

# Smallholder Farmers' Adaptation strategies to Climate change and Determinant Factors in Gedeo and West Guji Zones, Southern Ethiopia

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## Abstract

Now a day climate change is becoming the global concern particularly in agricultural sector. The problem is even worse in subsistence agriculture. Due to the negative impact of climate change in agricultural sector farmers are practicing different climate change adaptation strategies to minimize the negative impact on agricultural production. The purpose of this study was to identify the most prevalent adaptation strategies used by farmers and determinants in southern Ethiopia. Data was collected from 386 households using structured and semi-structured questionnaires. Descriptive statistics and Multinomial logit equation model were employed to identify types of adaptation options prioritized by the local community, to examine factors that influence the choice of farmers to employ adaptation options to climate change and to provide suitable policy implications on adaptation options to climate change. The result showed that different districts had different strategies for adapting to climate change. Therefore, the most important adaptation strategies in Abaya district were soil and water conservation, tree planting, and grain storage; in Bule district the most important adaptation strategies were soil and water conservation, tree planting, and agroforestry practices; and in Dilla-zuria farmers prioritized tree planting and enset planting. Farmers' decisions to implement climate change adaptation strategies have been influenced by determinants of climate change in both positive and negative ways. According to the results, policies and methods that promote farmers' involvement in the design and implementation of adaptation alternatives using a bottom-up approach are necessary for improved climate change anticipation rather than concentrating on minimizing the adverse impact. This can be accomplished by strengthening farmers' organizations for the purpose of exchanging experiences in order to increase public adaptation capacity, incorporating climate change training into educational policies, improving agricultural extension systems in light of climate change, and strengthening institutional capacity to produce climate information at the local level.

**Key words:** Adaptation strategies, Climate change, Gedeo zone, West Guji zone

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## INTRODUCTION

Agriculture is one of the most vulnerable sectors to the growing risks of climate change (Ado et al., 2019; Alves et al., 2020; Getahun et al., 2021), placing pressure on global food supply networks (Geburu et al., 2020). Smallholder farmers are particularly vulnerable to the consequences of

climate change, according to a number of studies (Berger et al., 2017; Mulwa et al., 2017; Fahad and Wang, 2018; Marie et al., 2020; Antwi-Agyei and Nyantakyi-Frimpong, 2021). The impact of climate change is greatest in developing nations because of their limited capacity for adaptation and lack of access to other revenue streams (Ali and Erenstein, 2017; Fahad and Jing, 2018).

Limiting the harm caused by climate change is a pressing challenge for the international community. Sub-Saharan Africa is expected to warm more than the rest of the world, and some parts of the region will get less rainfall (Niang et al., 2014). According to a growing amount of data, extreme events such as droughts and floods have occurred often (Dasgupta et al., 2014). These affect smallholder farmers in developing countries, whose primary source of income is rain-fed agriculture (Pachauri et al., 2014).

Ethiopia is among the poor countries most vulnerable to the consequences of climate change, according to Paul et al. (2018). Ethiopia's vulnerability is exacerbated by its heavy reliance on rain-fed agriculture (Paul et al., 2018). Rainfall patterns have a direct impact on this industry's success (Gebru et al., 2020). Food shortages and, in the worst situations, famines are brought on by changes in seasonal patterns or inadequate rainfall. Climate change-related disasters, such as droughts, floods, and erratic rainfall, have made the country's need for food aid more urgent. To reduce the possible effects of climatic variability and change, farming communities should adapt on their own (Khan et al., 2021). Several common Adaptation strategies have been identified in the literature, including the use of drought-resistant crop varieties (Anik et al., 2021; Marie et al., 2020; Ponce, 2020; Bedeke et al., 2019; Kebede et al., 2019), crop diversification (Antwi-Agyei et al., 2021; Asfaw et al., 2018; Simotwo et al., 2018); crop rotation (Mairura et al., 2021); use of irrigation technologies (Antwi-Agyei et al., 2021; Ureta et al., 2020); and modifying planting dates (Ponce, 2020, Jamshidi et al., 2019; Masud et al., 2017). Policymakers may learn a lot by evaluating how farming communities are coping with the effects of climate change. Furthermore, evaluating the elements that affect the household's adaptation strategy selection is essential to reducing the effects of climate change (Bedeke et al., 2019).

According to a number of studies, farmers encounter different adaptation strategies based on the size and type of their farms, the climate, and additional contexts such as ecological, cultural, local, political, institutional, and socioeconomic factors (Gemeda et al., 2023; Getahun et al., 2021;

Hirpha et al., 2020; Mihiretu et al., 2019; Alemayehu & Bewket, 2017; Tofu, 2016). Additionally, research was done on the factors that influence farmers in various regions of Ethiopia to adopt climate change and variability adaptation strategies (Kemal et al., 2022; Adego & Woldie, 2022; Eshetu et al., 2021; Regasa & Akirso; Gebru, et al., 2020).

Although numerous studies have been conducted to identify the climate change adaptation strategies used by Ethiopian farmers, there are relatively few area-specific studies that concentrate on these strategies, and the factors influencing the adoption of climate change adaptation mechanisms are scarce in southern Ethiopia (Saguye, 2016). In the study area there are few researches has been done in the subject area. As a result, research on adoption factors and climate change adaptation is needed in the field. Understanding climate change adaption techniques may be crucial in swaying decision-makers. Therefore, the objective of this study was to determine the most significant climate change adaptation strategies used by smallholder farmers and to identify determinant factors.

## **METHODOLOGY**

### **Description of the Study Area**

The study was conducted in Abaya district of West Guji Zone and Dilla-zuria and Bule districts of Gedeo zone, southern Ethiopia. The Dilla-zuria district lies between latitudes 6°15'05" N and 6°26'35" N and longitudes 38°15'55" and 38°24'02" E. The district's slope ranges from 39.4% to 51.5% and its altitudinal range is between 1350 and 2550 meters. The monthly rainfall is between 83.7 and 310 mm, with an average rainfall of 172.9 mm. It has bimodal rainfall between March and June and September and October, with the largest rainfall between May and September and the lowest between October and February. The average monthly temperature is between 15.4°C and 17.9°C. Agriculture, agroforestry, trade, handicrafts, temporary jobs in coffee processing, and labor work are the main sources of income.

Bule district is located between latitudes 6° 04' 16" and 6° 23' 50" North and 38° 16' 20" and 38° 26' 11" East longitudes. The Bule district experiences an average annual temperature of 15.1°C to 22.5°C and an average annual rainfall of 1,200–1,800 mm. Bule district has 65% highland (Dega) and 35% mid-highland (Woina Dega) agro-ecology. There are two distinct wet seasons in the district: the long rainy season, which runs from July to December, and the short rainy season, which runs from March to May. Rain-fed annual crop production, which includes barley, wheat, maize, and pulse crops like beans and peas, dominates the district's main land use types. Coffee, enset, bamboo, apples, and other tree species including *Aningeria attissima* (Kerero), *Erythrina Abyssinica* (Korch), *Cordia africana* (Wanza), *Milletica ferruginea* (Birbira),

and *Eucalyptus* (especially *Eucalyptus globules*) are the common ones.

Abaya is situated in latitude 6°14'N and longitude 30°10'E. The district lies between 1200 and 2060 meters above sea level. The average annual temperature ranges from 16°C to 28°C, and the average annual rainfall is 1223 mm. The district has two different agro-climatic conditions: lowland (70%) and midland (30%). A transitional land use type between the upstream and downstream areas reflects a sedentary agro-pastoral lifestyle. Maize, groundnuts, barley, "teff," sorghum, haricot beans, wheat, field peas, and faba beans were the main crops grown. Although coffee is a major source of income, enset is also grown in the area, which provides some food security during dry seasons.

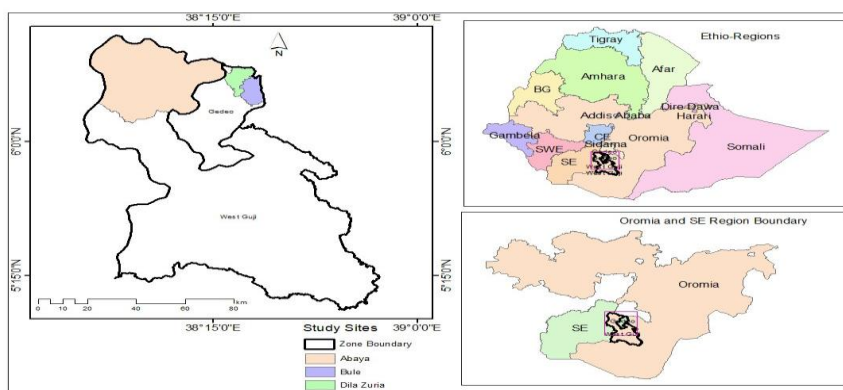


Figure 1. Map of study site

## Sampling Techniques and Sample Size Determination

### Sampling Techniques

A multi-stage sampling procedure was employed in the study to choose samples that fairly represented rural households in the study area. In order to select samples that accurately reflected rural homes in the study area, a multistage sampling approach was used. Three districts; Abaya, Dilla-zuria, and Bule were purposefully chosen to represent the low-land, mid-land, and highland agro-ecologies during the first phase. Highland agro-ecology was represented by Bule, midland by Dilla-zuria, and lowland by Abaya. Purposive sampling technique was used in the second stage to choose representative kebeles.

Andida and Michile-sisota from Dilla-zuria district; Samaro and Bunata from Abaya district and Gubato and Ilalcha from Bule district were the selected kebeles. Three hundred seventy-six respondent households were selected at random on the third stage. The number of sample households in each kebele was allocated proportionately.

Data on household income, landholding, household adaptation measures to climate change, demography, and other household economic and socio-demographic information were collected. Respondent households were chosen at random for the third stage. Based on the number of households in each kebele, the 376 respondents that made up the overall sample size were

allocated proportionately to each kebele. Systematic random sampling was used to assign the number of households in each kebele, which was received from the corresponding kebeles offices.

**Sample Size Determination**

To determine the required sample size, the formula developed by Yamane (1967) was applied at 95% confidence level.

$n = N / (1 + N(e)^2) \dots\dots\dots 1$   
 Where: n is the required sample size for the research  
 N= population size  
 e = is level of precision (= 0.05)  
 As a result, 376 sample homes in all were chosen at random from a total of six kebeles, or in accordance with the population size of the kebeles that were chosen (Table 1).

**Table 1. Distribution of sampled households**

District	Kebele	Agro-ecology	Male headed HH	Female headed HH	Total HH	Sample HH
Abaya	Hasegola	Low-land	874	203	1077	65
	Samaro	Low-land	848	157	1005	60
Bule	Sika	High-land	522	63	585	35
	Suko	High-land	403	59	462	28
Dilla-zuria	Andida	Mid-land	1080	120	1200	72
	Sisota	Mid-land	1622	317	1939	116
<b>Total</b>			<b>5349</b>	<b>919</b>	<b>6268</b>	<b>376</b>

HH= household write the source

**Data Type and Collection Methods**

For this study, both quantitative and qualitative data were collected. Qualitative data was gathered at the community level through focus groups and key informant interviews. To collect information at the household level, a home survey was also conducted using structured questions. Three focus groups with 10 participants each were held with different groups of old aged farmers who had resided in each kebele for a considerable amount of time. The participants were selected from the kebele as per recommended by kebele DAs and admiration. The researcher has developed checklist and translated to Amharic and in the Amharic version of the checklist was also translated to Gedeuffa (for Bule and Dilla zuria districts) and to Afaan oromo (for Abaya district). DAs has played facilitation role in conducting the survey and key FGD. Similar to this, key informant interviews were carried out with capable members of the community, including agricultural staff, government office officials, and senior farmers with a wealth of farming expertise for about an hour. The issue regarding climate change trend, impact of climate change on agriculture and common climate change adaptation strategies implemented by the farmers has been raised.

**Method of Data Analysis**

In this study, descriptive statistics including frequency, percentage, figures, and tables were used to summarize and illustrate socioeconomic and demographic data. In order to compare the differences across different agro-ecologies for various socioeconomic and demographic characteristics, the t test and Chi-square tests were also employed. The primary purpose of this test is to determine if the difference is statistically significant. The analysis was carried out using SPSS and STATA software.

**Empirical Specification of the Model (MNL)**

We tested the null hypothesis: independent variables have no impact on the choice of dependent variables (crop diversification, drought-resistant varieties, early maturing varieties, and soil and water conservation). Hence, farmers chose an adaptation strategy if the expected utility from it exceeded that of other adaptation strategies such that:

$$Y_i = \begin{matrix} Y_i \text{ if } V_i > V_j \\ Y_i \text{ if } V_i \leq V_j \end{matrix} \dots\dots\dots (2)$$

where,  $Y_i$  represents the strategy type  $i$ ,  $Y_j$  an alternative strategy type  $j$ ,  $V_i$  and  $V_j$  the corresponding expected indirect utility values of

strategy type  $i$  and its alternative  $j$ , while  $Y^*$  represents the strategy type chosen. Therefore, we can view farmers' decisions on the adaptation strategy within a random utility discrete choice model. This is particularly appropriate for modeling discrete choice decisions, such as between adaptation strategies, because it is an indirect utility function where an individual with specific characteristics associates an average utility level with each alternative adaptation strategy in a choice set. In this framework, the utility function is assumed to be known for each farmer, but some of its components are unobserved by the researcher. This unobserved part of the utility is treated as a random variable. For the  $i$  strategy decision, the expected indirect utility was then modeled as the sum of the observed variables and non-observed random component:

$$V_i = \beta_1 X_i + \epsilon_i \dots \dots \dots (3)$$

As in Eq. (1), we can write the choice utility of implementing any alternatives as follows:

$$V_j = \beta_1 X_j + \epsilon_j \dots \dots \dots (4)$$

Where,  $\beta_1 i$  and  $\beta_1 j$  are vectors of parameters. Hence, farmers can decide simultaneously whether to choose one or more adaptation strategies conditional upon the vectors of explanatory variables  $X_j$  and  $X_i$ . In this approach; we can use a multivariate logit model to study the farmers' joint decisions to adaptation strategy. The empirical specification of the model takes the form:

$$Y^*_{ij} = V_i = \beta_1 X_i + \epsilon_1 \dots \dots \dots (6)$$

with  $j = 1, 2, 3, 4, 5$

$$Y_i = 1 \text{ if } Y_i^* > 0 \text{ and } 0 \text{ otherwise} \dots \dots (7)$$

where,  $Y_i^*$  is an unobservable latent variable denoting the probability of choosing  $j$  type of adaptation strategy, for  $i = 1$  (Agroforestry),  $i = 2$  (crop diversification),  $i = 3$  (irrigation)  $i = 4$  (improved variety)  $i = 5$  (compost)  $i = 6$  (Shifting cropping time)  $i = 7$  (Migration)  $i = 8$  (Grain storage)  $i = 9$  (Enset)  $i = 10$  (Soil and water conservation)  $i = 11$  (Tree planting)  $i = 12$  (Fertilizer). Thus, empirically the model can be specified as follows:

$$Y_{I1} = \beta_1 X_{ij1} + \epsilon_{i1} \dots \dots \dots (8)$$

$$Y_{I2} = \beta_2 X_{ij2} + \epsilon_{i2} \dots \dots \dots (9)$$

$$Y_{I3} = \beta_3 X_{ij3} + \epsilon_{i3} \dots \dots \dots (10)$$

$$Y_{I4} = \beta_4 X_{ij4} + \epsilon_{i4} \dots \dots \dots (11)$$

$$Y_{I5} = \beta_5 X_{ij5} + \epsilon_{i5} \dots \dots \dots (12)$$

$$Y_{I6} = \beta_6 X_{ij6} + \epsilon_{i6} \dots \dots \dots (13)$$

$$Y_{I7} = \beta_7 X_{ij7} + \epsilon_{i7} \dots \dots \dots (14)$$

$$Y_{I8} = \beta_8 X_{ij8} + \epsilon_{i8} \dots \dots \dots (15)$$

$$Y_{I9} = \beta_9 X_{ij9} + \epsilon_{i9} \dots \dots \dots (16)$$

$$Y_{I10} = \beta_{10} X_{ij10} + \epsilon_{i10} \dots \dots \dots (17)$$

$$Y_{I11} = \beta_{11} X_{ij11} + \epsilon_{i11} \dots \dots \dots (18)$$

$$Y_{I12} = \beta_{12} X_{ij12} + \epsilon_{i12} \dots \dots \dots (19)$$

where,  $Y_{I1} = 1$ , if a farmer chooses Agroforestry (0 otherwise),  $Y_{I2} = 1$ , if the farmer chooses crop diversification (0 otherwise),  $Y_{I3} = 1$ , if the farmer chooses irrigation (0 otherwise),  $Y_{I4} = 1$  if the farmer chooses improved variety (0 otherwise),  $Y_{I5} = 1$  if the farmer chooses compost (0 otherwise),  $Y_{I6} = 1$  if the farmer chooses Shifting cropping time (0 otherwise),  $Y_{I7} = 1$  if the farmer chooses Migration (0 otherwise),  $Y_{I8} = 1$  if the farmer chooses Grain storage (0 otherwise),  $Y_{I9} = 1$  if the farmer chooses Enset (0 otherwise),  $Y_{I10} = 1$  if the farmer chooses Soil and water conservation (0 otherwise),  $Y_{I11} = 1$  if the farmer chooses Tree planting (0 otherwise),  $Y_{I12} = 1$  if the farmer chooses Fertilizer (0 otherwise);  $X_i$  = vector of factors influencing the choice of coping strategy (age, gender, Education, Land holding size, Farming experience, Income, Extension service and Altitude),  $\beta_j$  = vector of unknown parameters ( $j = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12$ ), and  $\epsilon$  = is the error term.

## RESULT AND DISCUSSION

### Demographic and Socioeconomic Characteristics of Households

Most of the respondent in Abaya and Bule district had access to irrigation while only 28.3% of the respondents in Dilla-zuria district had access to irrigation. The result also showed that there was significant difference between districts in households' access to irrigation. This is may be due to the fact that Dillazuria district (the midland) is dominantly covered by perennial crop like coffee, fruit and enset while the lowland district (Abaya) is mainly covered by annual crop like teff and maize and Bule (the highland district) is mainly covered by annual crop like barely and Faba bean. Out of the total respondents, 96 %, 73.3% and 48.4% of the sampled household heads have an access to health service in their locality in Abaya, Dilla-zuria and Bule district respectively and there is significant

difference between the districts in this regard. Regarding access to agricultural input, 97.6 %, 58.8% and 54.7% of the sampled household heads have an access in Abaya, Dilla-zuria and Bule district respectively and there is significant difference between the districts (Table 2).

### **Households' Adaptation Strategies**

Farm households were asked regarding their main methods of adaptation to climatic variability and change. The findings were provided by smallholder farmers in the three districts that correspond to the agro-ecological zones of the lowlands, midlands, and highlands. Table 4 lists the twelve adaptation strategies that were found to be employed by the farmers in the research area. Agroforestry practices, crop diversification, irrigation, the use of better varieties, composting, harvesting water, changing cropping periods, fertilizer, grain storage, onset and soil conservation are some of these adaptation measures. The study's findings demonstrated that different districts employ different strategies for adapting to climate change. 95.3%, 90.6%, and 87.5% of the farmers who responded said that agroforestry, planting trees, and onset plants were the most prevalent adaptation practices used in the Bule district. As climate change adaptation measures, farmers in the Dilla-Zuria district plant trees, onset plants, and apply fertilizer to accelerate crop development. Of the total respondents, their percentages are 95.7%, 89.4%, and 88.3%, respectively. It was found that districts varied greatly in how they applied the following climate adaptation strategies. Agroforestry, fertilizer, irrigation, grain storage, onset plants, and mixed farming all had  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.01$ , and  $P < 0.01$ , respectively. This variation provides more proof that adaptation strategies are location-specific and differ from one locality to another (Dendir and Simane, 2021).

### **Determinants of Farmers' Choices of Adaptation Strategies to Climate Change**

The factors influencing farmers' decisions to implement adaptation strategies against the effects of climate change were estimated using an MNL model. Although estimations do not

accurately reflect the size of change or the probabilities, the MNL model's parameter estimates were utilized to indicate the direction of the independent variables' impact on the dependent (response) variable (Table 5). Probabilities and measures that are anticipated to change within the probabilities determine the marginal impacts of marginal probabilities. Specifically, adaption decisions are made by deviating from the mean in the independent variable (Greene, 2000). This study only interprets and discusses factors that were statistically significant at less than or equal to 10% probability levels.

### **Age of the Household Head**

The study's findings indicated that while the age of the household head had a negative influence on the decision to implement irrigation, the use of improved crop varieties, composting, mixed farming, soil conservation and tree planting, and fertilizer application as climate change adaptation strategies, it had a positive influence on the decision to apply agroforestry practices and shifting cropping times (Table 5). In this sense, the decision to modify planting times and engage in agroforestry is favorably correlated with age. This indicates that the likelihood of agroforestry practice and crop time shifting increases by 23.7% and 8.8%, respectively, with the age of the household head. The indigenous expertise of the farmers in the research area may be the cause of the favorable influence of age on agroforestry adoption. The farmers in the study region are motivated to adopt agroforestry methods by indigenous knowledge and cultural beliefs, and older people are more inclined than younger people to accept these beliefs, according to a study by Getachew M. & Abiyot M (2017). In order to counteract the detrimental effects of climate change on agriculture, this study also discovered that age significantly and favorably correlated with changing the dates of planting. The rationale might be that farmers with more experience may be better able to evaluate the risks associated with investing in adaptation choices.

**Table 2. Descriptive statistics of dummy variable on characteristics of the households**

Dummy variable	District						P-value
	Abaya		Dilla zuria		Bule		
	N	%	N	%	N	%	
Irrigation (Yes)	66	52.8	53	28.3	35	54.7	.000
Credit access (Yes)	65	52.0	80	42.8	35	54.7	.143
Access to saving institutions (Yes)	64	51.2	78	41.7	34	53.1	.171
Access to extension service (Yes)	69	55.2	79	42.2	33	51.5	.057
Access to market (Yes)	125	100	187	100	64	100	1.00
Access to health service (Yes)	120	96.0	137	73.3	31	48.4	.000
Access to agricultural input (Yes)	122	97.6	110	58.8	35	54.7	.000

**Table 3: Descriptive statistics of continues variable on characteristics of the households**

Variable	District												P-value
	Abaya				Dilla zuria				Bule				
	Mean	S. dev.	Min.	Max.	Mean	S. dev.	Min.	Max.	Mean	S. dev.	Min.	Max.	
Age	52	11.75	32	75	55	11.10	32	75	53	9.046	38	70	.024
Education	4	3.64	0	12	4	3.35	0	12	4	3.743	0	12	.656
Family size	8	3.81	2	15	8	3.17	2.0	14.0	8	3.091	3	15	.416
Ratio	1.0	1.78	0	13	0.8	0.96	0	3.7	0.5	0.463	0	2.3	.032
Road distance	3.8	2.04	2	10	5	2.25	2	8	4	1.816	2	8	.000
Total Income	30008	54051	8000	600,000	38267	29516	5000	150000	34609	20993	20000	150000	.179
Land size	2.1	1.11	0.5	5.0	0.3	0.36	0.2	1.5	0.6	0.592	0.3	3	.000
No of livestock	15	13.66	0	50	1	1.05	0	6	1	1.07	0	5	.000

**Table 4. Climate change adaptation strategies by district**

Adaptation strategy	Abaya		Bule		Dilla-zuria		P-Value
	Yes		Yes		Yes		
	Frequency	%	Frequency	%	Frequency	%	
Agroforestry *	49	39.5	56	87.5	148	78.7	.017
Crop diversification	106	85.5	53	82.8	117	62.2	.853
Irrigation ***	65	52.4	20	31.2	69	36.7	.000
Improved variety	105	84.7	52	81.2	160	85.1	1.000
Compost	37	29.8	56	87.5	135	71.8	.092
Shifting cropping time	107	86.3	45	70.3	132	70.2	1.000
Fertilizer ***	106	85.5	46	71.9	166	88.3	.000
Grain storage **	116	93.5	16	25.0	1	0.5	.003
Enset ***	33	26.6	56	87.5	168	89.4	.000
Soil and water conservation	117	94.4	61	95.3	165	87.8	.999
Tree planting	117	94.4	58	90.6	180	95.7	1.000

\*\*\*, \*\*, \* Significant at 1, 5, and 10% probability level, respectively

The results of the work of (Destaw & Fenta, 2021; Molla E. & Desta G., 2023) support the finding who observed that older agricultural households are better able to forecast crop production trends than younger ones. The application of compost, irrigation, improved crop varieties, soil conservation, and tree planting, on the other hand, are negatively correlated with age. In this regard, there is a negative correlation between age and the decision to utilize irrigation, better crop varieties, compost, mixed farming, soil conservation, and tree planting. The results show that the likelihood of applying irrigation, using an improved crop variety, applying compost, mixed farming, planting trees for soil conservation, and applying fertilizer decreases with increasing household age by 21.7%, 5.1%, 17.4%, 6.9%, 5.8%, and 8.1%, respectively. The likelihood of employing irrigation decreases with age, maybe because farmers become less likely to engage in labor-intensive tasks like irrigation agriculture as they get older. The findings of this study are in agreement with the findings of a study by Gameda, D. O., & Garedew, W. (2023). In other words, younger farmers are more likely than older farmers to employ enhanced crop varieties, as the likelihood of doing so decreases with household age.

In contrast to older farmers, younger farmers are more interested in managing risk and are more

flexible in their decision-making process. They also seek information and support from governmental and non-governmental organizations and are less inclined to stick to older local varieties. This finding is consistent with Obayelu et al. (2014), who concur that younger farmers are more likely to seek out new information and technologies. However, it contradicts the findings of Gebre et al. (2015) and Ayalnesh B. (2020), who discovered that the likelihood of utilizing an improved variety rises as household age increases. The labor-intensive nature of the composite preparation activity may be the cause of the 17.4% decline in farmers' likelihood of using composite application as a climate change adaptation technique, as indicated in table 6. Older farmers may not be able to perform this task due to its labor-intensive nature. The findings also indicate that farmers were less likely to use soil conservation techniques as adaptation strategies as they became older. This suggests that elderly farmers are less likely than younger farmers to adopt adaptation strategies for soil and water conservation. Therefore, when it comes to using soil and water conservation techniques, younger households are more proactive than older ones. Because it takes more work to conserve soil and water.

**Table 5. Parameter estimates of multinomial logit model for climate change adaptation decision**

Adaptation	Age	Gender	Education	Land holding size	Farm experience	Income	Extension service	Altitude
Agroforestry	1.718*** (0.000)	3.293*** (0.000)	0.087 (0.483)	-0.609*** (0.000)	0.484* (0.006)	2.572** (0.001)	-1.454* (0.034)	0.306 (0.312)
Crop diversification	-	-0.314 (.604)	.852*** (.000)	-.356* (.021)	-.183 (.368)	-.469 (.349)	1.371* (.034)	.253 (.422)
Irrigation	-	1.915** (.003)	.450** (.001)	-.139 (.327)	.270 (.161)	17.76*** (.000)	2.342** (.001)	-1.637*** (.000)
Improved variety	-.411* (.022)	.987 (.053)	.268 (.046)	.478** (.002)	-.259 (.190)	.570 (.386)	2.134*** (.000)	.661* (.031)
Compost	-1.459*** (.000)	-.050 (.930)	.334* (.012)	.431* (.005)	-.351 (.095)	4.633*** (.000)	1.877** (.001)	1.690*** (.000)
Shifting cropping time	.477** (.004)	.820 (.108)	-.135 (.271)	.207 (.101)	1.338** * (.000)	-.143 (.765)**	1.047* (.035)	-.563* (.021)
Grain storage	.457 (.060)	-.390 (.589)	-.078 (.685)	.336 (.075)	-.007 (.975)	.351 (.546)	-.151 (.833)	-5.845*** (.000)
Enset	-.435 (.241)	.184 (.846)	-.078 (.685)	-.230 (.303)	.189 (.582)	.675 (.280)	-.167 (.850)	32.213 (.989)
Soil and water conservation	-	3.826** (.001)	1.141** (.001)	-.644 (.075)	.385 (.403)	-.588 (.557)	-.009 (.995)	-.145 (.832)
Tree planting	-	-17.188 (.998)	.003 (.992)	.391 (.139)	.060 (.884)	.343 (.741)	1.823* (.019)	.459 (.405)
Fertilizer	-.803*** (0.000)	-.469 (.565)	.277 (.057)	.386* (.022)	.465* (.024)	.032 (.951)	1.649* (.002)	.176 (.057)

\*\*\*, \*\*, \* Significant at 1, 5, and 10% probability level, respectively

The findings concur with those of Atinkut & Mebrat (2016), Esubalew & Getnet (2023), and Obayelu et al. (2014), who pointed out that younger households are more likely than older ones to implement adaptation strategies for soil and water conservation. The outcome, however, runs counter to the findings of Gebre et al. (2015) and Ayalnesh B. (2020), who discovered that the likelihood of using soil conservation practices as a strategy for adapting to climate change rises as household age increases. Tree planting is a labor-intensive activity, which may be the reason why farmers are less likely to plant trees as a climate change adaptation strategy as they get older. However, several research findings contradict the results of this study. Research by Ayalnesh B. (2020), Oo et al. (2017), and Belay et al. (2017) has demonstrated that the likelihood of a home planting trees increases with the age of the household head.

**Sex of the Household Head**

Table 5's findings indicate that, in comparison to the base category, the likelihood of adopting agroforestry practices, irrigation, and soil conservation as adaptation methods was considerably higher for households led by men. According to the findings, the likelihood of implementing agroforestry, irrigation, and soil and water conservation as climate change adaptation techniques increased by 45.6%, 25.6%, and 12%, respectively, for households led by men (Table 6). Male-headed households were more likely than female-headed households to practice adaptive methods, as predicted. Male-headed households may have greater access to technologies and climate change information than female-headed households, according to a study by Deressa et al. (2008) that examined farmers' choices of climate change adaptation strategies in

another region of Ethiopia. They were therefore better equipped than the female-headed ones to employ a variety of adaptation techniques (Demetriades & Esplen, 2010). This outcome is consistent with the findings of Abayineh and Belay (2017) and Ayalnesh B. (2020). On the other hand, Wondimagegn and Lemma (2016) argued that women engaged in a greater number of agricultural tasks and gained more knowledge and expertise in a variety of adaptation techniques.

### **Educational status of the household**

The findings in Table 5 demonstrate that farmers' adoption of crop diversification, irrigation, composting, soil and water conservation, and fertilizer application as climate change adaptation techniques are all significantly improved by education. According to Table 6's marginal effect, the likelihood of implementing crop diversification, irrigation, composting, soil and water conservation, and fertilizer application practices as climate change adaptation strategies could rise by 11%, 6.6%, 4.3%, 4.7%, and 3.7%, respectively, with higher educational attainment. Because they are aware of the potential advantages of the suggested climate change adaptation measures, educated farmers are expected to embrace new technologies (Hassan & Nhemachena, 2008). The findings indicate that households with higher levels of education are more likely than those with lower levels of education to adopt irrigation technology as a method for adapting to climate change. According to Gebre et al. (2015) and Khan et al. (2021), education is one of the socioeconomic elements that affect adaptation strategy at the farm level. The findings also showed that farmers are more likely to use crop diversity as a climate change adaptation strategy as their educational attainment rises. The findings of the study by Fadina and Barjolle (2018) corroborated this conclusion. The findings indicate that the likelihood of using soil and water conservation measures as a strategy for adapting to climate change increases as educational attainment rises. This result was also supported by Tagel and Veen (2013).

### **Landholding Size**

The uses of improved variety, compost and fertilizer application are positively and significantly correlated with landholding size. Nonetheless, it has a strong negative correlation with crop diversification and agroforestry practices. According to Table 6, the likelihood of adopting better varieties, grain storage movement, and fertilizer application as climate change adaptation strategies increases by 5.8%, 5.4%, 3%, and 4.8%, respectively, with an increase in landholding. Additionally, as landholding size increased, the likelihood of using enset plants, crop diversification, and agroforestry as climate change adaptation decreased by 11.1%, 4.6%, and 5%, respectively, according to the same data. According to Abdi et al. (2015), there is a favorable correlation between the size of a landholding and the utilization of better crop varieties as adaptation strategies. Because it requires significant expenditure, there may be a negative correlation between the amount of land holdings and the use of climate change adaptation measures. According to a 2017 study by Abayineh and Belay, farmers who own a lot of land are more inclined to take on the risk of climate change or use adaption strategies that may require significant financial outlays. They have a big plot, which allows them the confidence to not worry about adaptation strategies to lessen the effects of climate change.

### **Farm Experience**

The findings in Table 5 demonstrated that adjusting cropping times as a method for adapting to climate change is positively impacted by Farm experience. This is because a farmer's knowledge of the detrimental impacts of climate change on agriculture in the past is supported by their experience on the field. This is due to the presumption that more seasoned farmers are more knowledgeable about weather data and how it affects farming methods. Compared to farmers with less agricultural expertise, farmers with more years of experience are more likely to apply fertilizer and modify cropping times as climate change adaptation strategies by 5.3% and 7.7%, respectively. This finding is consistent with Hossain et al. (2022) and Tanti et al. (2022) and

suggests that more seasoned farmers possess information and expertise about climate change than less seasoned ones. In addition to suggesting that more seasoned farms typically have more knowledge of crop varieties, crop rotation, and farmers' decisions to either increase or decrease farm cultivated area in order to survive farming in the face of climate change, the findings also conclude that farmers with more agricultural practices have a greater chance of implementing adaptation strategies. According to a study by Amare et al. (2018), the likelihood of implementing better farming methods rises with farm experience.

### **Income**

The study's findings showed that, income significantly influences the use of agroforestry, irrigation, and composite applications as strategies for adapting to climate change. According to Table 6's marginal effect result, a rise in household income can raise the probability of using irrigation, agroforestry, and composite applications as strategies for adapting to climate change by 43.9%, 45%, and 41.8%, respectively. This suggests that farmers with higher incomes are more likely than those with lower incomes to implement climate change adaptation strategies. This is due to the fact that farmers who earn more money may buy more agricultural inputs. This makes it easier for individuals to get over financial obstacles and better adapt to the effects of climate change. The work of Marie et al. (2020), which found that wealth significantly positively influenced households' adaption tactics, supports this finding. It does, however, run counter to the findings of Feleke et al. (2016), who found that households' adaption tactics were significantly impacted negatively by income.

### **Extension Service**

Farmers' decisions to adopt crop diversification, irrigation, improved variety compost application, tree planting, and fertilizer application as climate change adaptation strategies were positively and significantly impacted by the frequency of extension visits, while farmers' decisions to engage in agroforestry as a climate change adaptation strategy were negatively impacted. In comparison to farmers without access to

extension services, Table 6 shows that farmers who have contact with extension agents are more likely to use crop diversification, irrigation, improved variety compost application, tree planting, and fertilizer application by 23.1%, 32%, 25.8, 23.4, 26.1%, 9.7%, and 20%, respectively. However, the likelihood of using agroforestry as a climate change adaptation method drops by 34.1% as extension contact increases. A farmer with more extension contact will be better able to comprehend the negative effects of climate change on their farming activities as well as how to counteract these effects. This is implied by the positive effect of extension contact in adopting climate change adaptation strategies. Numerous authors endorsed the study's findings. This outcome is in line with the findings of Stefanović (2015) regarding tree planting, Nhemachena et al. (2014) regarding irrigation, Abrahm et al. (2017) regarding crop diversity, and Atube et al. (2021) with the use of better crop varieties.

According to research by Alemayehu & Bewket (2017), Asrat & Simane (2018), Ahmed et al. (2016), Belay et al. (2017), and Molla et al. (2023), farmers' adoption of climate change adaptation measures is significantly aided by extension access. However, this finding deviates from previous research by Wondimagegn and Lemma (2016) who shown that extension contacts on crop cultivation might be more focused on profitability and less on climate change risk adaption strategies.

### **Altitude**

The agro-ecology of the study area is represented in this study by the variation in altitude gradients. According to the study's findings, households in various agro-ecologies employ various climate adaptation strategies because of variations in soil types, farming methods, slope, and climate. The findings in Table 5 showed that, using composite applications as a method for climate change adaptation is positively impacted by an increase in attitude gradient or by living in a highland area. As a climate change adaptation method, it has detrimental effects on off-season grain storage and irrigation application.

**Table 6 Marginal effect due to independent variables**

Adaptation	Age	sex	Education	Land holding size	Farm experience	Income	Extension service	Altitude
Agroforestry	0.237*** (0.000)	0.456*** (0.000)	-0.003 (0.850)	-0.111*** (0.000)	0.040 (0.083)	0.439** (0.000)	-0.341*** (0.000)	-0.016 (0.690)
Crop diversification	-0.215*** (0.000)	-0.021 (0.773)	0.110*** (0.000)	-0.046** (0.005)	0.000 (1.000)	-0.008 (0.878)	0.231** (0.001)	0.008 (0.826)
Irrigation	-0.217*** (0.000)	0.256 ** (0.003)	0.066*** (0.000)	-0.012 (0.515)	0.047 (0.058)	0.450*** (0.000)	0.320 (0.000)	-0.228*** (0.000)
Improved variety	-0.051* (0.025)	0.149 (0.029)	0.023 (0.189)	0.058** (0.002)	-0.057 (0.029)	0.002 (0.976)	0.258*** (0.000)	0.069 (0.077)
Compost	-0.174*** (0.000)	0.020 (0.788)	0.041* (0.013)	0.033 (0.072)	-0.056 (0.033)	0.418* (0.000)	0.234** (0.001)	0.155*** (0.000)
Shifting cropping time	0.088* (0.002)	0.143 (0.125)	-0.006 (0.758)	0.052 (0.016)	0.070*** (0.000)	0.077 (0.377)	0.261** (0.002)	-0.082 (0.053)
Grain storage	0.021 (0.284)	-0.034 (0.569)	0.004 (0.791)	0.054*** (0.000)	0.025 (0.209)	0.083 (0.046)	0.040 (0.455)	-0.329*** (0.000)
Enset	-0.007 (0.729)	0.063 (0.279)	-0.014 (0.229)	-0.050*** (0.000)	-0.004 (0.846)	-0.021 (0.577)	-0.066 (0.165)	0.278*** (0.000)
Soil and water conservation	-0.069*** (0.000)	0.120*** (0.000)	0.047*** (0.000)	-0.009 (0.472)	0.016 (0.271)	-0.012 (0.723)	0.034 (0.406)	0.014 (0.534)
Tree planting	-0.058*** (0.000)	-0.084 (0.390)	0.008 (0.443)	0.029* (0.012)	0.004 (0.799)	0.045 (0.363)	0.097** (0.002)	0.042 (0.059)
Fertilizer	-0.081*** (0.000)	-0.055 (0.538)	0.037* (0.019)	0.048* (0.011)	0.053* (0.016)	0.012 (0.839)	0.200*** (0.000)	0.021 (0.540)

\*\*\*, \*\*, \* Significant at 1, 5, and 10% probability level, respectively

As altitude gradient increases, the likelihood of applying composite and planting enset crops as climate change adaptation increases by 15.5% and 27.8%, respectively, according to table 6's marginal effect of the variable. However, the likelihood of using irrigation, moving to a different location, and storing grain for the off-season decreases by 28.8%, 34.6%, and 32.9%, respectively. As stated in the study area description section of this work, the community in the lowland area is mostly agro-pastoralist, and the area is known for producing livestock by planting cereals like maize, which may be the cause for irrigation in the lowland altitude of the study area. These kebeles experience droughts more frequently than the highland portion of the research, and farmers there frequently stockpile grain out of concern about the upcoming season's climate shift. In contrast, farmers in higher altitudes are known to plant enset plants to stop soil erosion and mitigate the harmful effects of climate change. The research area's highland region is characterized by a steep slope that is prone to soil erosion. Farmers in the region frequently use enset plants to stop soil erosion,

especially during unpredictable rainstorms. Highland farmers are also known for using composites to preserve soil and moisture. The study's findings generally demonstrated that farmers in various agro-ecologies employ various methods for adapting to climate change. The usage of various climate change adaptation measures differs by agrological zone, as verified by the work of Atinkut & Mebrat (2016) and Legese et al., (2013).

**CONCLUSIONS**

This study provides an extensive analysis of climate variability adaptation strategies employed by smallholder farmers across three agro-ecological zones in southern Ethiopia. The findings reveal that farmers adopt a range of strategies, including Agroforestry, crop diversification, irrigation, improved variety, compost, shifting cropping time, Migration, Grain storage, Enset, Soil and water conservation, Tree planting Fertilizer and often combining them to enhance effectiveness. These choices are influenced by factors such; Age of household, sex of household, educational status, land holding size, farm experience, income of the household,

access to extension service and altitude. This study highlights that successful climate adaptation depends on prioritizing farmers' needs, as top-down policies often overlook crucial factors like market demand and cultural preferences. This sentiment underscores the critical need for participatory and context-sensitive approaches in adaptation planning to enhance policy effectiveness and enhance success in combating adverse impact of climate change on small holders' livelihood. The findings of this study provide a roadmap for designing inclusive, context-specific policies that address the multifaceted challenges of climate adaptation, ultimately supporting the broader goals of food security and climate resilience.

### RECOMMENDATIONS

From the research we can recommend that area specific adaptation measures are critical, as agro-ecological conditions and socio-economic factors significantly affects farmers' decisions. Policies should prioritize gender-sensitive approaches to ensure female-headed households have equal access to resources and decision-making opportunities.

Various socioeconomic and demographic factors in the research area influenced farmers' decisions to select effective adaptation techniques. It is imperative that policymakers in the agriculture sector give adequate consideration to interventions that increase access to adult education, extension services, training for female farmers, and information on climate change adaptation strategies. In order to complement existing adaptation activities and give farmers up-to-date knowledge on climate change, development agents will expand their interactions with farmers. To improve farmers' ability to adapt to climate-related extremes, this would be crucial. It is recommended that studies on the gender-specific effects of climate change be carried out in order to provide inclusive and efficient solutions. By implementing these recommendations, policymakers and development practitioners can strengthen smallholder farmers' adaptive capacity and resilience to climate variability. This, in turn, will contribute to sustainable agricultural development and improved livelihoods in vulnerable regions like southern Ethiopia.

### AUTHOR CONTRIBUTIONS

T.F.B conceptualized the study; collected the data; entered the data, analyzed and interpreted the data, and drafted the manuscript; Z.M and G.H. Conceptualization, data analysis, critically reviewed and approved the final version of the manuscript.

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The authors declare no competing interests.

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