nonresponses and/or incomplete information} = 422$$



Source: GIS, 2022

Figure 1. Map of the Study Area.

2.3. Econometric Model

A multivariate probit (MVP) approach was used for the empirical analysis. MVP models the effect of a set of regressors for each of the adaptation strategies simultaneously, while allowing free correlation among the unobserved factors [21]. When farmers experience production risk, they do not necessarily choose adaptation strategies to mitigate the risk,

but choose a particular strategy to take advantage of complementarity or substitutability with alternative choices. Therefore, while adopting a particular adaptation strategy, a farmer may also choose other strategies. A dummy dependent variable representing the adaptation strategies used by farmers were used to mitigate the effect of climate change on their farms.

A multivariate probit model was employed since it allows simultaneously using all the climate change adaptation strate-

gies and limits or eliminate the possible correlation problems between error terms [1, 15]. Farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate induced risks and constraints than adopting a single strategy. It assumes that each respondent has binary responses for each choice of adaptation practices. This model reflects the influence of the set of explanatory variables on each of the different options and allows error terms to be freely correlated [21].

3. Result and Discussion

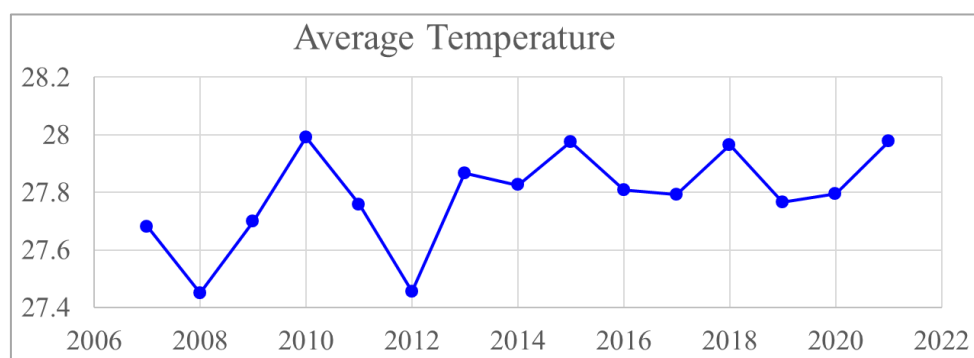
Farm Households Perception of Climate Change

Farmers' understanding of climate change and risk is critical for incorporating climate adaptation into agricultural development strategies and plans. Assessing farmers' percep-

tions of climate change is necessary for the implementation of adaptation strategies. In this study, respondents were asked if they had noticed any changes in temperature and rainfall in addition to the items listed in Table 1 over the previous ten years in 2021.

Accordingly, all the farm households perceived that temperature is changing. The majority (97.2%) of them responded that, the temperature was rising (67.9%) and becoming more irregular (29.3%). The perceptions of farm households about the rising temperature are also in line with the result of [12] who examined the recent years temperature in Ethiopia and showed slight increment.

The data obtained from meteorological agency of National Metrological Agency for 15 consecutive years also showed the slight increment in temperature in the region (Figure 2).



Source: National Meteorological Agency, 2022

Figure 2. Trend of average temperature of Benishangul Gumuz Region.

Regarding the changes in rainfall patterns and distribution, 48% of the respondents claim that rainfall patterns and intensity have been decreasing over the past ten years and 29.3% of

them perceived that the pattern and distributions remain irregular. The majority of respondents (82.3%) had noticed variations in rainfall patterns, amount, and intensity.

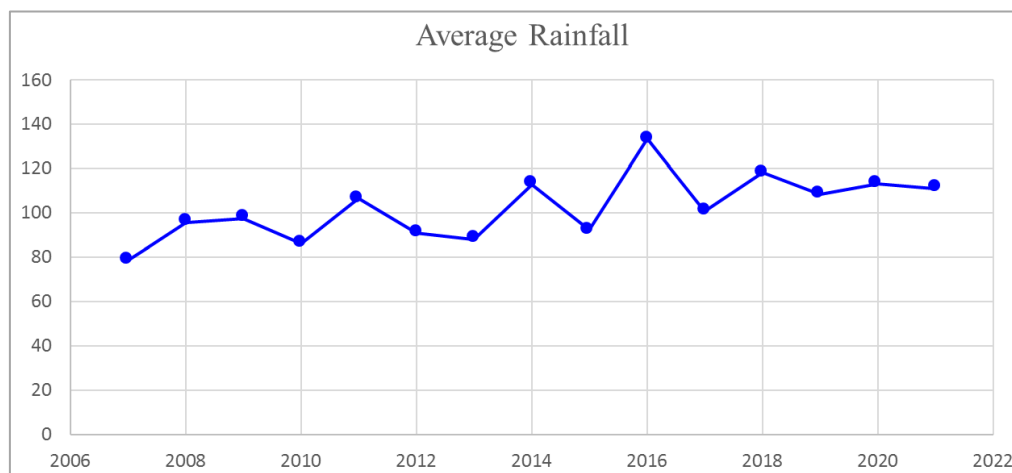


Figure 3. Trend of average rainfall in Benishangul Gumuz Region.

The results also revealed that the majority of respondents (54.7%) had noticed heavy storms before rainfall and an increase in crop pests and diseases (69.7%). Respondents also agreed on a high daily temperature (89.4%) and an increase in the frequency of drought (79.5%) and flooding (32.3%).

Table 1. Farmer's perceptions of climate change.

Farmers' perception of climate change	Response (Yes %)
Change in patterns, amount and intensity of rainfall	82.3
Heavy storms	54.7
Pest and diseases of crops	69.7
High daytime temperature	89.4
Change in heat and cold period	62.1
Frequency of drought	79.5
Flooding	32.3

Source: Computations from survey data, 2022

Distribution of Adaptation Strategies to Climate Change

Furthermore, farm households who claimed to have observed climate change over the past 10 years were asked if they had responded to the impact of climate change through use of different adaptation strategies. The sampled households of the study area respond to climate change stresses by using mutually inclusive adaptation strategies such as crop diversity, soil and water conservation practice, small scale irrigation, crop rotation, adjusting planting date and improved crop varieties as climate change major adaptation strategies. Moreover, farmers who did not adapt (only 10.1%) have given many reasons for their failures to adapt which include lack of information, lack of money and shortage of land.

Table 2. Distributions of Adaptation Strategies Employed by Farm Households.

Adaptation Strategies	Mean	Standard Error
Mulching	0.49	0.501
Soil conservation practices	0.65	0.479
Planting trees	0.27	0.446
Small scale irrigation	0.65	0.476
Crop diversification	0.70	0.457

Adaptation Strategies	Mean	Standard Error
Improved crop varieties	0.64	0.480
Applications of Agrochemicals	0.64	0.482
Crop rotations	0.56	0.498
Adjusting planting date	0.59	0.493
Switching to short maturing crops	0.53	0.500

Source: Own computation result based on survey data, 2021

Table 2 shows the distribution of adaptation strategies pursued by sampled farm households. The result indicated that the most frequently adopted strategies include crop diversification, soil conservation practice, small scale irrigation, crop rotation, improved crop varieties, and adjusting planting date and farm households respond to climate change stresses by using mutually inclusive adaptation strategies (Table 2).

The data collected in 2021 revealed that some households use two or more strategies in one season to adapt to climate variability and a little of them uses none strategies. Rainfall shortage in the grain filling stage of crops was a critical problem that resulted in serious damage as to households' response. Rainfall problems at the beginning time was also a threat to crop production and respond for late start of rain by changing sowing season and crop type.

Determinants of Adaptation Strategies of Climate Change in the Study Area

This section discusses the results from the multivariate probit model. The likelihood ratio test ($\chi^2(15) = 82.5469, P > 0.000$) of the independence of the error terms of the different adaptation equations is rejected (Table 3). Thus, this study adopts the alternative hypothesis of the mutual interdependence among the multiple adaptation strategies. The result therefore supports the use of multivariate probit model.

The results conveyed that all explanatory variables which are included in the study significantly affect the adaptation strategies against climate change stresses except sex and off farm income of farm households in the study area (Table 3). The significant factors are discussed as follows:

Age of the household head exhibited a positive relationship in influencing the decision to adopt the choices of crop diversification and use of improved varieties and negatively the decision to adopt soil conservation practices strategies. The positive relationship to crop diversification and use of improved varieties strategies shows farm households mostly devote their live time, base their livelihoods on agriculture and it is believed that the older the household head, the more experience they have in farming and climate change adaptation strategy. The result is in line with the study of [28]. On the

other hand, the negatively relationship between age and soil conservation might be due to the fact that farmers are expected to make stone bunds, ridging, mulching, and conservation agriculture as soil conserving mechanisms which are labor intensive and aged farmers may lack to perform such

activities due to being aged. The result is also in consonance with the study of [11, 23] who found a negative effect of age on farmers choice of different adaptation strategies.

Determinants of Farm Household's Choice of Adaptation Strategies to Climate Change.

Table 3. Multivariate probit simulations result for farm household's climate change adaptation strategies.

Explanatory Variables	Crop Diversity Coeff. (Std.Err)	SC Practice Coeff. (Std.Err)	SS Irrigation Coeff. (Std.Err)	Crop Rotation Coeff. (Std.Err)	AP Date Coeff. (Std.Err)	Impr Varieties Coeff. (Std.Err)
Age	0.014 (0.008)*	-0.02 (0.008)***	0.001 (0.008)	0.004 (0.008)	-0.003 (0.008)	0.014 (0.008)*
Sex	0.218 (0.227)	0.308 (0.219)	-0.022 (0.219)	0.339 (0.222)	-0.332 (0.216)	0.201 (0.212)
Educ. status	-0.027 (0.026)	0.031 (0.025)	0.001 (0.025)	0.026 (0.025)	0.044 (0.026)*	-0.013 (0.025)
Family size	-0.008 (0.019)	-0.028 (0.019)	-0.001 (0.018)	-0.048 (0.019)**	0.022 (0.019)	-0.033 (0.019)*
Dependency ra	-0.106 (0.062)*	-0.102 (0.059)*	-0.052 (0.058)	-0.068 (0.059)	-0.021 (0.057)	-0.047 (0.058)
Total Land	0.057 (0.024)**	-0.035 (0.021)*	0.046 (0.022)**	0.042 (0.021)**	-0.009 (0.021)	0.022 (0.02)
Experience	0.016 (0.009)*	0.017 (0.008)**	0.022 (0.008)***	0.003 (0.008)	0.001 (0.008)	-0.0004 (0.008)
Credit access	0.270 (0.139)*	0.228 (0.137)*	-0.057 (0.138)	0.068 (0.138)	0.516 (0.139)***	-0.143 (0.136)
Exte. contact	-0.009 (0.071)	0.004 (0.070)	0.046 (0.07)	0.005 (0.071)	0.151 (0.071)**	-0.056 (0.070)
Access to Mkt	-0.052 (0.026)**	0.003 (0.026)	0.037 (0.026)	0.013 (0.026)	-0.024 (0.026)	0.032 (0.026)
Livestock	-0.017 (0.011)	0.0004 (0.011)	-0.008 (0.011)	0.018 (0.011)*	-0.001 (0.011)	0.001 (0.011)
Climate Info.	0.054 (0.140)	-0.077 (0.139)	0.248 (0.138)*	0.349 (0.14)**	0.094 (0.141)	-0.051 (0.139)
Training acc	0.159 (0.137)	-0.028 (0.134)	0.088 (0.134)	-0.012 (0.135)	-0.091 (0.136)	0.232 (0.134)*
lnFarminco.	0.175 (0.078)**	0.011 (0.075)	0.049 (0.076)	0.067 (0.076)	-0.007 (0.076)	0.08 (0.075)
lnOffarminco.	-0.004 (0.034)	0.03 (0.034)	-0.031 (0.034)	-0.014 (0.034)	-0.03 (0.036)	-0.012 (0.033)
_cons	-2.30 (0.857)***	0.061 (0.813)	-1.128 (0.815)	-1.4 (0.828)*	-0.434 (0.815)	-1.247 (0.805)
Rho2	0.030					
Rho3	0.307***	-0.0099				
Rho4	-0.058	0.152*	-0.301***			
Rho5	-0.232***	0.090	0.022	-0.060		
Rho6	-0.049	0.158*	-0.261***	0.434***	0.140*	
Pre prob to adapt	0.542	0.498	0.473	0.453	0.444	0.435
Joint probability (success) = 0.0164						
Joint probability (failure) = 0.0292						
Likelihood ratio test of Rhoij = 0, chi2 (15) = 82.5469, prob>chi2 = 0.0000						
Draw number = 100; No of observation = 385; Wald chi2(84) = 169.11; Log likelihood= -1466.5808						

***, **, and * show levels of significance at 1%, 5% and 10%, respectively.

Source: model output based on survey result, 2022

Educational status of farm households was directly and statistically significant use of adjusting planting date adaptation strategy. This might be education distinct individuals with the necessary knowledge on how to access information in climate change adaptation strategies. The model output is also in line with the result of [12, 14] who enlightened that farm households with higher level of education were more likely to adapt with different adaptation strategies to the climate change. [26] also suggested that literacy status of farm households' increases awareness about the consequences of climate change on productivity and reduce climate change impact.

The coefficient of family size is negative and statistically significant in influencing the choice of crop rotation and improved crop varieties adaptation strategies. A negative association between family size and climate change adaptation strategies has also been found in several studies [2, 5, 28]. This association could be attributed to the ability of the household to supply surplus labor to non-farm activities and the income generated could be invested in climate change adaptation strategies as found by [24, 13].

The coefficient of dependency ratio is negatively and statistically significant in affecting the choice of crop diversification and soil conservation practices adaptation strategies to climate change. A high dependency ratio is supposedly indicative of the dependency burden on the working population, as it is assumed that the economically active proportion of the population will need to provide for the health, education, pension, and social security benefits of the non-working population [17]. Low depreciation ratio reveals that many of the household members were within the economically active age range while the infants and aged were few in number. Thus, the climate change adaptation strategies by the household head increases as the dependency ration reduces.

Land is always associated with greater wealth, more capital and resources. land size is positive and statistically significant in influencing the choices of crop diversification, small-scale irrigation, crop rotation but negatively and statistically significant in influencing the choice soil conservation practices. Farmers with large landholdings are likely to have more capacity to try out and invest in climate risk adaptation strategies through the use of crop diversification, small-scale irrigation, and crop rotation but less participated in soil conservation practices. The reason might to due to fact that farmers with more land holding can benefit from the economics of scale of it as compared to those who had small land holding size. This result is consistent with [8].

The coefficient of years of experience in farming is positive and statistically significant in influencing all the choice of crop diversification, soil conservation practices and small-scale irrigation adaptation strategies. Years of experience in farming exposed farmers to knowledge of adaptation

options. Experienced farmers are likely to be savvy enough to reduce losses through the use of adaptation strategies. The result is in line with the study by [9] who found significant connections between farming experience and farmers adaptation strategies.

Access to credit was positively and statistically significant to the choices of adopting the crop diversification, soil conservation practices and adjusting planting date of adaptation strategies. The existence of reliable credit lines that farmers could activate had empowering effect on the probability of choosing climate change adaptation methods. As adaptation invariably involves committing financial resources, inadequate funds constrain even the consideration of options, except where there are available and accessible credit windows [27].

Frequency of extension contact had statistically significant and positive relationship with the adaptation strategy of adjusting planting date (Table 3). The hands-on knowledge exchanges with extension agents including those exposing the dangers of climate change and the merits of alternative adaptation paths, underpins the adaptation strategies made by the farmers [23].

Access to the nearest market center is significantly and negatively affected use of crop diversification as adaptation strategy. This could be due to the fact that better access to markets enables farm households to obtain information on climate change and other important inputs they may need if they are to change their practices to cope with predicted changes in future climate [28]. The result is in line with the study by [26].

Livestock ownership measured in Total Livestock Unit is positively and statistically significant in influencing the choice of the use of crop rotation adaptation strategy. Farmers with large herd size have better chances to invest on tools required for farm activities and increased income for the use of crop production. In addition, Livestock plays a very important role by serving as a store of value and by providing traction (especially oxen) and manure required for soil fertility maintenance and increased use of crop rotation as adaptation to climate change. This result is also similar with [8, 19, 26] who found a positive and statistical significance between Livestock ownership (TLU) and adaptation strategies.

Access to climate information has shown positive and significant association with small scale irrigation and crop rotation as adaptation options. Access to climate information has been found to promote farmers' investment in adaptation methods in Ethiopia. In agreement with this finding, [22] had indicated that access to climate information increases the probability adopting different adaptation strategies by creating awareness and favorable condition for farming practices that are suitable under climate change and also it is an important precondition for farmers to take up adaptation

measures to climate change.

Participation in climate change related training program is found to be positively and significantly related to the choices of using improved varieties as adaptation strategy. This is because farmers participated on training would have better awareness about climate change and possible adaptation strategies. This result is consistent with the finding of [26].

Farm income related positively and statistically significant with the choices of crop diversification adaptation strategy. Farmers who earned more income from their farming activities presumably had more resources in the form of backup savings to invest on adaptation infrastructure. This result is strengthened by [9] who found a positive and significant relationship between farm income and choices of different adaptation strategies.

4. Conclusion and Policy Implications

Climate variability and change is a serious threat to the livelihoods of rural communities because they are very sensitive to such changes. It is, therefore, essential to understanding the various strategies used by farmers to mitigate the adverse impact of climate change. In all, a total of four hundred and twenty-two (422) farm households were interviewed. However, 395 copies of questionnaire out of the 422 administered to the farmers had complete and adequate information for analysis implying a response rate of 93.6%.

Farm households adopt different kinds of adaptation strategies to reduce the negative consequences of climate change so as to maintain and/or to improve their livelihood. Accordingly, this study pointed out that 64.7%, 70.4%, 65.5%, 64.2%, 63.6% and 58.9% of the farmers were soil and water conservation practice, crop diversity, small scale irrigation, improved crop varieties, agrochemical applications and adjusting planting date, respectively.

Multivariate probit model was employed to analyze the determinants of farm household's choice of adaptation strategies related to climate change. MVP result also confirms that age, educational status, dependency ratio, total land holding, farm experience, distance to the market and farm income of farm households have a significant impact on the use of soil conservation practices as adaptation strategy to climate change. It also showed that age, access to credit service, frequency of extension contacts and distance to the market have a significant impact to the use of crop diversity to adapt to climate change. On the other hand, Total land holding, experience in farming and distance to the market significantly affect the use of small-scale irrigation as adaptation strategy to climate change. Moreover, Family size, distance to the market, total livestock holding and farm income are significant in determining the choice of improved varieties as adaptation strategy. Sex, dependency

ratio, total land holding, distance to the market and non/off-farm income have a significantly affect the choice of application of agrochemicals as an adaptation strategy to climate change. Finally, frequency of extension contacts, distance to the market, farm income and non/off-farm income significantly determined farmers' use of adjusting planting date to adapt to climate change impacts.

Thus, Future policy should focus on towards supporting improved extension service, facilitating the availability of credit especially to adaptation technologies, improving farmers farm income earning opportunities, improving their literacy status, and improving their access to markets. Investment in institutions such as extension services is essential for development and might encourage farmers to adopt appropriate climate change adaptation strategies. Thus, the government, stakeholders, and donor agencies must provide capacity-building innovations around the agricultural extension system on climate change using information and communication technologies.

Moreover, encouraging informal social net-works and environmental settings enhance the adaptive capacity of small-holder farmers to reduce the adverse effects of climate change and to help economic development and food security status.

Abbreviations

CSA	Central Statistical Agency
MVP	Multivariate Probit

Conflicts of Interest

The authors declare no conflicts of interest.

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