Farm households' adaptive strategies in response to climate change in lowlands of southern Ethiopia

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Abstract

Purpose – This study aims to investigate the adaptation strategies they practice and the factors that influence their use of adaptation strategies.

Design/methodology/approach – The mixed-method sequential explanatory design was used to triangulate the data collected. Multistage sampling was used to select 400 sampled households for household surveys. Eight focus groups, each with eight to ten participants, and 24 key informants, were specifically chosen based on their farming experiences. Chi-square tests, one-way ANOVA and a binary logit model were used to analyze the data.

Findings – The majority of farmers used simple and low-cost adaptation strategies like changing planting dates, selling livestock and off-farm and nonfarm work. A minority of farmers used advanced adaptation strategies like crop diversification and water harvesting for irrigation. The result further revealed that: the age of the household head, educational status of household heads, farm size, livestock ownership, farming

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experiences, household income, access to credit and access to climate information significantly influenced the adoption of the adaptation strategies. Public policy should provide water harvesting and irrigation technology, climate-related information and the provision of microcredit facilities to enhance the farmers' resilience to climate change risks.

Originality/value – Although several studies on climate change adaptation strategies are available, this paper is one of the few studies focusing on a particular agro-ecological zone, an essential precursor to dealing with current and projected climate change in the area. It provides helpful insights for developing successful adaptation policies that improve adaptive capacity and agricultural sustainability in southern Ethiopia's lowlands.

Keywords Agriculture, Climate change, Adaptation strategy, Adopter and non-adopter, Smallholder farmer

Paper type Research paper

1. Introduction

Climate change is globally happening and already causing a wide range of impacts on human and natural systems [Intergovernmental Panel for Climate Change (IPCC, 2014)]. The impacts of climate change will be strong in developing countries where millions of people are substantially dependent on natural ecosystems for livelihoods and well-being (Weatherdon *et al.*, 2016; IPCC, 2007) reported that Africa is one of the most vulnerable continents to climate change and variability. This is partly due to a higher reliance on natural resources, such as agricultural land, forests and water which are very sensitive to changes, affecting the environment. The agricultural sector in subSaharan Africa is believed to be negatively affected by climate change. The impact of climate change is more pronounced on smallholder farmers who are highly dependent on agriculture (Deressa, 2014). Land degradation, frequent floods and droughts are among the manifestations of climate change leading to productivity losses.

Ethiopia, like the majority of African countries, is usually mentioned as a nation that is highly vulnerable to climatic variability and change (Conway and Schipper, 2011). Agriculture is the largest sector in the Ethiopian economy. It accounts for more than 40% of GDP, almost 84% of foreign exchange revenues and about 77% of all employment (UN, 2018). However, the sector has remained substantially unchanged and smallholder farmers' reliance on rain-fed agriculture and traditional agriculture practices puts pressure on the nation's efforts to achieve food security (Gezie, 2019; Hilemelekot *et al.*, 2021; Gebru *et al.*, 2020). Although the sector contributes significantly to the broader economy, it is one of the most exposed to the threats and effects of climate change since it is highly vulnerable to climate-related disasters like droughts and food shortages (Rosenzweig *et al.*, 2014). The development of livelihoods in northern Ethiopia is highly influenced by changes and variability in rainfall patterns (Gezie, 2019). Rain-fed agriculture provides the majority of Ethiopia's rural population with their primary means of subsistence in the country's Southern Province. Therefore, among other issues, unexpected rainfall, crop pests and diseases, shortage of fodder for livestock, climate-related diseases like malaria and small farmlands have a direct impact on the food security and crop production of the underprivileged in southern Ethiopia (Teshome, 2017).

Wolaita Zone is among the most severely affected areas in southern Ethiopia due to climate change and variability (Bedeke, 2018). Climate change and variability have aggravated the vulnerability of the people in the region to climate change impacts and contributed to the overall degradation of natural resources. Climate change-induced problems, such as drought and land degradation are vital physical challenges to rain-fed agriculture in the Wolaita Zone (Murugan and Israel, 2017). The recurrent droughts occurring in the region are one of the indicators of susceptibility to climate change (Lemma, 2016). Moreover, the lowland area in the zone has faced low rainfall amounts and increased flooding as manifestations of climate extremes over the past few years. Besides, farmers' agricultural production in the zone has been declining over time

(Bedeke *et al.*, 2020). Therefore, mitigation and adaptation mechanisms are crucial to coping with climate change-driven challenges (Marie *et al.*, 2020).

According to the IPCC, climate change vulnerability refers to the susceptibility of a species, system or resource to the harmful effects of anthropogenic climate change and other stressors. It consists of three components: sensitivity, exposure and adaptive capacity (IPCC, 2007). The degree of sensitivity and exposure to climate change hazards is greatly determined by the severity of their repercussions (Cardona *et al.*, 2012; Mortreux and Barnett, 2017). Climate vulnerability is visible in economic and social sensitivity to interannual precipitation variability and extreme climate events, particularly drought (Gao and Mills, 2018; Simane *et al.*, 2016). Adaptive capacity entails the capacity of the system to withstand variability and changes to minimize potential damages, cope with negative consequences and possibly even benefit from these changes (Smit and Wandel, 2006).

Higher exposure and sensitivity imply increased vulnerability, but adaptive capability moderates vulnerability and affects a system's exposure and sensitivity (Datta and Behera, 2022). As a result, increasing the adaptive capability of rural farmers is critical for lowering vulnerability. Therefore, farmers' adoption of proper adaptation methods is vital for reducing the adverse effects of climate change, and farmers with higher adaptive capacity are predicted to be better suited to adjust to rapidly changing climatic conditions (Datta and Behera, 2022).

Adaptation to climate variability is the process by which stakeholders make adjustments by reducing the actual and expected adverse effects of climate on their livelihoods (IPCC, 2014). However, a combination of factors influences the farmers' perception of climate variability and their decision to use certain adaptation strategies (Hassan and Nhemachena, 2008). A better understanding of how smallholder farmers perceive climate change and the adaptation strategies they practice is needed to make policies and design programs aimed at promoting successful adaptation in the agricultural sector (Belay *et al.*, 2017).

Farm-level climate change adaptation strategies can be linked when specific adaption measures are used concurrently or sequentially, promoting the adoption of other strategies (Kassie *et al.*, 2015). As the number of adaptation strategies increase, they are more likely to be interdependent, even though one approach can be used in place of another when evaluated separately (Belay *et al.*, 2017). For example, the potential of drought-tolerant crop types may be fostered by the use of animal manure and crop residues, which have the potential to boost soil water conservation and moisture content during the dry seasons (Wainaina *et al.*, 2016). Recognizing smallholder farmers' relative vulnerability to climate change provides a range of effective adaptive strategies that could help to improve household resilience capacity and support sustainable livelihood development (Bedeke *et al.*, 2020).

Several studies have been undertaken on climate change adaptation mechanisms and their adoption factors in Africa and Ethiopia. For example, Lemessa *et al.* (2019) focused on climate change adaptation techniques in response to food security in eastern Ethiopia. However, this study did not address agroecology bases. Likewise, Asfaw *et al.* (2018) in north-central Ethiopia focused on the general adaptation situations of smallholder farmers on the household adoption determinants considered in different agro-ecological zones. Belay *et al.* (2017) and Bedeke *et al.* (2019) conducted an adoption of climate change adaptation strategies by smallholders in Ethiopia by considering three districts that cover diverse topographic and socioeconomic conditions. Not all farm households are equally capable of adopting adaptation strategies due to variations in their farming and livelihood contexts

(Falco *et al.*, 2014). Furthermore, the effectiveness of current adaptation solutions varies greatly among Ethiopia's varied smallholder population (Berger *et al.*, 2017).

Several existing studies have looked at barriers to adaptation with little emphasis on the household adoption determinants considered in different agro-ecological zones (highland, lowland and midlands). Unlike the previous studies, the present study focused on a particular agro-ecological zone that aims to fill this gap and provide vital information for developing effective adaptation policies that enhance adaptive capacity and agricultural sustainability in the lowlands of southern Ethiopia. Understanding agroecology-based adaptation is crucial to developing and implementing proper adaptation strategies that can alleviate the adverse effects of climate change (Marie *et al.*, 2020). The objectives of the study presented in this paper are to:

- identify the main adaptation strategies used by smallholder farmers; and
- identify the factors that affect the adoption of adaptation strategies in the lowlands of Wolaita, southern Ethiopia.

The subsequent sections of this paper, Section 2 discusses the method used, Section 3 the findings and discussions, and Section 4 offers Concussions and Recommendations.

2. Methods

This section describes in detail the study setting, sampling technique, data sources and collection methods and data analysis.

2.1 Study site

This study focused on the lowlands of farm households in Wolaita, southern Ethiopia, located between 6.4 0–7.1 0 N and 37.4 0–38.2 0 E, latitude and longitude, respectively. The area is characterized by three agroecology zones, out of which Dega (high land) accounts for 9%, Woina Dega (Midland) accounts for 56% and Kola (lowland) 35%. Typically, Wolaita has two harvest seasons: the Belg, which occurs between mid-March to mid-May (short rainy season) and the Meher, which occurs between July and September (long rainy season) [Wolaita Zone finance and economy development department (WZFEDD, 2019)]. The amount, duration and intensity of rainfall in the zone vary and generally decrease from highland to lowlands (WZFEDD, 2019). The rainfall distribution in the study lowlands area is bimodal, with the highest rainfall in the wet season and the lowest rainfall in the past half of the dry season (Megresa and Woldetsadik, 2022). Extreme climate events, such as increased floods, droughts and erosion directly impact production and reduce the livelihood options of the rural poor in the lowlands of the study area (Bedeke *et al.*, 2018). The gradual and extreme weather changes has a shock on agricultural production in the area (Tera and abu Wolde, 2016). The study by Aboye *et al.* (2022) showed that between the periods of 2000–2019, in the study area, the average annual rainfall was between 703 mm and 1,362 mm, while the average minimum and maximum temperatures were 17 °C and 30 °C, respectively. The map of the Wolaita Zone indicates that the study districts as is shown in Figure 1.

2.2 Research design

This study adopted a mixed-methods sequential explanatory design that combines qualitative and quantitative approaches (Creswell and Creswell, 2017; Ivankova *et al.*, 2006).

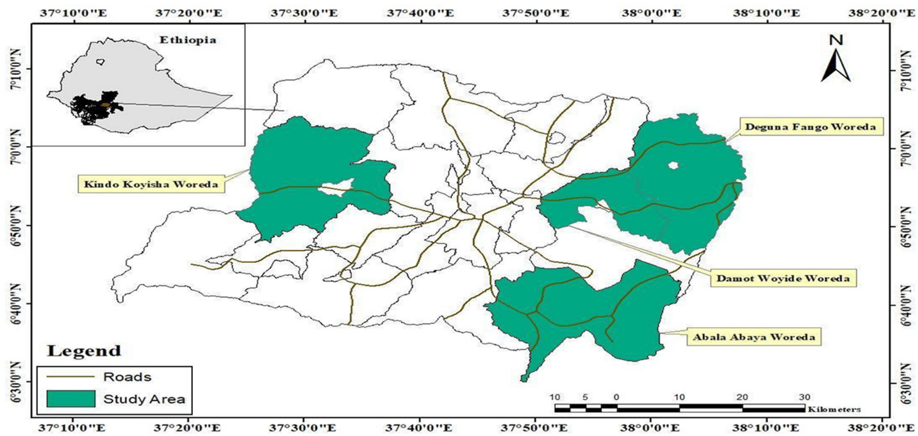

Figure 1. Map of Wolaita Zone showing the study districts

Source: GIS/RS satellite map, September 2022

In this design, a researcher collects and analyzes quantitative data first, followed by qualitative data. Both data are then combined.

2.3 Sampling technique and sample size

In this study a multistage sampling procedure was used to select survey respondents. This sampling process allows for the selection of small sample units from larger ones while ensuring that all components have an equal probability of being chosen (Boansi *et al.*, 2017; Tesfaye and Seifu, 2015). Wolaita Zone was purposively selected at the principal stage as it is one of the most climate-vulnerable zones in the southern region of the country. Out of the 16 districts in the Zone, four of them, namely, Duguna Fango, Damot Woyede, Abala Abaya and Kindo Koyisha, were purposively selected because of their relatively large areas of lowland. Two villages from each district were then randomly selected.

Cochran's (1977) formula equation (1), was used to determine the sample size of the study population:

$$n_0 = Z^2 pq / e^2 \tag{1}$$

where n is the sample size, Z^2 is the chosen critical value for the desired confidence level ($Z = 1.96$ at 0.05). p is the estimated proportion of an attribute that is present in the population, and q is $1-p$. e is the desired level of precision with a 95% confidence level.

Finally, a probability proportional to size sampling technique CSA (2016) was used for selecting 400 household heads from the eight chosen villages.

2.4 Data sources and method of collection

The study data were gathered using a mix of household surveys, focus group discussions (FGDs) and key informant interviews. A structured questionnaire was used to collect household data through face-to-face interviews with household heads on socioeconomic and demographic variables and the adaptation techniques used by farm households in response to climate change. For this, four data collectors were recruited and trained on how to conduct the interview schedule and approach the farm households. The questionnaire was pretested by 10% of the total sample

(40 farm households) to identify unnecessary redundancy and inconsistencies. Based on results, the questionnaire was revised and refined. The finalized survey was conducted on a broad scale of 400 farm household heads between September 2020 and November 2020.

In addition, the qualitative data was collected through FGDs and key informant interviews to understand the knowledge and experience related to the topic at hand and strengthen the survey data. Eight FGDs, each with 8–10 members (men and women) and six key informants in each study district participated. Key informants and FGD members were purposefully selected by considering farming experiences. Unstructured interview guide checklists were designed to keep the FGD and key informant interview focused on the study's objectives by allowing respondents to express themselves freely with their permission.

The guided checklist included topics on:

- What were they doing to adapt to climate change?
- What are the factors that affect the adoption of the adaptation to climate change?

2.5 Method of data analysis

To analyze and present the data collected from sampled households, descriptive statistics (frequency, mean, maximum, minimum and standard deviation), inferential tests (Chi-square and one-way ANOVA test) and binary logit model were used. Qualitative data were coded and thematically analyzed. After computing the descriptive statistics and inferential tests, a binary logit model was used to identify determinants of household's adoption of adaptation options where the dependent variable was found to be dichotomous.

Considering the binary nature of the dependent variables a binary logit model was used to analyze the factors determining use of farmers' adaptation strategies since this model is frequently used in similar previous studies (Atube *et al.*, 2021; Uddin *et al.*, 2014; Sertse *et al.*, 2021). The binary logit model gives more precise results than similar binary models like the linear probability model, which has certain limitations in terms of heteroscedasticity and distribution abnormality of the error term (Gujarati, 2022). In the binary model, we assumed that a farmer adopts an adaptation measure that has the maximum outcome in terms of yielding higher profit or reducing the adverse impacts of climate uncertainties (Mekonnen *et al.*, 2021).

According to Gujarati (2022), a binary logistic model specification is used to model climate change adaptation strategies of farmers involving dummy dependent variables with binary choices. The logistic distribution function for the decision on adopting adaptation measures to climate change can be specified as:

$$\log_{it}(P) = \text{Log}\left(\frac{1}{1-P}\right) \tag{2}$$

$$\text{let Pi} = \text{pr}\ \left(\frac{y=1}{\text{x}-\text{xi}}\right), \text{then the model can be written as} \tag{3}$$

$$\text{pr} = \left(\text{y} = \frac{1}{\text{x}}\right) = \frac{exp^{x'b}}{1+\text{e}^{\text{x}'\text{b}}}; \text{Log}\left(\frac{pi}{1-Pi}\right) = \log_{it}(Pi) = \beta o + \beta 1xi \tag{4}$$

where; Pi is a probability of deciding to adopt adaptation strategies (dependent variable), xi's are the independent variables, $\beta 0$ is the intercept and $\beta 1$ is the regression coefficient. We can write the model in terms of odds as:

$$\left(\frac{pi}{1-Pi}\right) = exp^{(\beta o+\beta 1xi)} \quad (5)$$

study of determinants of smallholder farmers' adoption of climate change by Saguye (2016) in southern Ethiopia, the dependent variables (representing the adoption of adaptation strategies) were binary, and their values were 1 for a farmer who used at least one of the listed adopted strategies and 0 for a farmer who used none. This study used the same approach as used by Saguye (2016) to distinguish between farmers who adopted climate change adaptation strategies and those who did not in the study area. The independent variables that are hypothesized to affect the farmers' adoption of the listed adaptation strategies in this study include selected demographic, socioeconomic and institutional characteristics of farmers. Based on the review of past studies on adaptation strategies (Saguye, 2016; Belay *et al.*, 2017; Patnaik *et al.*, 2019; Bedeke *et al.*, 2018), the following explanatory variables were considered in this study and examined for their effect on adoption of adaptation to climate change strategies (Table 1).

3. Result and discussion

Farmers in the study area perceived an increase in long-term temperature and declining rainfall and they experienced climate change impacts, such as reduced crop production, flooding, crop losses, drought, malaria and animal disease (Aboye *et al.*, 2022). This section presents and discusses: the adaptation measures that study farmers used to respond to climate change impacts, differences between adopter and nonadopter households: and the key factors that affect farm households' adoption of adaptation strategies.

3.1 Adaptation strategies of smallholder farmers to climate change and variability

The study found that farmers used different adaptation strategies in response to the effects of climate change (Table 2). The results show that 71.5% of farm households adopted one or more adaptation strategies to reduce the negative impact of climate change. These ranged from the most commonly adopted practice of changing crop planting dates to the least adopted response of migrating to another area. The study found that 28.5% of farm households in the study area did not use any adaptation strategies to respond to climate change effects.

3.1.1 Changing planting dates. Among the adaptation strategies indicated in Table 2, changing planting dates was the most widely practiced (71.5% overall) by farmers in the study area. A recent study found that the study area's rainfall pattern was unpredictable and erratic; and often inadequate during the cropping seasons (Aboye *et al.*, 2022). This situation forced farmers to change the planting dates of their crops. This result is in line with the study in Ethiopia by Belay *et al.* (2017), who reported that the most widely practiced strategy farmers used to reduce the impacts of climate change, particularly in the lowlands, was to change crop planting dates and to undertake crop diversification.

3.1.2 Crop diversification. Crop diversification refers to the practice of planting different crops on the same plot through mixed cropping or intercropping (Zakari *et al.*,2022), and one option for smallholder farming to ensure and mitigate the consequences of climate change,

Table 1. Description of the variables that determine the adoption of adaptation strategies and their hypothesis

Variables	Definition and measurements of the variables that determine the adoption of adaptation strategies	Hypothesis
Gender	Gender is a dummy variable, as 1 = Male, 0 = Female. Female-headed households are less likely to adopt adaptation strategies to respond to climate change risks (Belay *et al.*, 2017)	Positive/negative
Age	Age is a continuous variable (years); as the farmer's age increases, the likelihood of adopting adaption strategies is less (Nguyen *et al.*, 2021; Islam *et al.*, 2021)	Positive/negative
Education	Education is a dummy variable, 0 = No formal education, 1 = Formal education. Farmers, who have higher levels of education, are more likely to adopt climate change adaptation strategy (Funk *et al.*, 2020; Hirpha *et al.*, 2020)	Positive
Household size	Household size is continuous variable (number). A larger household size is associated with greater labor resources (Opiyo *et al.*, 2016), as the number of households size increases, the likelihood of adaptation strategies increases (Opiyo *et al.*, 2016)	Positive
Farm size	Farm size is a continuous variable (hectare). It affects the adoption of adaptation strategies to respond to climate change (Mahaarcha, 2019)	Positive/negative
Farming experience	Farming experiences is continuous (years), as the years of farming experience increase the likelihood of adopting the adaptation strategies increases (Belay *et al.*, 2017)	Positive
Extension advisory contact	Extension advisory contact is continuous variable (number contact per a year), as extension advisory contact increases, increase the probability of farmers adopting adaptation strategies (Adeagbo *et al.*, 2021)	Positive
Livestock ownership	Livestock holding in Tropical Livestock Unit (TLU) is continuous variable; having a high TLU increases the probability of farmers adopting adaptation strategies (Zeleke *et al.*, 2022)	Positive
Access to climate information	Access to climate information is a dummy variable, 1 = Yes, 0 = No; having access to climate information encourages farmers to adopt adaptation measures (Asrat and Simane, 2018; Marie *et al.*, 2020; Mihiretu *et al.*, 2023)	Positive
Access to credit	Access to credit is a dummy variable, 1 = Yes, 0 = No; having access to credit enhances the likelihood of adopting adaptation strategies (Atube *et al.*, 2021)	Positive
Household income	Annual household income is continuous (Ethiopian Birr); high household income can increase the probability of adopting adaptation methods (Esfandiari *et al.*, 2020; Nguyen *et al.*, 2021)	Positive

Source: Based on the authors' review of the literature (2020)

as well as establishing resilient agricultural systems that can highly contribute to household food security (Mango *et al.*, 2018). In the study area crop diversification was used by 61% of smallholder farmers. To minimize the risk of the total loss of their crops and increase crop productivity, farmers planted a variety of crops on the same plot, such as coffee, haricot beans and maize: and they reported mentioned that all of these crops grew well. This result is consistent with the findings of Uddin *et al.* (2014), who found that diversified cropping practices, reduced overall farm risk and expanded opportunities for farm profit generally helped to boost farmers' average incomes.

3.1.3 Drought-tolerant crops. The majority (58.3%) of households used drought-tolerant crops, such as cassava, *Enset* (*ventricosum*) and pigeon peas to respond to difficult farming conditions and changing climates.

In the FGDs, women also disclosed that they benefited greatly from the production of *Enset* when food for their families and their animals was in short `y. One woman reported:

> *In my home garden, I have three rows of Enset (one contains more than six plants of Enset), and three Ensets can process food. As a result, I use it for house consumption, selling products, and feeding my animals. It saved my animals' lives from starvation. I also gain income and food for my family.*

The finding from a FGD undertaken in the study is comparable to the findings of earlier studies conducted in southern Ethiopia by Mohammed *et al.* (2013) and Dalle and Daba (2021), who stated that Enset is a multipurpose crop used for food, fodder, fiber and medicine and other things. Additionally, the Enset plant is drought-tolerant and is a perennial crop, enhancing the soil and climate in the area.

3.1.4 Selling livestock. Livestock rearing was common in the study area, with 87% of households reporting engaging in livestock farms. The study findings show that more than half of the households sold livestock as an adaptation strategy to respond to the changing climate. Livestock can serve as both a source of productive physical capital (animal power) and social capital for owners (reputation and community ties) in the context of livelihood assets (DFID, 1999). Selling livestock helps smallholder farmers by giving immediate relief from climate-related impacts. However, the study found that this strategy can have a negative impact on farm households, which erodes households' assets. One of the key informants explained that:

> *My milking cow and heifer were both sold after a flood destroyed one hectare of maize crops. At the time, it protected my family from going hungry and helped me to pay back the loan. I don't have any livestock at the moment. I am worried about the future.*

The results from key informants showed that selling livestock depletes household assets.

3.1.5 Off-farm and nonfarm work. Off-farm and nonfarm work was another adaptation mechanism practiced by the smallholder farmers in the study area. Smallholder farmers had diversified their sources of livelihood to enhance incomes and spread their livelihood risk. The study findings showed that 48.3% of farmers had diversified their livelihood strategies using off-farm and nonfarm work. Planting trees alongside crops was also an adaptation

Adaptation strategies	No. of respondents	%
Change planting dates	286	71.5
Crop diversification	244	61
Growing drought tolerant crops	233	58.3
Selling livestock	207	51.8
Off-farm and nonfarm work	193	48.3
Tree planting alongside crops	184	46
Practice crop rotation	132	33
Constructing soil and water conservation (SWC) structure	91	22.8
Water harvesting for irrigation	62	15.5
Migrate to another area	33	8.3
No adoption strategies used	114	28.5

Source: Owen survey (2020)

Table 2. Adaptation strategies used by small holder farmers in response to climate change and the proportion of respondents that practiced them in the study area ($n = 400$)

strategy that was used by 46% of farmers to provide natural shade for farmers' crops during dry periods.

3.1.6 Crop rotation. The study found that crop rotation had been used by 33% of smallholder farmers as an adaptation strategy to climate change. Crop rotation increases crops' climatic adaptability by enhancing water dynamics, soil health and biological conditions in plant systems (Yu *et al.*, 2022). A proportion of the farmers (22.8%) also used soil and water conservation techniques, which included check dams, stone bunds, soil bunds, cutoff drains, area closure, terracing and mulching practiced to avoid the risk of flooding, improve soil moisture and organic matter retention and reduce soil erosion. A similar result was reported by (Likinaw *et al.*, 2022).

3.1.7 Water harvesting for irrigation. A small proportion of farmers (15.5%) used water harvesting for crop irrigation purposes. This may be due to the farmers' limited technical skills and financial capacity to use irrigation effectively. Even though rivers exist in some areas of the study, they are mostly inaccessible for irrigation due to the high cost of constructing irrigation systems. This result is in line with a study by Likinaw *et al.* (2022) conducted in northwest Ethiopia, which discovered that limited irrigation potential and a lack of financial resources are the main barriers to implementing irrigation as an adaptation strategy for managing the risk of climate change.

3.1.8 Migration to other places. Migrating to other places for searching financial resources for the family is one of the adaptation strategies to climate change (Zakari *et al.*, 2022). However, migration to other areas was the least used of the identified adaptation strategies (8.3% of the farmers). Smallholder farmers get benefits from migrant people, and it gives instantaneous reprieve to them from climate-related risks. However, it can impact farm household labor availability. During FGDs and key informant interviews, households claimed that young people no longer resided in the area because their families were unable to meet their needs; as a result, they migrated in search of labor throughout the city. These situations deplete the labor availability for farming in the area. The results from the key informants and FGDs showed that migrations to other places reduce family labor in households.

3.2 Comparison of adopters and nonadopters of adaptation strategies among farm households

This section compares the farm households who have adopted climate adaptation strategies ($n = 286$) and those who reported not adopting the adaptation strategies ($n = 114$) in terms of their demographic and socioeconomic characteristics (Table 3).

3.2.1 Comparison among continuous variables. The findings presented in Table 3 show that there is no significant association between the ages of the household head of the adopter households relative to the nonadopter households. The analysis indicates a statistically significant difference ($p < 0.05$) in household size between adopter and nonadopter households. A larger household size is associated with greater labor resources, allowing the household to do a wider variety of productive work (Opiyo *et al.*, 2016).

Farm size is a crucial variable for agricultural production in the rural area. The study found that the average farm size was higher in the lowland areas than in the other highlands and midlands. The study revealed significant differences ($p < 0.01$) among adopter and nonadopter households in farm size. Livestock is important in the study area, and the vast majority (87.2%) of the farm households owned livestock of different types, which includes cattle, sheep, goats, donkeys and poultry. Analysis indicates that the numbers of livestock owned is statistically significant ($p < 0.01$) between adopter and nonadopter farm households and suggests that households that own more livestock were more likely to adopt

Continuous variable	Adaptation categories Adopter ($N = 286$)	Nonadaptor ($N = 114$)	Total mean	F value
Mean age of household heads (years)	44.26	44.13	44.22	0.011
Mean household size	6.44	5.96	6.30	4.001**
Mean farm size (Ha)	1.32	0.59	1.12	37.223***
Mean livestock owned (TLU)	2.88	1.23	2.41	42.652***
Mean years of farming experiences	25.20	23.86	24.82	2.277
Extension advisory contact (contacts per year)	12.96	10.89	12.34	5.425**
Mean household income (Ethiopian Birr)	33,699	8,623	26,553	111.485***
Discrete variable	Adopter ($N = 286$)	Non-adopter ($N = 114$)	Total ($N = 400$)	χ^2 value
Sex of household heads				
Male	237 (82.9%)	82 (71.9%)	319 (79.75%)	6.023**
Female	49 (17.1%)	32 (28.1%)	81 (20.25%)	
Education of household head				
No formal education	99 (34.6%)	57 (50%)	156 (39%)	8.109***
Primary and above	187 (65.4%)	57 (50%)	244 (61%)	
Access to credit				
Yes	107 (37.4%)	1 (0.9%)	108 (27%)	
No	179 (62.6%)	113 (99.2%)	292 (73%)	55.064***
Access to climate information				
Yes	99 (34.6)	13 (11.4)	112 (28)	21.73***
No	187 (65.4)	101 (85.6)	288 (72)	

Notes: Level of significance: ** $p < 0.05$, *** $p < 0.001$
Source: Owen survey (2020)

Table 3. Comparison of adopter and nonadopter households by demographic and socioeconomic variables ($N = 400$)

an adaptation strategy as compared to those with relatively fewer livestock. The findings show that all respondents have more than 20 years of farming experience in the study area, and the analysis results indicate that there was no statistically significant difference in levels of farming experience between the two groups.

Institutional support like credit facilities, extension services and other rural infrastructure development is central to development. The survey results indicate that the mean frequency of extension advisory contact per year is higher at 13 in the adopter households relative to 10.89 in the nonadopters and statistically significant differences among the two groups (Table 3). This suggests that farm households who had more contact with extension workers were more likely to adopt adaptation strategies compared to nonadopter households. A study by Adeagbo *et al.* (2021) found that access to extension services allows farmers to get high-quality information on how to deal with climate change and its effects on their farms.

The results in Table 3 show that the households with higher income use more adaptation strategies than those of fewer income households. The analysis in Table 3 indicates that household income is statistically significant differences ($p < 0.01$) between adopter and nonadopter households. The finding suggests that farmers who have higher incomes adopt more adaptation strategies to minimize the negative effect of climate change. This result corresponds with the study by Nguyen *et al.* (2021), who reported that farmers with high household incomes can manage the risk of climatic variability by using different adaptation measures.

3.2.2 Comparison among discrete variables. The majority of the surveyed household heads were men (79.8% males), with 20.2% women, which reflects the national average of 22.1% in rural areas (CSA, 2016). The result of the study (Table 3) shows that higher percentages of men were in the "adopter" category relative to women. The analysis indicates that there is a statistically significant difference ($p < 0.05$) between the sex of household heads and adoption of adaptation strategies. The study found that 35.7% of the adopter households accessed credit services while only one (0.9%) of the nonadopters used credit services. The findings in Table 3 indicate that formally educated household heads (primary level and above) were more likely to have adopted the adaptation strategies compared to those households in which the household heads did not have formal education. This suggests that household heads with a high level of education are more likely to adopt adaptation strategies in response to the effects of climate change. Farmers with a higher level of education are likely to become more assertive and dynamic as they engage in economic and political activities (Alemayehu *et al.*, 2018).

The study found that access to credit was statistically different ($p < 0.01$) between the adopter and nonadopter households (Table 3). The study of perceptions of climate change and adaptation in Kenya by Opiyo *et al.* (2016) confirmed that access to credit facilities alleviates cash restrictions and allows households to invest in production inputs for climate change adaptation. Access to climate information is another factor determining the adoption of adaptation strategies in response to the adverse effect of climate change. The survey results in Table 3 indicate that 28% of households got climate-related information like a timely weather forecast through radio and newspapers as well as from extension workers, while the majority (72%) reported that they did not receive climate information. The test result (Table 3) reveals that the difference in access to climate information is statistically significant ($p < 0.01$) between adopters and nonadopters households.

3.3 Determinants of farmers' adaptation strategies to climate change

The binary logistic regression analysis was used to assess the determinants of farmer's adaptation strategies to the effects of climate change. Before the data analysis, the multicollinearity among the continuous explanatory variables was detected by the variance inflation factor. The correlation matrix method was also used to detect the degree of association between the dummy explanatory variables. The pseudo R^2 is used here to determine the goodness of fit. The results in Table 4 showed that the pseudo R^2 with values of 0.3647 indicates an excellent model fit. Furthermore, the computed Chi^2 of 174.36 indicated that the model is statistically significant at probability levels of less than of $p < 0.1$ or less.

In Table 4, the majority of the farmers' determinants of adaptation strategies to climate change in the regression analysis in Table 4 show signs that support the authors' prior hypothesis that was presented in Table 1. Eight of the 11 hypothetical variables, such as age, farming size, education, farming experience, livestock ownership, access to climate information, access to credit and annual household incomes, are statistically significant at probability levels of $p < 0.1$, $p < 0.05$ and $p < 0.001$, as evidenced by their coefficient signs and the following discussion focuses primarily on those statistically significant variables that influence smallholder farmers to adopt adaptation strategies.

3.3.1 Age of household heads. The findings in Table 4 indicate that age is negatively and significantly ($p < 0.05$) related to farmer's adaptive strategies to climate change effects. This means that the likelihood of adopting adaption strategies reduces as the farmer's age increases. This finding confirmed that younger farmers are more inclined than older farmers to apply adaptation practices. Young farmers may have better access to climatic data, are

Variables	Coef.	SE	Z	$p > z$
Gender	−0.304	0.364	−0.84	0.404
Age	−0.043	0.020	−2.12	0.034
Education	0.023	0.019	1.24	0.021
Household size	−0.050	0.071	−0.70	0.481
Farm size (Hectare)	−6.327	2.661	−2.38	0.017
Farming experience (years)	0.056	0.028	2.01	0.044
Extension advisory contact	−0.011	0.019	−0.55	0.584
Livestock ownership (TLU)	0.349	0.107	3.26	0.001
Access to climate information	0.657	0.392	1.68	0.094
Access to credit	3.857	1.053	3.66	0.000
Household income	7.561	2.644	2.86	0.004
Constant	−0.268	0.775	−0.35	0.730
Number of obs LR Chi^2		400 174.36		
Log likelihood		−151.866		
Prob > Chi^2		0.000		
Pseudo R^2		0.3647		

Source: Owen survey (2020)

Table 4. Binary logit model parameter estimates on determinants of adaptation strategies to the effects of climate change

more innovative and are more interested in integrating new technology and methods (Esfandiari *et al.*, 2020). In contrast, older farmers have a lot of experience with their traditional farming practices and they are usually risk averse, thus they are predicted to be less responsive to change. These findings are consistent with those of Nguyen *et al.* (2021) and Islam *et al.* (2021) by way of response that older farmers are less willing to use current agricultural methods or cutting-edge technologies since they are more accustomed to using traditional methods and are reluctant to modify their behavior.

3.3.2 Education. The results indicated that the level of education had a significant ($p <$ 0.05) and positive influence on the adoption of adaptation strategies in farm households. The finding implies that those household heads with higher levels of education had a higher probability of adopting climate change adaptation strategies. Educated farmers are more responsive to the adoption of new farming technologies, they have better access to scientific information and this allows them to learn about and practice adapting to climate change on their farms (Funk *et al.*, 2020). This result aligns with the findings of Hirpha *et al.* (2020), who indicated that education significantly influences how rural farming communities adapt to climate change.

3.3.3 Farm size. The study found that farm size had a significant ($p < 0.05$) and negative relationship to farmers' adaptive strategies to climate change. The result implies that as farm size increases there is less likelihood of farmers implementing climate change adaptation strategies. This may be because larger farms require high investment and necessitate significant agricultural inputs, such as improved seeds, fertilizer, pesticides and irrigation to adopt climate change adaptation strategies. These findings are consistent with those of Fadina and Barjolle (2018) and Uddin *et al.* (2014), who found that smaller farms are more likely to adopt adaptation strategies to climate change. Further, they reported that due to significant investment requirements, farmers with less land tend to adopt modern technological measures, while farmers with large farms prefer to adopt traditional methods. Another reason for being less likely to use adaptive strategies might be labor constraints and crop loss due to climate variability. During key informant interviews, farm households mentioned that they were "unwilling to use all our farm sizes because we very much suffer from the risks of climate variability and labor constraints."

One of the male farmers from the FGDs stated:

> *I have three hectares of land. Due to the past three consecutive Belg production seasons failing, I fear using all available land. In the 2019 production season, I only used 1.5 hectares for crops. From those planted crops, a half hectare was destroyed by floods.*

The finding suggests that due to frequent droughts, inadequate rainfall and labor constraints, the farmers with bigger land sizes in lowlands are less likely to adopt adaptation strategies to climate change.

3.3.4 Farming experiences. The study found that duration of farming experience was significantly ($p < 0.05$) and positively associated with adopting adaptation strategies to the effects of climate change. As the years of experience increased, it was more likely that these households adopted the adaptation strategies relative to those with fewer years of farming experience. This suggests that more experienced farmers had a better understanding of weather information and its implications for agricultural activities. The findings were comparable to those of Belay *et al.* (2017), who found that farming experiences aided in increasing awareness of the adverse effects of climate change on agriculture.

3.3.5 Livestock holding. The results revealed significant ($p < 0.01$) and a positive association between using adaptive strategies and ownership of livestock and found that higher livestock ownership increased the likelihood that farmers use adaptation measures to lessen the effects of climate change. The finding implies that as the number of livestock increases, the likelihood of using adaptive strategies also increases. These results are consistent with those of Zeleke *et al.* (2022), who suggested that livestock ownership significantly and positively influences farmers' choice of adaptation strategies.

3.3.6 Access to climate information. Access to climate information is an important variable that affects adopting adaptation strategies (Nguyen *et al.*, 2021). The analysis shows that access to climate information has a positive and significant ($p < 0.1$) association with adopting adaptation strategies to climate change. This result implies that access to weather information increases the probability of implementing climate change adaptation strategies. These findings are similar to the study from Asrat and Simane (2018), who reported that having access to climate information encourages farmers to invest in adaptation measures. A study by Marie *et al.* (2020) and Mihiretu *et al.* (2023) also showed that farmers that get climate change and adaptation information from reliable sources are more likely to adopt and use more strategies.

3.3.7 Access to credit. Access to credit has a positive and significant ($p < 0.01$) effect on farmers adopting adaptation strategies (Table 4). The results indicate that having access to credit enhances the likelihood of adopting adaptation strategies. This can be explained by the fact that access to credit reduces financial constraints and uncertainty, thus contributing to an increased adoption of adaptation strategies. This suggests that farmers with access to credit can invest agricultural inputs (improved seeds and chemical fertilizer), using crop diversification and small-scale irrigations, thus reducing the negative effect of climate change on food production. This result is in line with the findings of Atube *et al.* (2021), who stated that farmers with access to finance might invest in effective farming techniques, perhaps reducing the adverse effects of climate change on food production.

3.3.8 Household income. Household income is a major determinant of farmer resilience. The study found a positive and statistically significant ($p < 0.05$) relationship between household income and the application of climate change adaptation methods. The result shows that higher-income farmers were more likely to use adaption strategies than lowerincome farmers. The study's findings indicate that high household income can increase the probability of adopting adaptation methods to respond to the negative consequences of climate change. This finding is similar to Esfandiari *et al.* (2020) and Nguyen *et al.* (2021), who found that higher-income households were more likely to adopt climate change adaptation techniques.

4. Conclusions and recommendations

The agricultural sector remains a source of livelihood for rural communities in Ethiopia but faces the challenge of changing climate. This study investigated the adaptation strategies they practice to respond to climate change risks and the factors that influence their use of adaptation strategies in the lowlands of Wolaita, southern Ethiopia.

The study found that nearly 71.5% of the respondents adopted different adaptation strategies to respond to climate variability and change, such as changing planting dates, crop diversification, growing drought-tolerant crops, selling livestock and off-farm and nonfarm works, among others. The remaining (28.5%) respondents did not adopt any adaptation strategies. There were statistically significant differences in the adoption of adaptation strategies between adopter and nonadopter households in terms of sociodemographic and farming variables, as well as specific institutional relationships. The farmers' adoption of adaptation strategies was determined by the age and educational status of the household head, size of land holdings, livestock ownership, farming experiences, access to climate information, access to credit services and annual household income. Identification of local adaptation strategies is vital and could serve as a framework for stakeholders to support interventions that can mitigate vulnerability situations for farm households.

Many household adaptation strategies are limited to simple and low-cost measures. A minority of farmers adopted advanced adaptation strategies, such as crop diversification, constructing SWC structures and water harvesting for irrigation. This study recommends that public policy provide water harvesting and irrigation technology, which are easily managed at the household and community level, to enhance the farmers' resilience to climate change risks. Selling livestock and migrating to other places can hurt farm households by reducing household assets. Therefore, the study recommends that government and nongovernmental organizations provide improved livestock breeds and small ruminant animals, such as goats, sheep and poultry at affordable prices for farmers that are easy to manage and reach in short periods.

The study suggested that in the lowlands area of Woliata, labor constraints, droughts, erratic rainfall and the large investment needed for bigger farm sizes prevented farmers from adopting adaptation strategies. Due to this reason, the farmers are concerned about crop losses. Therefore, public policy should focus on these challenging lowland areas to support large irrigation projects, which are vital to reducing risks from climate variability. Providing climate change information, extension services and creating access to markets is crucial. Therefore, including these activities in the existing formal extension channels of the Ethiopian Ministry of Agriculture and other line ministries will be vital to farmers.

This study only addressed a particular agro-ecological zone (lowlands). Therefore, it would be necessary to do studies focusing on adaptive strategies of farming households in the midlands and highlands agroecology that help make informed policy decisions and design agroecology-based innovative development interventions. The results from this study offer a way for smallholder farmers to improve their livelihoods and assure food security by reducing their vulnerability and increasing their capacity for adaptation. It gives up-to-date details and adds to the body of knowledge for the scientific community regarding the agroecology-based adaptation strategies used by farm households to be resilient to climate change.

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