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# Smallholder Farmers' Climate Change Adaptation Practices and their Determinants in Negelle Arsi District, Central Rift Valley of Ethiopia

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**Abstract**

*Climate change presents an unavoidable challenge that disproportionately affects developing nations. In Ethiopia, the livelihoods of smallholder farmers heavily depend on rain-fed agriculture, making them particularly vulnerable to recurrent droughts and unpredictable rainfall patterns. Therefore, adaptation mechanisms are crucial for addressing the impacts of climate change. This study aims to assess the climate change adaptation practices of smallholder farmers and their determinants in the Negelle Arsi district. A cross-sectional survey design with a mixed-methods approach was employed. Both primary and secondary data were collected, utilizing systematic random sampling to identify the sampled households. Primary data were gathered through a survey questionnaire involving 184 households, supplemented by four focus group discussions and four key informant interviews. Secondary data relevant to the study were obtained from both published and unpublished sources. Data analysis involved descriptive statistics, chi-square tests, and a multivariate probit model. The results revealed that the dominant adaptation strategies employed by smallholder farmers in the study area included improved crop varieties, adjusting planting dates, crop diversification, terracing, and reserving crop residues. The maximum likelihood estimates from the multivariate probit model indicated that the probabilities of households adopting these adaptation measures were 93% for improved crop varieties, 85% for adjusting planting dates, 57% for crop diversification, 90% for practicing terracing, and 91% for reserving crop residues. The implementation of these strategies varied by agro-ecological location. Significant factors influencing the choice of climate adaptation strategies included education, family size, access to communication devices, farm size, extension services, membership in social organizations, and agro-ecological location. Consequently, future policy should focus on raising awareness among farmers and extension workers regarding the determinants of climate change adaptation. Additionally, it is essential to implement location-specific measures that are appropriate for both current and projected climate conditions.*

**Keywords/Phrases**: Adaptation strategies, Climate change, Negelle Arsi, Smallholder farmers'

## 1 Introduction

Almost all nations worldwide are affected by climate change, though its magnitude varies depending on specific national contexts. Climate change has adverse, multidimensional effects on life systems as a whole. According to the United Nations Framework Convention on Climate Change (UNFCCC) (2011), climate change refers to alterations in the composition of the Earth's atmosphere, driven by human activities and, to some extent, natural climate variability observed over comparable time periods.

Low-income countries in Asia and Africa are already under significant stress, and the impacts of climate change are expected to exacerbate this situation. The Intergovernmental Panel on Climate Change (IPCC) (2007) warns that unless effective adaptation strategies are implemented promptly, some African countries could lose up to 50% of their yields from rainfed agriculture by 2020, severely compromising food access in many regions across the continent.

The climate change adaptation mechanisms in the African context have a long history and occur within dynamic socio-economic, technological, biophysical, and political environments that vary by time, place, and sector (Bewuketu, 2017). According to Gbetibouo *et al.* (2010), farmers in the Limpopo Basin of South Africa have already observed long-term climate changes and are responding through strategies such as crop diversification, adjusting planting dates, using irrigation, and supplementing livestock feed.

In Ethiopia, smallholder farmers are particularly vulnerable to the impacts of climate change due to their heavy reliance on rainfall and exposure to non-climatic stressors such as poverty, inadequate infrastructure, a rapidly growing population, low adaptive capacity, and inefficient institutional support (Seid and Tamiru, 2016; FAO, 2018b).

These farmers possess valuable indigenous knowledge and long-standing experience that are essential for coping with hazardous environmental conditions, including climate change and variability (Haileab, 2018). For Ethiopia, adaptation is crucial to mitigating the effects of climate change. Common adaptation measures include the use of improved crop varieties, crop diversification, adjusting planting dates, irrigation, livelihood diversification, water harvesting, and soil water conservation (FAO, 2015; Solomon *et al.*, 2016).

However, the choices of adaptation strategies among farmers vary based on access to resources, infrastructure, education, technology, location, biophysical conditions, social structures, financial capacity, and institutional mechanisms (Nhemachena & Hassan, 2008; Tamiru, 2020). Numerous studies have been conducted in Ethiopia on climate change and adaptation techniques, particularly focusing on basin and drought-affected areas. Nonetheless, the impacts of climate change are increasingly becoming a threat across various environmental conditions and agro-ecological settings (Nhemachena & Hassen, 2008; Pickson and He, 2021). Therefore, analyzing climate change adaptation requires specific attention to the socio-economic and institutional characteristics of different locations (Jha and Gupta, 2021).

Negelle Arsi district is situated in the Central Rift Valley region of Ethiopia, characterized by three distinct agro-ecological zones. The majority of farmers in this area are smallholders who rely on rain-fed agriculture. Repeated episodes of drought have become a common challenge, leading to reduced crop yields and livestock mortality (Zenebe *et al.*, 2018; Tewodros, 2021). Furthermore, many residents in the district's lowland agro-ecology face severe and chronic food insecurity, along with widespread malnutrition.

Previous studies by researchers such as Yoseph *et al.* (2015) and Abreham *et al.* (2017) have explored similar topics in specific areas. However, none of these studies addressed climate change adaptation practices in relation to agro-ecological settings. Given that each agro-ecological zone necessitates specific adaptation measures, understanding these requirements is essential for identifying effective strategies. Additionally, other researchers, including Abreham (2017) and Tewodros (2018), employed binary logistic regression models to analyze factors influencing farmers' choices of adaptation strategies against climate change. A limitation of this model is that it considers only a single adaptation choice made by farmers, assuming that they can select only one strategy at a time, without accounting for potential correlations or interdependencies between various adaptation practices (Yu *et al.*, 2008).

In reality, farmers often adopt multiple adaptation strategies simultaneously, and these strategies may be interconnected (Nhemachena and Hassen, 2008). Adoption decisions can vary based on cultural factors, resource endowments, objectives, preferences, and different socio-economic backgrounds. Therefore, this study aims to examine the climate change adaptation practices of smallholder farmers and their determinants in Negelle Arsi district, Central Rift Valley, Ethiopia.

## 2 Material and Methods

The study was conducted in the Negelle Arsi district, located within the West Arsi zone of the Oromiya regional state in Ethiopia. The district shares borders with Adamitulu Jido Kombolcha district to the northwest, Shashemene district to the southeast, Heben Arsi district to the east, and Shalla district to the west. It is situated 225 km south of the national capital, Addis Ababa, with geographical coordinates ranging from 7$^o$10'N to 7$^o$40'N latitude and 38$^o$20'E to 38$^o$50'E longitude (Figure 1).

The altitude of the district varies from 1,500 to 2,800 meters above sea level, and annual rainfall ranges between 500 and 1,200 mm. The district is home to three major Rift Valley lakes: Lake Langano, Lake Abijata, and Lake Shalla, as well as the Abijata-Shalla National Park.

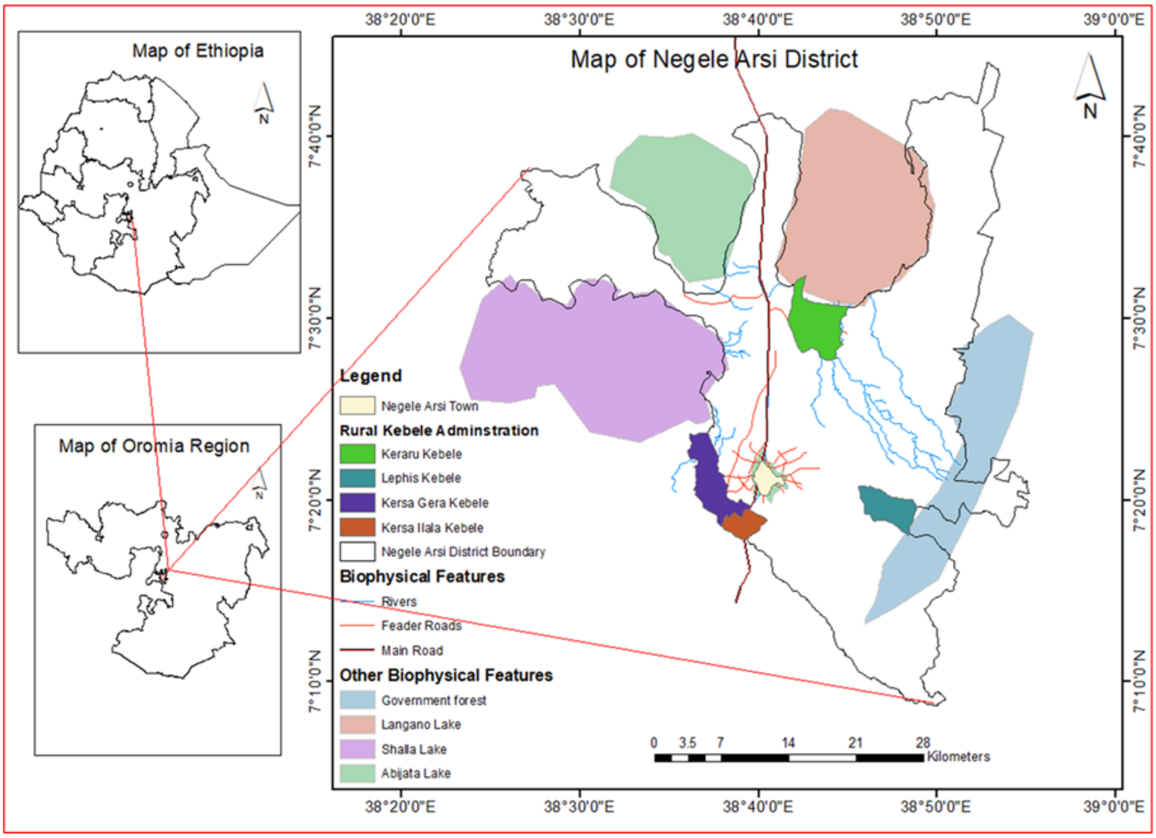


**Figure 1.** Location Maps of Negelle Arsi District.
Source: Developed from CSA 2007 using ArcMap 10.7 software

The major crop cultivation occurs during the main rainy season. Of the total agricultural land, which covers 48,479 hectares, approximately 41,749.6 hectares were dedicated to various crops during the 2022 production year of the main rainy season. Additionally, a short rainy season planting was conducted on 8,652.5 hectares from March to May of the same year.

The primary crops grown in the district include wheat, maize, Eragrostis teff, barley, sorghum, beans, and various vegetables such as potatoes, cabbage, and onions. The average farm size per household is about 1.5 hectares (FAO, 2015). Common crop pests include stalk borers, cutworms, bollworms, aphids, and armyworms, while prevalent crop diseases consist of rust, leaf virus, wilt, leaf blight, bacterial blight, and bean chocolate spot.

Livestock farming in the area includes cattle, sheep, goats, horses, donkeys, and poultry. The district serves as a key trade route for beef and dairy farming, which are commercialized in various locations.

# 3 Research Design and Data Sources

The research design utilized a cross-sectional survey, with data collection occurring at a single point in time during the study period. This technique is advantageous as it allows researchers to gather information about the current status or recent past of the cases under investigation (Rani, 2003). Additionally, a mixed-methods approach was employed to triangulate qualitative and quantitative data.

This research drew on both primary and secondary data sources to meet its objectives. Primary data were collected from households of smallholder farmers through face-to-face surveys, interviews, and group discussions. Secondary data were obtained from both published and unpublished sources by reviewing relevant documents, research reports, journals, and online resources.

## 3.1 Sample Size Determination and Sampling Technique

Multi-stage sampling techniques were employed to identify the study kebeles and respondent households. In the first stage, Negelle Arsi district was purposefully selected due to its vulnerability to the impacts of climate change, stemming from its geographical location in the Central Rift Valley. According to the agro-ecological classification by Temesgen *et al.* (2009), the study area is categorized as hot to warm sub-moist lowlands, characterized by erratic rainfall and shallow soils. The FAO (2015) reported that rainfall patterns in Ethiopia are generally influenced by altitude; for example, middle and higher altitudes (above 1,500 meters) receive significantly more rainfall than lowland areas. Additionally, Akilu and Alebachew (2009) and the Negelle Arsi District Agricultural Office (2021) found that the study area has experienced extreme climate events, including recurrent droughts and floods.

In the second stage, the study area was divided into three major agro-ecological zones (AEZs) using a stratified sampling technique. Farmers from different agro-ecological settings have varying vulnerabilities to the impacts of climate change and different experiences with adaptation strategies (Kothari, 2004). These strategies are influenced by various factors, including the biophysical, socioeconomic, and institutional contexts of the study population. Accordingly, of the thirty-six rural kebele administrations, seven kebeles belong to the highland zone, eighteen to the midland zone, and eleven to the lowland zone.

In the third stage, four administrative kebeles (two from the lowland zone, one from the midland zone, and one from the highland zone) were selected using simple random sampling techniques. This approach ensures that each agro-ecological zone is represented and that communities within the same AEZs are likely homogeneous regarding socio-economic, cultural, ecological, and other relevant factors.

Lastly, in the fourth stage, the list of the study population (sample frame) was obtained from the respective kebele administrations. The sample size was determined using the formula provided by Yamane (1967), which is widely applicable, easy to calculate, and effective for survey studies, resulting in a minimal error term. The required sample size was calculated at a 93% confidence level with a 7% margin of error, as an error of less than 10% is considered acceptable (Kothari, 2004; Tewodros, 2018).

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

Where “n” is the sample size, “N” is the population size (sample frame), and “e” (0.07) is the margin of error.

$$n = \frac{[}{1}801][1 + 1801(0.07)^2] = 184$$

Hence, the questionnaire was completed by 184 household heads. After determining the sample size, the respondent household heads were selected and contacted using a systematic random sampling technique. A key advantage of systematic random sampling is its simplicity in implementation; it encourages diversity, minimizes inclusion or exclusion errors, and is particularly effective when the population has homogeneous characteristics (Zinger, 1980).

## 3.2 Methods of Data Collection

The study employed four data collection tools to gather quantitative and qualitative data relevant to the research objectives. The main tools used for data collection are as follows:

**Questionnaire Survey**: A structured questionnaire, comprising both close-ended and open-ended questions, was developed to address the research questions. To ensure clarity and facilitate meaningful conversation, the questionnaire was crafted using straightforward and understandable language. The completeness, readability, and language construction of the questionnaire were reviewed by an individual with expertise in the subject matter. The questionnaire included detailed items regarding smallholder farmers' views on climate change and the response mechanisms they employ to mitigate its negative effects. Additionally, it captured the demographic, socioeconomic, and institutional characteristics of the study area to provide a comprehensive understanding of the research questions. The survey was conducted by enumerators familiar with the study area and the local language, who received appropriate training and orientation prior to data collection. All activities were closely supervised by the researchers, and face-to-face interviews were conducted with 184 sampled respondents.

**Focus Group Discussion (FGD)**: A checklist was prepared to explore smallholder farmers' perceptions of climate change over the past 20 years (2001 to 2021) and the existing adaptation strategies. This approach allowed the researchers to triangulate data obtained from the questionnaire survey and key informant interviews. Four focus group discussions, each consisting of eight individuals, were organized in Kersa Ilala, Kersa Gera, Lephis, and Keraru kebeles. FGD participants were purposefully selected with the assistance of the kebele chairpersons and included delegates, elders, model farmers, and youth representatives who had lived in the study area for at least 20 years. Participation was based on individual interest.

**Key Informant Interview (KII)**: The third technique utilized for primary data collection was key informant interviews, which helped cross-check and substantiate data gathered through quantitative methods (Elder, 2009). Relevant data were collected through interviews with experts in climate change and related fields, involving four KIIs at the district level. Interviews were conducted with extension and natural resource experts from the Agriculture Office, an early warning expert from the Disaster Risk Management Office, and an irrigation expert from the Water and Irrigation Office of Negelle Arsi district. The selection of these sectors was based on their sensitivity to the impacts of climate change and their efforts to address these issues through institutional mechanisms. The interview checklist focused on smallholder farmers' perceptions, adaptation practices, and the socioeconomic characteristics affecting their choices of adaptation strategies. Each interview session was conducted separately and lasted on average for one hour, with the researchers managing the process and documenting the findings accordingly.

### 3.3 Methods of Data Analysis

Descriptive statistics were utilized to analyze the demographic, socioeconomic, and institutional characteristics of the study area. This analysis included measures such as percentages, maximum and minimum values, means, frequencies, standard deviations, and other metrics of central tendency. The data were summarized and presented using SPSS version 21 software.

Additionally, the Pearson chi-square test was employed to compare variations in adaptation strategies practiced across different agro-ecological zones in response to climate change. A multivariate probit model was also applied (using STATA version 12) to analyze the factors influencing farmers' choices of adaptation strategies.

Both dependent and independent variables were considered to examine the factors affecting smallholder farmers' adaptation decisions regarding climate change impacts. Independent variables are explanatory variables that influence the values of the dependent variables. The relationships among these variables, which address the research objectives, are summarized in Table 1.

The dependent variables, identified from the literature review and various climate change adaptation methods used by farmers in the study area, include Improved Crop Varieties (ICV), Adjusting Plantation Dates (APD), Crop Diversification (CD), Water and Soil Conservation (WSC), and Reservation of Crop Residues (RCR). The identified independent variables are also presented in Table 1 below.

**Table 1.** Description of variables and measurement

| Definition of Variable | Measurement of Variable | Expected Effect | | | | |
|---|---|---|---|---|---|---|
| | | ICV | APD | CD | WSC | RCR |
| Sex of HH head | 1= Male; 2= Female | +/- | +/- | +/- | +/- | +/- |
| Age of HH Head | Years | +/- | +/- | +/- | +/- | +/- |
| Education level | Years | + | + | + | + | + |
| Family size | Number | +/- | +/- | +/- | + | + |
| Communication Device | Yes=1, No=2 | + | + | + | + | + |
| Farm size | Hectare | + | + | + | + | + |
| Extension Access | Yes=1, No=2 | + | + | + | + | + |
| Social Support System | Yes=1, No=2 | + | + | + | + | + |
| Credit Access | Yes=1, No=2 | + | + | + | + | + |
| Agro-ecology Setting | Yes =1, No =0 | +/- | +/- | +/- | +/- | +/- |

The multivariate probit technique (MVP) is appropriate to study smallholder farmers who employ more than one adaptation strategy based on the complementarity and substitutability approach (Yu *et al*., 2008; Nhemachena *et al*., 2014). Farmers' conditions to practice or not practice for any adaptation strategy can be determined using the relative benefit of each practice. Let $U_j$ be the benefit in the state of choosing $j$ as an adaptation measure and, whereas, $U_0$ be the benefit in the state of not choosing $j$ as an adaptation measure. Therefore, the farmer "$f$" decides to use "$j$" adaptation option if the perceived benefit from option "$j$" is greater than not being chosen by the farmer, which is given by:

$$U_j(x'_{fj}\beta_j + e_{fj}) > U_0(x'_{fj}\beta_j + e_{fj}),\ j \neq k$$

Based on the above information, $S^*_{fj}$ is unobserved net benefit of using or not using j adaptation measure and determined by:

$$S^*_{fj}\ (\text{strategy}) = x'_{fj}\beta_j + e_{fj} \quad j = 1, 2, \ldots, n$$

S*fj represents practicing or not practicing an adaptation strategy by farmers, $x'_{fj}$ is a predictor that determines farmer $f$ who practices $j^{th}$ adaptation strategy (where $j$= 1, 2, ..., $n$ and denotes any climate change adaptation strategies). $\beta_1, \beta_2, ..., \beta_n$ are a vector parameters to be estimated for $j^{th}$ strategies, and random error terms $\varepsilon_1, \varepsilon_2, ..., \varepsilon_n$ are distributed as multivariate normal distribution with zero means, unitary variance. The relationship across the error terms of several latent equations can be explained with a non-zero off-diagonal $n$ x $n$ contemporaneous correlation matrix $R = \rho_{fj}$, with density $\emptyset$ ($\varepsilon_1, \varepsilon_2, ..., \varepsilon_n; R$). The unobserved characteristics of farmers' which affect the choice of adaptation strategies may be a source of error term. The state of unobserved preferences of farmers ($S^*_{fj}$) related to the $j^{th}$ choice of adaptation strategy described in equation 11 is transformable into an observable binary outcome, which is stated by:

$$S_{fj} = 1 \text{ if } S^*_{fj} > 0$$
$$S_{fj} = 0 \text{ if } S^*_{fj} \leq 0$$

$S_{fj} = 1$ if $U_j > U_0$ and $S_{fj} = 0$ if $U_j < U_0$, state that, $S$ is a binary dependent variable taking the value of 1 if the farmer $f$ chooses the $j$ adaptation strategy of interest; and otherwise 0, if the farmer failed to choose it (Hassen, 2015). This study considered five adaptation strategies to be analyzed the influences of deriving factors on each of these strategies.

These include: $S_1$ = Uses of improved crop varieties, $S_2$ = Adjusting planting dates, $S_3$ = Crop diversification, $S_4$ = Terracing, and $S_5$ = Reserving crop residues. The maximum likelihood estimation maximizes the sample likelihood function is a product of 5-variate integration of standard normal probability ($\emptyset$) which is given by:

$$Pr(S1,\ S2,\ \ldots,\ S5/x) = \int_{-\infty}^{(2s-1)x'\beta_1} x \int_{-\infty}^{(2s-1)x'\beta_2} \ldots x \int_{-\infty}^{(2s-1)x'\beta_5} \emptyset\ \varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n; Z'RZ\ d\varepsilon_2 d\varepsilon_1$$

Where, $Z = diag\ 2y\ 1\text{–}1, \ldots, 2y\ 5\text{-}1$.

# 4 Results And Discussion

## 4.1 Climate Change Adaptation Strategies

There is no one-size-fits-all adaptation to climate-related risks; adaptation strategies vary contextually and spatially among communities and individuals. Frequency statistics were used to assess the adaptation measures practiced by household heads. Farmers in the study area have developed various mechanisms to mitigate the negative impacts of climate change, with the most commonly practiced strategies summarized in Table 2. The response values from household heads reflect multiple answers for a single adaptation option since farmers may implement more than one adaptation strategy simultaneously.

**Table 2.** Summary of adaptation strategies utilized by smallholder farmers

| Adaptation strategies | Number of Respondents (n=184) | Percent (%) |
|---|---|---|
| Improved crop varieties | 171 | 92.9 |
| Adjusting plantation dates | 157 | 85.3 |
| Crop diversification | 104 | 56.5 |
| Terracing | 166 | 90.2 |
| Irrigation | 8 | 4.3 |
| Reserving crop residues | 169 | 91.8 |
| Emergency Support | 54 | 29.3 |

Source: computed from survey result (February, 2022).

Table 2 shows that the most important adaptation strategies practiced by respondent household heads include using improved crop varieties (92.9%), adjusting planting dates (85.3%), crop diversification (56.5%), terracing (90.2%), and reserving crop residues (91.8%). In contrast, irrigation was the least commonly used adaptation strategy among the respondents.

Although various factors—such as agro-ecological specifics, cultural influences, and the effectiveness of the measures—affect the choice and implementation of these adaptation strategies, most of them are relatively easy to implement and affordable for many smallholder farmers. Focus group discussion (FGD) participants noted that irrigation requires significant investment and skills, making it unaffordable for most smallholder farmers.

The MVP regression model was applied to analyze the types of adaptation strategies used by respondents and the effects of driving factors on their choices. Before running the model, the data were checked for multicollinearity to determine whether inter-correlation existed among the independent variables, using the variance inflation factor (VIF) as a measure (Nhemachena *et al*., 2014). The VIF value was found to be 1.31, indicating that there were no issues with multicollinearity.

The probability of smallholder farmers selecting any adaptation strategy in response to climate change is influenced by demographic, socioeconomic, and institutional characteristics. These variables were analyzed to assess their significant impact on household heads' choices of adaptation strategies. According to Table 3, the probabilities of households choosing and implementing improved crop varieties, adjusting planting dates, diversifying crops, terracing, and reserving crop residues as forage are 93%, 85%, 57%, 90%, and 91%, respectively. These findings align closely with the summary of adaptation strategies used by farmers presented earlier in Table 2.

It was hypothesized that smallholder farmers would jointly employ two or more adaptation strategies. Consequently, there is a 46% likelihood of respondents choosing all five adaptation strategies together, while the likelihood of choosing none of them jointly is only 0.12%. The likelihood ratio test for the model ($\chi^2(10) = 28.12$, p = 0.0017) and Rho = 0 at a 5% significance level indicate that at least one combination of strategies is statistically different from zero. The correlation matrix revealed significant joint correlations among the non-mutually exclusive adaptation strategies practiced by respondents (Table 3).

Thus, the error term arises from the interdependence of these adaptation strategies, based on the relative benefits they provide to farmers when implemented together. The Stimulated Maximum Likelihood (SML) estimation indicated that the probability of farmers selecting any adaptation strategy depends on whether the overall benefit of the typical climate adaptation strategies being used exceeds that of other strategies.

**Table 3.** Correlation Matrix of Adaptation Strategies

| Matrix category | Use of improved crop varieties ($\rho 1$) | Adjusting planting dates ($\rho 2$) | Crop diversification ($\rho 3$) | Terracing ($\rho 4$) | Reserving crop residues ($\rho 5$) |
|---|---|---|---|---|---|
| $\rho 2$ | -0.237 | | | | |
| | -0.253 | | | | |
| $\rho 3$ | 0.268 | 0.197 | | | |
| | -0.172 | -0.146 | | | |
| $\rho 4$ | 0.51*** | 0.117 | 0.459*** | | |
| | -0.17 | -0.191 | -0.152 | | |
| $\rho 5$ | 0.127 | 0.037 | 0.42** | 0.597*** | |
| | -0.3 | -0.203 | -0.179 | -0.162 | |
| Predicted probability | 0.93 | 0.854 | 0.566 | 0.901 | 0.92 |
| Joint success probability = 46% | | | Pro. Failure = 0.12% | | |
| Likelihood ratio test of $\rho 21 = \rho 31 = \rho 41 = \rho 51 = \rho 32 = \rho 42 = \rho 52 = \rho 43 = \rho = 53 = \rho 54 = \rho 65 = 0$: | | | | | |
| $\chi^2$ (10)= 28.1171; prob > $\chi^2$ = 0.0017 | | | | | |

***, ** and * significant at 1%, 5% and 10% probability level, respectively.

Source: computed from survey result (February, 2022).

Table 3 illustrates the results of possible combinations of five adaptation strategies practiced by farmers. The correlation coefficients for these combinations were determined at significant levels of 1% and 5%. This indicates that the choice of climate change adaptation strategies is interdependent (Table 3). The relationships among the latent variables can exhibit either positive correlation (complementarity) or negative correlation (substitutability) between different adaptation options utilized by farmers. Consequently, due to the interdependency of these strategies, smallholder farmers may implement more than two adaptation strategies simultaneously.

There is a positive and significant relationship between the adoption of improved crop varieties and terracing, crop diversification and terracing, crop diversification and reserving crop residues, and reserving crop residues and terracing, with significance levels of 1%, 1%, 5%, and 1%, respectively. In contrast, the relationship between the use of improved crop varieties and adjusting planting dates is negatively correlated, though this relationship is not statistically significant. Farmers often utilize adjusting planting dates and improved crop varieties interchangeably due to liquidity issues, which help them save on additional costs. When farmers face shortages of improved crop varieties, adjusting the planting date becomes a priority measure to adapt to changing climate conditions.

On the other hand, the effects of climate change and variability are intensifying and becoming increasingly unpredictable. As a result, farmers are compelled to adopt a flexible approach to adapt to fluctuating climate conditions. Institutional support, including timely technical assistance and climate information services, is critical in shaping farmers' choices of adaptation measures and enhancing their effectiveness in addressing climate-related stresses.

## 4.2 Comparison of Climate Change Adaptation Strategies based on AEZS

A specific approach tailored to the agro-ecological setting is essential for overcoming the risks and impacts associated with climate change (Wondmagegn and Lemma, 2016). In this context, farmers in the study area were asked for their views on the adaptation strategies they practice in response to climate change. The Pearson chi-square test ($\chi^2$) was used to compare the adaptation strategies employed by smallholder farmers based on the agro-ecological zones (AEZs). The results indicate that a majority of smallholder farmers implement one or more adaptation strategies simultaneously (Table 4). These strategies include the use of improved crop varieties, adjusting planting dates, crop diversification (including crop rotation), terracing, irrigation, reserving crop residues, and emergency assistance for food-insecure households. Findings from focus group discussions (FGDs) and key informant interviews (KIIs) were compared with household interviews and empirical evidence from various scholars, aligning with the farmers' responses.

**Improved Crop Varieties**: This strategy is already being utilized by smallholder farmers across all AEZs in the study area. Specifically, approximately 92.5%, 93.8%, and 92.7% of respondents in the highland, midland, and lowland AEZs, respectively, practice agronomy through the use of improved crop varieties as climate change adaptation strategies (Table 4). The variation in the use of improved crop varieties across the three AEZs is statistically insignificant ($\chi^2$ = 0.68, p = 0.967). This suggests that the practice is widespread among respondent households in all AEZs and is effective in addressing climate-related impacts.

Historically, the effects of climate change were most pronounced in lowland areas, but these issues have now extended to midland and highland AEZs. According to participants in the FGDs, production in the midland and lowland areas during the short rainy season (belg) has become increasingly unproductive. Similarly, one participant from the highland area shared their experiences regarding long-term rainfall patterns, comparing them to the current situation in 2022.

"*So far, the area is known to have a bimodal rainfall distribution with a timely and sufficient amount. In particular, the short rainy season, which is locally named as the belg season, starts in early March and ends in May of the normal time. Adequate rainfall during the spring season is required for easy land preparation at the beginning of June. The main sources of our income and food security (wheat, potatoes, cabbage, and maize) are determined by production during a short rainy season. However, since 2000, crop production during the short rainy season has been challenging due to the insufficient amount of rainfall and unpredictability of the rainfall conditions. This interview testified that the effect of climate change imposed a significant decline in rainfall and socio-economic challenges on the respondents in the study area.*"

The views of key informants indicated that rainfall during the 'Arfasa' (short rainy season) has been interrupted for 15 to 45 consecutive days, depending on the agro-ecological zone (15 days in highland areas and 45 days in lowland areas). As a result, many farmers in the lowland regions have shifted their practices to include measures such as transitioning from agriculture to livestock production, selling forest products, and relying on emergency aid. Radio, television, and institutions (such as the Disaster Risk Management office, Agricultural office, NGOs, and farmer cooperatives) play a crucial role in providing smallholder farmers with information about rainfall and temperature.

The use of multiple adaptation mechanisms across all AEZs is particularly important for addressing the negative impacts of climate change. According to the FGDs, farmers are utilizing specialized crop varieties, including short-growing and drought-tolerant crops.

Taddese *et al.* (2018) also found that climate change has altered land use patterns, leading to the introduction of short-growing crops such as maize, haricot beans, peppers, and sugarcane in areas where they were not traditionally cultivated. All FGD participants noted that these specialized crop varieties are capable of withstanding drought, excessive rainfall, and disease infestations, thereby making farming systems more resilient.

However, survey respondents and FGD participants expressed concerns regarding supply challenges. Additionally, many agricultural inputs currently used by farmers are ecologically unsuitable. A similar study conducted by Kabir *et al.* (2021) found that the majority of farmers in the southwestern coastal regions of Bangladesh were using improved crop varieties that require less water and can tolerate higher temperatures and salinity.

**Adjusting Plantation Dates**: Adjusting planting dates is the second most common adaptation strategy, utilized by 70%, 89.5%, and 89.5% of sampled households in the highland, midland, and lowland areas of the study region, respectively (Table 4). There was a statistically significant difference in the practice of adjusting planting dates among AEZs ($\chi^2$ = 9.59, p = 0.008), with the strategy being more prevalent in the midland and lowland areas compared to the highland area.

Unpredictable and variable rainfall patterns have compelled farmers to actively utilize weather information and indigenous knowledge to adjust their planting dates. Radio, television, and institutions (such as the Disaster Risk Management office, Agricultural office, NGOs, and farmer cooperatives) play a critical role in providing smallholder farmers with essential rainfall and temperature information.

Key informants reported that rainfall during the 'Arfasa' (short rainy season) has been interrupted for 15 to 45 consecutive days, depending on the agro-ecological zone (15 days in highland areas and 45 days in lowland areas). According to evidence from FGDs, over the past two decades, the area typically received reliable spring rainfall from March to May. Unfortunately, this pattern has changed, leading to late onset and early cessation of rains. Temesgen *et al.* (2011) noted that farmers in lowland AEZs have observed these changes more acutely than those living in midland and highland areas.

Farmers in lowland regions, having long experience with climate variability, are already adapting to these challenges. However, Urgessa and Amsalu (2014) found that the likelihood of smallholder farmers in the highland AEZ adjusting their planting dates has increased by 16.19%.

**Crop Diversification**: Crop diversification is widely practiced in the study area as a strategy to mitigate the risks of crop failure rather than simply maximizing yields. The results indicate that 79.2% and 60.4% of respondents in the midland and lowland AEZs, respectively, engage in crop diversification through intercropping or crop rotation (Table 5). In contrast, this practice is less common among highland farmers, with only 20% of interviewed households utilizing it as a climate adaptation strategy. The chi-square test results show a significant difference in the practice of crop diversification among farmers in different AEZs, with $\chi^2$ = 32.3 and p = 0.000 (Table 4).

A similar study by Taddesse *et al.* (2018) reported that 37.7%, 57.6%, and 68.6% of respondents from highland, midland, and lowland areas, respectively, utilized crop diversification to mitigate the impacts of climate change. According to FGDs, the most commonly grown field crops for intercropping that enhance soil management include Eragrostis teff paired with sorghum, maize with potatoes, and sorghum with chickpeas. The researcher also observed these practices during field visits. Participants in the FGDs emphasized their extensive practical experience with the benefits of mixing crops with varying attributes, such as maturity periods, drought tolerance, input requirements, and end uses of the products.

**Irrigation**: Irrigation serves as another climate change adaptation strategy, particularly reliable in conditions of unpredictable rainfall and prolonged dry seasons. Table 4 shows that 8% of respondents in the lowland area practice irrigation, primarily using small rivers such as the Lephis and Gedemso Rivers. There is a statistically significant variation in irrigation practices among smallholder farmers across different agro-ecological settings ($\chi^2$ = 7.67, p = 0.022). However, despite the river's potential, existing irrigation practices serve only a limited number of farmers located near watershed areas and are mostly implemented in a traditional manner. No respondents reported using irrigation in the midland and highland parts of the study area.

FGDs and KIIs indicated that poor irrigation practices in the region stem from a lack of investment, inadequate technology, and insufficient attention from local government. The overall decline in rainfall across all seasons has heightened the need for irrigation to mitigate the negative impacts on agricultural production during dry periods. Additionally, limited rainfall reduces the availability of water sources for irrigation, underscoring the importance of local government efforts to implement water harvesting systems and advance irrigation technologies.

**Terracing**: During field observations, the researcher noted various structural measures for soil and water conservation, including the construction of terraces and bunds aimed at minimizing soil erosion and maintaining soil fertility. Farmers reported that terracing not only improves groundwater recharge but also reduces soil erosion. As a result, terracing is widely adopted by farmers in the region. According to Abreham (2017), terracing is one of the primary soil and water conservation practices used in hilly areas where soil erosion is a significant issue, and it is also beneficial in moisture-deficit regions.

Data from Table 4 reveal that 75%, 91.7%, and 95.8% of respondents reported practicing terracing in the highland, midland, and lowland AEZs, respectively. There is a significant variation in terracing practices among farmers in different locations, with $\chi^2 = 16$ and $p = 0.001$. The study found that terracing and other soil conservation activities are more commonly implemented in the lowland and midland areas than in the highland regions. This trend is partly due to the severe destruction of vegetation in the hill areas of the lowland and midland AEZs, driven by local farmers' search for farmland, construction materials, and firewood. This degradation has led to extensive soil erosion in the downhill areas of the farmlands.

Additionally, incentives provided by the Productive Safety Net Program (PSNP) and humanitarian organizations have encouraged communities to engage in soil and water conservation activities in the project area. According to key informant interviews, more attention has been given to lowland areas due to their heightened moisture deficits and fragile landscapes compared to other regions. This finding aligns with Megerse (2018), which reported that approximately three-fourths (74.8%) of households in the study practiced terracing as an adaptation strategy, enhancing water infiltration and reducing soil erosion.

**Entitlement for Relief Aid**: The evidence presented in Table 4 indicates a significant difference in entitlement to emergency aid among respondent households across the highland (0%), midland (16.7%), and lowland (47%) zones of the study area ($\chi^2 = 11.74$, $p = 0.000$). This finding aligns with the studies by Yoseph *et al.* (2015) and Abreham *et al.* (2017), which report that the productivity of major crops has been progressively declining over the last two decades in arid and semi-arid regions of the central rift valley, exposing farmers to food insecurity. Similarly, Eyasu (2020) identified food aid as a coping mechanism for climate extremes and variability in Ethiopia.

According to a report from the district's Disaster Risk Management (DRM) office (2022), a significant portion of the lowland areas, along with some midland regions, has experienced low rainfall distribution, leading to total production losses. In response, emergency relief efforts have been implemented through close collaboration between local governments and various humanitarian organizations.

**Table 4.** The variation of adaptation practices based on AEZs

| Adaptation option | Status | Highland | | Midland | | Lowland | | $\chi^2$ value | P-value | Observed count | Phi value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Count | % | Count | % | Count | % | | | | |
| Use improved crop variety | Practiced | 34 | 92.5 | 45 | 93.8 | 89 | 92.7 | 0.68 | 0.967 | 2.83 | 0.019 |
| | Not practice | 3 | 7.5 | 3 | 6.2 | 7 | 7.3 | | | | |
| Adjusting Planting Dates | Practice | 28 | 70 | 43 | 89.6 | 86 | 89.6 | 9.59 | 0.008*** | 5.87 | 0.228 |
| | Not practice | 12 | 30 | 5 | 10.4 | 10 | 10.4 | | | | |
| Crop Diversification | Practice | 8 | 20 | 38 | 79.2 | 58 | 60.4 | 32.3 | 0.000*** | 17.39 | 0.419 |
| | Not practice | 32 | 80 | 10 | 20.8 | 38 | 39.6 | | | | |
| Terracing | Practice | 30 | 75 | 44 | 91.7 | 92 | 95.8 | 14 | 0.001*** | 3.91 | 0.276 |
| | Not practice | 10 | 25 | 4 | 8.3 | 4 | 4.2 | | | | |
| Irrigation | Practice | 0 | 0 | 0 | 0 | 8 | 8.3 | 7.67 | 0.022** | 1.74 | 0.204 |
| | Not-practice | 40 | 100 | 48 | 100 | 88 | 91.7 | | | | |
| Store crop residues | Practiced | 37 | 92.5 | 47 | 97.9 | 85 | 88.5 | 3.79 | 0.151 | 3.26 | 0.143 |
| | Not practice | 3 | 7.5 | 1 | 2.1 | 11 | 11.5 | | | | |
| Entitled Relief support | Receive | 0 | 0 | 8 | 16.7 | 46 | 47.9 | 36.3 | 0.000*** | 11.74 | 0.444 |
| | Not receive | 40 | 100 | 40 | 83.3 | 50 | 52.1 | | | | |

*, **, and *** indicate 10%, 5%, and 1% level of significance respectively.

Source: from survey result (February, 2022).

## 4.3 Determinants of Climate Change Adaptation Strategies

Table 5 presents the estimated results of the MVP model. The likelihood ratio, indicated by the Wald test (Wald $\chi^2(55) = 91.69$, p = 0.0014), suggests that the model fits the data reasonably well, demonstrating strong explanatory power and rejecting the null hypothesis at the 1% significance level.

**Table 5.** MVP Analysis result for the determinants of adaptation strategies

| Independent variables | | Dependent variables | | | | |
|---|---|---|---|---|---|---|
| | | Improved crop variety | Adjusting planting dates | Crop diversification | Terracing | Store crop |
| Age | Coefficient | 0.006462 | -0.00946 | -0.00349 | -0.02354 | -0.03077 |
| | Std. Error | -0.02344 | -0.01935 | -0.01509 | -0.02114 | -0.02308 |
| Sex | Coefficient | -0.17139 | -0.31474 | -0.06982 | 0.33225 | 0.3742 |
| | Std. Error | -0.55465 | -0.42573 | -0.34647 | -0.43419 | -0.5809 |
| Family Size | Coefficient | 0.124411 | 0.24101*** | -0.00262 | 0.13531* | 0.12786 |
| | Std. Error | -0.09597 | -0.08915 | -0.05507 | -0.08099 | -0.10331 |
| Education Level | Coefficient | 0.423602** | -0.0045 | -0.01433 | 0.15231 | -0.11444 |
| | Std. Error | -0.2087 | -0.14777 | -0.11465 | -0.16689 | -0.20361 |
| Communication device | Coefficient | 0.486143 | 0.85703*** | 0.335434 | -0.11206 | 1.25225*** |
| | Std. Error | -0.38587 | -0.29122 | -0.25934 | -0.37352 | -0.36706 |
| Farmland Size | Coefficient | -0.26095 | -0.40891 | -0.32378 | 1.0721* | 3.41595 |
| | Std. Error | -0.44666 | -0.3963 | -0.30856 | -0.61301 | -100.362 |
| Extension | Coefficient | 0.77357** | 0.40262 | 0.265204 | 0.41057 | -0.06495 |
| | Std. Error | -0.36511 | -0.3174 | -0.25489 | -0.35299 | -0.44864 |
| Credit Access | Coefficient | 0.45945 | 0.06366 | -0.12621 | -0.3145 | -0.01327 |
| | Std. Error | -0.45167 | -0.31056 | -0.22701 | -0.3235 | -0.35902 |
| Membership in SSS | Coefficient | -0.36492 | 0.45116 | 0.62073** | 0.26521 | 0.00259 |
| | Std. Error | -0.46541 | -0.30011 | -0.24336 | -0.36884 | -0.4149 |
| Agro-ecology | Coefficient | -0.00186 | 0.41595*** | 0.41793*** | 0.66514*** | -0.41334* |
| | Std. Error | -0.19543 | -0.15405 | -0.12713 | -0.17782 | -0.23501 |
| Cons | | -0.18801 | -1.13461 | -0.62703 | -1.1186 | -2.21008 |
| | | -1.23387 | (0.94305)* | -0.79983 | -1.18204 | -100.366 |

Multivariate probit (SML, # draws =5, Log likelihood= -280.41228, Number of observation & Simulation = 184, Wald $\chi^2$ (55) = 91.69, Prob. > $\chi^2$ = 0.0014.

***, ** and * significant at 1%, 5% and 10% probability level, respectively.

Source: from survey result (February, 2022).

According to Table 5, smallholder farmers' choices of adaptation strategies to climate change are evaluated based on various driving factors, including household characteristics, economic conditions, social capital, institutional commitments, and agro-ecological settings (highland, midland, and lowland). These factors significantly influence farmers' adaptation decisions in response to climate change. The effects of 13 explanatory variables on the choices of climate change adaptation strategies by respondent household heads are discussed below.

**Age of Household Heads**: The results from the MVP model indicate that the age of the household head is positively associated with the use of improved crop varieties but negatively associated with adjusting planting dates, crop diversification, terracing, and reserving crop residues (Table 5). However, these relationships are statistically insignificant. Older household heads are less likely to adjust planting dates, as this requires updated weather information and evidence-based decision-making, areas in which older farmers may have less exposure to new information and technology compared to their younger counterparts.

Similarly, older farmers are less likely to engage in crop diversification, terracing, and reserving crop residues, likely due to the physical demands of these activities. This finding aligns with the work of Abebe (2019), which found a negative correlation between the age of the household head and the practice of irrigation. Haftu *et al.* (2016) also reported that older individuals are less likely to engage in soil and water conservation practices. Conversely, Abreham *et al.* (2017) found that a unit increase in the age of the household head resulted in a 9% and 12% increase in the likelihood of practicing soil and water conservation and changing crop varieties as climate change adaptation strategies, respectively.

**Sex of Household Heads**: The gender of the household head negatively influences the use of improved crop varieties, timing of planting, and crop diversification. Women tend to prefer adaptation strategies that require less labor, avoiding labor-intensive activities such as soil and water conservation and tree planting (Wendmagegn and Lema, 2016). Conversely, gender is positively related to the practice of terracing and reserving crop residues; however, these relationships are not statistically significant (Table 5).

A study by Bewuketu (2017) found that the gender of the household head significantly and negatively affects the use of agroforestry. Similarly, Abebe (2019) reported that male-headed households are more likely to plant different crop varieties and engage in crop diversification as climate change adaptation measures. In contrast, Paulos and Belay (2018) noted that male-headed households are more inclined to adopt new agricultural technologies, largely because female-headed households often have less access to resources, information, and agricultural technologies compared to their male counterparts.

**Family Size**: The size of the household is an important factor positively affecting the adjustment of planting dates and terracing, with significance levels of 1% and 10%, respectively (Table 6). A larger number of individuals in a household enhances the sharing of weather information regarding past and future trends, which helps determine the best times for agronomic activities. More family members increase exposure to various public media, facilitating access to weather-related information.

Similarly, Tamiru (2020) found that household size significantly and positively influences farmers' decisions to choose improved crop varieties and irrigation. A larger family size also contributes to labor-intensive activities such as soil conservation practices. According to the data in Table 5, each additional household member increases the probability of choosing terracing as a climate change adaptation strategy. This finding aligns with the work of Hurgesa *et al.* (2020), which indicated that a greater number of economically active household members support the adoption of labor-intensive farming technologies.

**Education**: The education level of the household head positively and significantly influences the likelihood of choosing improved crop varieties at a 5% significance level (Table 5). Smallholder farmers with additional years of schooling are more likely to adopt improved crop varieties compared to those with lower educational attainment. Education enables farmers to acquire new information and farming technologies that enhance their agricultural practices and mitigate the effects of climate change. This finding is consistent with the studies by Abebe (2019), Helen *et al.* (2021), and Girma *et al.* (2022), which report that educated farmers are better equipped to understand and utilize scientific knowledge in selecting appropriate crop varieties, including drought- and disease-tolerant options.

**Farmland Size**: The size of farmland owned by farmers is a crucial determinant of their livelihoods. According to Table 5, farmland size positively and significantly affects the practice of terracing at a 10% significance level. Farmers with larger plots can implement a greater variety of soil conservation practices (such as soil bunds, terraces, and cut-off drains), which help stabilize soil nutrients and increase moisture retention. Additionally, Nhemachena and Hassan (2008) noted that larger landholdings increase the likelihood of applying irrigation as a response to climate change. Similarly, Abreham *et al.* (2017) asserted that increased farmland ownership enhances the likelihood of planting fodder trees.

**Communication Device**: The use of cell phones provides substantial benefits to farmers by offering updated information and enabling evidence-based decisions regarding adaptation strategies (FAO, 2015). Table 5 shows that the use of communication devices, such as mobile phones, is positively and significantly related to adjusting planting dates and storing crop residues at a 1% significance level. Farmers can access timely early warning messages from local Disaster Risk Management Offices and extension workers through phone conversations, allowing them to take proactive measures against climate-related risks. Additionally, communication devices facilitate low-cost, efficient communication with extension workers or others who can provide relevant information.

**Extension Advice**: Extension visits have a positive effect on the use of improved crop varieties, significant at a 5% level (Table 5). This suggests that extension services increase the likelihood of farmers adopting improved crop varieties, particularly short-growing and drought-tolerant crops. Extension advice helps farmers enhance their agricultural practices and supports evidence-based decision-making. Similar studies by Temesgen *et al.* (2009) and Solomon *et al.* (2016) confirmed that extension visits improve the likelihood of using improved crop varieties. However, key informant responses indicate that extension services in most parts of the study area are often fragmented, typically occurring once every quarter or even less frequently. Moreover, many extension services lack support from farm demonstrations.

**Access to Credit Services**: Farmers' access to affordable credit influences the likelihood of using improved crop varieties and adjusting planting dates, although it is negatively related to crop diversification, terracing, and reserving crop residues as climate change adaptation mechanisms (Table 5). However, these relationships are statistically insignificant. Access to credit can alleviate financial difficulties, enabling farmers to purchase essential farm inputs, new technologies, and other resources that help mitigate the negative impacts of climate change (Hassen and Nemachena, 2014). The negative relationship suggests that practices like terracing and reserving crop residues do not require credit, as they primarily depend on labor rather than financial investment.

Social Support System: Membership in farmers' organizations, such as cooperatives and informal groups like Idir and Ikub, positively and significantly influences respondent household heads' choices regarding crop diversification as a climate change adaptation strategy, at a 5% significance level (Table 5). Being part of a social organization increases the likelihood of adopting crop diversification to counteract the negative effects of climate change. Meetings among group members facilitate training and experience-sharing on adaptation strategies. A study by Ayele (2008) on rural farmers in Walayita supports this finding, highlighting that social support during ceremonial events and risk-sharing can help prevent food shortages and protect vital assets.

**Agro-Ecological Setting**: Different agro-ecological settings are characterized by varying climate regimes and climate-related risks, necessitating specific adaptation responses tailored to each area. The results indicate that farmers' locations within different agro-ecological zones significantly affect their practices, including adjusting planting dates, crop diversification, and terracing (all at a 1% significance level), as well as the storage of crop residues for livestock feed (at a 10% significance level) (Table 5). Farmers in low-rainfall areas (lowlands) are more likely to adopt short-duration and diverse crops compared to those in high-rainfall areas, such as the highlands. A similar study by Gutu *et al.* (2012) found that households in lowland (Kolla) areas are more inclined to use drought- and pest-tolerant crop varieties than those living in highland and midland zones. Additionally, participants in FGDs from various agro-ecological zones reported that many farmers have experience in storing crop residues, which helps feed their cattle during prolonged dry periods.

### Limitation of the Study

The study was conducted in a spatially limited area, specifically the Negelle Arsi district, using a cross-sectional survey design. The population studied consisted solely of smallholder farmers and did not include other community groups, such as pastoral communities or state farms.

## 5 Conclusion and Implication of the Research

Smallholder farmers are already suffering from the impacts of changing and unpredictable climate conditions. In response to these challenges, they have adopted various adaptation strategies, including the use of improved crop varieties, adjusting (shifting) planting dates, crop diversification, terracing, and reserving (piling) crop residues. There are significant differences in the implementation of these strategies across agro-ecological zones (highland, midland, and lowland), reflecting the specific climate risks encountered in each area. The capacity of farmers to choose effective adaptation methods is influenced by various driving factors.

These findings are valuable for smallholder farmers and local government institutions, such as the agricultural office and the disaster risk management office of the district. They provide insights into the determinants of climate change adaptation strategies and help identify gaps related to socio-economic and institutional dimensions. Furthermore, these insights should be incorporated into the long-term development plans of institutions at various levels.

Overall, the measures currently practiced to mitigate the adverse effects of climate change are insufficient to address the existing and projected impacts. Vulnerability to climate change also varies across agro-ecological zones and between individual farmers. Consequently, local government and non-governmental institutions (such as the Agricultural Office, Disaster Risk Management Office (DRMO), Farmers' Cooperatives, NGOs, and other partners) need to address these gaps and build the resilience of smallholder farmers in the study area.

**Contribution of Authors**: The authors of this article contributed to the study design, material preparation, data collection, analysis, and manuscript preparation.

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**Availability of Data and Materials**: All data processed and utilized in this work are available within the manuscript.

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