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## Article

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Research in Globalization

## Provided in Cooperation with:

Elsevier

*Suggested Citation:* Bekuma, Teka; Mamo, Girma; Regassa, Alemayehu (2023) : Indigenous and improved adaptation technologies in response to climate change adaptation and barriers among smallholder farmers in the East Wollega Zone of Oromia, Ethiopia, Research in Globalization, ISSN 2590-051X, Elsevier, Amsterdam, Vol. 6, pp. 1-9, <https://doi.org/10.1016/j.resglo.2022.100110>

This Version is available at:

<https://hdl.handle.net/10419/331037>

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# Indigenous and improved adaptation technologies in response to climate change adaptation and barriers among smallholder farmers in the East Wollega Zone of Oromia, Ethiopia

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## ARTICLE INFO

### Keywords:

Adaptation  
Climate change  
Indigenous and Improved technologies  
Binary logistic regression model  
Smallholder farmers

## ABSTRACT

Agriculture is the foundation of economy for Ethiopia. The majority of people in the study area rely on rain-fed subsistence agriculture for their livelihood. As a result, smallholder farmers were more susceptible to climate change due to their reliance on a single rain season and lack of climate change adaptation technologies. The sustainability of food crop production, which employs the majority of the labor force in the nation, is threatened by climate change. The study's objectives were to look at indigenous and improved adaptation technologies in reaction to local climate change effects and barriers to adaptation among smallholder farmers. A closed-ended, semi-structured questionnaire was used to gather the data from 400 smallholder farmer household heads. An analysis of the variables influencing farmers' decisions regarding climate change adaptation was conducted using binary logistic regression model. The fitness and accuracy of the model were examined using an omnibus test of model coefficients. The study's findings showed that absence of crop insurance, a lack of training and demonstration, a lack of non-farm employment, a lack of weather forecasting and early warning, shortage of finance, the high price of farm inputs, and reliance on a single rain season were the main barriers preventing farmers from adapting to climate change. The most popular indigenous adaptation techniques used by smallholder farmers included mixed cropping of local variety, reducing social and religious rituals, mixed farming (local crop and livestock), and reducing the amount of food consumed. The primary improved adaptation strategies used by the farmers included the use of chemical fertilizers, various agrochemicals, and soil and water conservation methods. The binary logistic regression model's findings showed that access to extension services by household heads significantly and favorably influenced farmers' decisions to scale back social and religious rituals, reduce food consumption, sell livestock, and adopt improved mixed farming as a means of adapting to climate change. Farm experience significantly influenced the farmers' decision to practice improved mixed farming; access to the market significantly affected farmers' decision on soil and water conservation practices; and the age of the respondents significantly influenced the farmers' decision to practice improved crop variety as a response to climate change adaptation. The study's conclusions showed that a number of factors limited farmers' attempts to adapt to climate change. The study recommends that decisions regarding adaptation plans should concentrate on reducing these barriers.

## Introduction

One of the biggest local, regional, and global environmental, social, and economic problems is climate change. It is now becoming a substantial obstacle for smallholder farmers who depend on rain-fed agriculture to produce food on their farms worldwide (Workalemahu &

Dawid, 2021). Smallholder farming systems are directly responsible for providing food for hundreds of millions of the world's poorest people, who now must contend with a changing climate and the societal reactions that follow (Cohn et al., 2017). The production of smallholder farms is significantly impacted by climate change and variability (Obert, Mtali-Chafadza, & Mafongoya, 2017). The effects of climate change on

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<https://doi.org/10.1016/j.resglo.2022.100110>

Received 26 September 2022; Received in revised form 22 December 2022; Accepted 29 December 2022

Available online 30 December 2022

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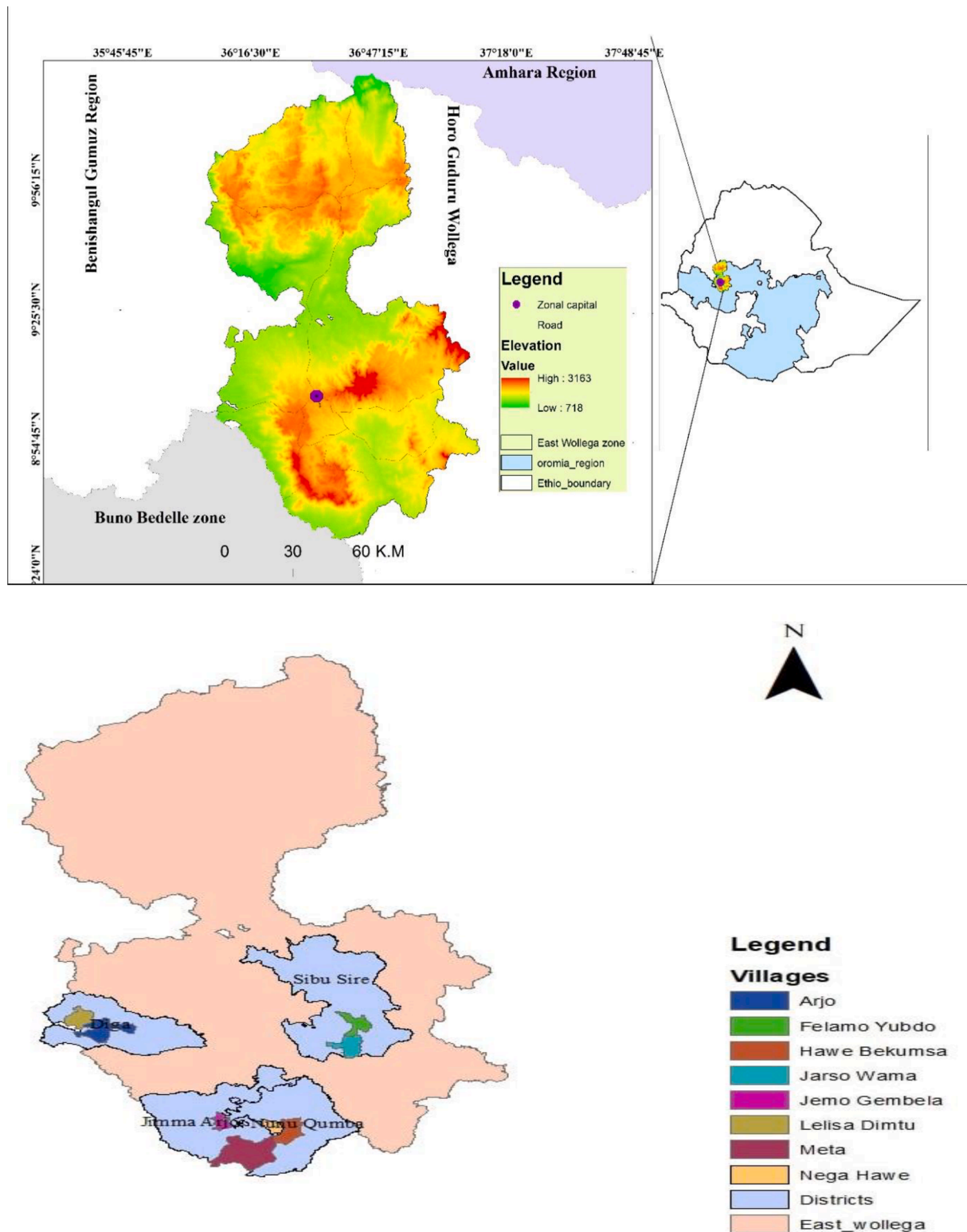


Fig. 1. Map of the study area.

agricultural activities in developing nations have been growing (Tazeze, Haji, & Ketema, 2012). The livelihoods of smallholder farmers in developing nations are anticipated to be severely negatively impacted (Nigussie et al., 2018). The length of the growing season is getting shorter, pests and insects are causing more crop damage, and weed infestation is getting worse, which are the main effects of climate change on local livelihoods (Bewket, 2012). Fig. 1..

Climate change is anticipated that it will have a negative impact on agricultural yields, especially in African nations like Ethiopia where crop production is highly dependent on environmental factors like temperature and rainfall (Mekonnen & Garuma, 2021). In recent decades, Ethiopia has faced significant environmental and socioeconomic challenges as a result of climate change (Marie, Yirga, Haile, & Tquabo, 2020). The Ethiopian economy is negatively impacted by climate change

and variability because the agricultural sector is so heavily dependent on natural rainfall and largely subsistence (Mengistu, 2011).

In order to combat the effects of climate change on agriculture in general and crop production in particular, adaptation is one of the most important strategies. In order to create an effective adaptation strategy against the changing climatic parameters, the scientific community, policymakers, and the general public of the nation have now come together (Upadhyay & Bijalwan, 2015). In many countries like Ethiopia where the risks are already present, adaptation measures that lessen vulnerability to climate change are very critical (Kaushik & Sharma, 2015). Farmers must adjust to climate change and find ways to lessen its effects because it is a universal phenomenon and will last forever in order to maintain agricultural output and achieve food security (Alam, Siwar, Jaafar, Talib, Bin, & Salleh, 2013). Real progress must be made in applying adaptation schemes in the farming sector if climate change issues are to be addressed and sustainability in the agricultural sector and environment promoted (Onu & Ikehi, 2016).

Previous studies identified that agricultural measures such as small-scale irrigation, agronomic techniques, diversification of sources of income, and conservation of soil and water are some of the most popular adaptation schemes used by farmers to lessen the negative effects of climate change (Abayineh & Belay, 2017). Smallholder farmers have adopted adaptation strategies like crop diversification, better breeding and variety, soil and water conservation, soil and plant-related schemes, and expansion into non-farming activities (Osei, 2017). Farmers have been witnessed to adapt in a number of ways, comprising the adoption of technological practices, on- and off-farm diversification, pastoralist mobility, and the use of weather forecasts (Rhodes, Jalloh, & Diouf, 2014). Agroforestry, crop rotation, intercropping, minimum tillage, maintaining soil cover, retaining residue, conserving water, improving the managing of livestock and soil carbon, and breeding plants and animals adapted for future climate situations are just a few of the key agro-ecological agricultural technologies and practices that are being promoted by numerous actors (Barnard, Manyire, & Tambi, 2015). Other studies discovered the most popular adaptation techniques, including the use of various crops, planting trees, conserving soil, altering planting dates, and irrigation (Bryan, Deressa, Gbetibouo, & Ringler, 2009). In order to adjust to climate change, farmers in Ethiopia's Nile Basin planted trees, conserved soil, planted crops early and late, and used irrigation (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009).

Findings of previous research showed that the household head's age, occupation, membership in a social group, access to credit, accessibility of extension services, availability of training opportunities, the occurrence of crop pests, and diseases, the price of inputs, and the attitude of the household towards climate change are among the factors which affected a farmer's decision on an adaptation approach (Shongwe, Masuku, & Manyatsi, 2014). Other study found that factors such as a farmer's education, farming experience, off-farm income, access to credit, and access to weather and climate information all had a significant impact on how well-equipped they were to deal with climate change (Mutunga Evelyn, Ndungu Charles, & Muendo, 2018). According to other study there is a strong correlation between gender, employment, knowledge of climate change, knowledge gained from extension services, scarcity of food, food security, and agricultural output (Maponya & Mpandeli, 2013).

Similarly, recent studies in the Assosa District of Western Ethiopia also reported that sex, literacy level, farming experience, family size, land ownership, access to credit, media access, extension interaction, farmer-to-farmer extension, farm revenue, off/non-farm revenue, livestock possession, market distance, and access to training all statistically affected the use of adaptation strategies by the smallholder farmers (Sani & Haji, 2016). The farmers in Ethiopia's Central Rift Valley area practiced crop variation, planting date modification, soil and water conservation, increasing the amount of input use, mixing crops with livestock, tree planting, and they were influenced by factors such as

education, family size, gender, age, livestock ownership, farming experience, incidence of communication with extension agents, farm size, access to markets, access to climate information, and incremental input use (Belay, Recha, Woldeamanuel, & Morton, 2017). According to another study, the likelihood that farmers will adopt strategies to maximize their long-term investment returns and decrease their need for short-term inputs is increased by the security of their land tenure (Asfaw, McCarty, Lipper, & Arslan, 2013).

Climate change incidences are unavoidable, and its negative effects on farmers' livelihoods and food security status necessitate quick action (Lemessa, Watebaji, & Yismaw, 2019). It is essential to comprehend local climate change conditions in order to implement context-specific responses to mitigate its negative effects (Mihiretu, Okoyo, & Lemma, 2020). Even though different studies have been carried out on climate change adaptations among smallholder farmers in different parts of the country, none of them have addressed the indigenous adaptation strategies specifically in the study area. Improved and indigenous climate change adaptation technologies employed by the smallholder farmers and influencing factors have not been adequately investigated and documented in the study area. To address this gap, the present study was conducted to identify barriers to adaptation, improved and indigenous climate change adaptation technologies and factors affected smallholder farmers' adaptation decisions in the study area so as to introduce local adaptation interventions. Therefore, the objectives of this study were: (1) to identify improved and indigenous adaptation technologies in response to climate change and barriers to adaptation and (2) to explore factors influencing of smallholder farmers' adaptation decision to climate change in the East Wollega Zone of Oromia, Ethiopia.

## Materials and procedures

### Description of the research area

The research was carried out in the Western Ethiopian region of Oromia National Regional State's East Wollega Zone. The zone has 17 districts and 289 villages. The zone's total land area is roughly 14,102.5 km<sup>2</sup>, or about 3.88 percent of the size of the Oromia National Regional State (EWZPEDO, 2017). It is located 331 km to the west of Addis Ababa, the capital of Ethiopia. The three categories of the zone's climate are highland (20.50 percent), midland (50.90 percent), and lowland (28.50 percent). The annual temperature ranges from 14 to 25 degrees Celsius, and the annual rainfall ranges from 1000 to 2400 mm (EWZPEDO, 2017). The rainy season is long in the summer (June to September), brief (March to April), and dry in the winter (December to February). For many Ethiopian highlands, the main rainy season lasts from June to September (Fita, 2014).

According to EWZPEDO (2017), there were 1,628,569 people living in the East Wollega zone overall, of which 824,195 (50.61 %) were men and about 804,374 (49.39 %) were women. About 81.12 % of the total population was rural during this year, with the majority of them directly working in agriculture. There were 195,578 households in the peasant villages of the zone in 2017, consisting of 175,173 males and 20,405 females. In 2017, the zone's population density was 115.034 people per square kilometer (EWZPEDO, 2017). The majority of the natural forest has been cut down to make way for local food production and fuel in the study area due to rapid human growth, which has significantly altered the land use system (Achal, 2014).

The two main economic pursuits in the study area are crop production and livestock keeping (Tek, Girma, & Alemayehu, 2022b). Production of crops and livestock provides food for households as well as sources of revenue. The primary cereal yields cultivated in the region are wheat, barley, teff, millet, sorghum, and maize. Crop production, which is primarily rain-fed agriculture, is a crucial activity for farmers' subsistence. Unpredictability in temperature and rainfall, shortening of the growing period, flood risks, and degradation of the soil are some of the main elements that affect the potential of the land (EWZPEDO, 2017).

**Table 1**  
Sample districts, villages and households for the study.

Sample Districts	No of total Villages	No of sample villages	Name of sample villages	No of sample households
Diga	21	2	Arjo and Lelisa	100
Jimma	20	2	Dimitu	100
Arjo			Jemo Gembela and Meta	
Nunu	20	2	Hawi Bekumsa and Nega Hawi	100
Kumba			FelamoYubdo and Jarso Wama	
Sibu Sire	19	2		100
Total	80	8		400

Source: EWZPEDO, 2017.

### Design of the study

#### Sampling strategy and sample size

To ensure representativeness and collect the necessary data, the purposive sampling method was employed to select sample districts, villages and households for the study. In order to include those regions those are primarily involved in crop production, four districts: Diga, Jimma Arjo, Sibu Sire, and Nunu Kumba were purposefully chosen based on secondary data. Then, in consultation with the experts and Development Agents (DA) in the study area, two sample villages from each sample district were specifically chosen to represent various agro-ecological zones. In the eight sample villages, there were a total of 5,700 households. In order to include farmers who have inhabited in the research area for at least 30 years, sample households were purposefully chosen from a list of registered farmers that was obtained from the respective village administration. The list of households maintained by the village administration served as a sampling frame for the selection of sample houses. The sample households included in the study were 400 from the 8 sample villages (50 households) from each village. The sample districts, villages, and households for the study are shown in Table 1 below. Using a formula created by Kothari (2004), the sample size was established as follows:

$$n = \frac{Z^2 * p * q * N}{e^2 (N - 1) + Z^2 * p * q}$$

$$n = \frac{(1.96^2)(0.5)(0.5)(5,700)}{(0.05)^2(5,700 - 1) + (1.96)^2(0.5)(0.5)}$$

$n = 400$  sample households. where,  $p$  = Sample proportion.

$N$  = Total Population

$q = 1 - p$

$Z$  = Confidence level

$n$  = Size of sample

$e$  = Standard error

#### Sources of data and data collection tools

Data from both primary and secondary sources were used in the research. Pre-tested closed and semi-structured questionnaires were used to gather primary data from household surveys. A secondary source of information was systematically reviewed from related published research articles.

#### Variables the study

The study made use of both independent (explanatory) and dependent variables. The smallholder farmers' selection of an adaptation strategy from a range of different adaptation options was a dependent variable. The independent variables were elements that affected the choices made by the farmers in reaction to climate change. This includes the sex of the household head, age, farming experience, education,

**Table 2**  
Variables used in the binary logistic regression model.

Variables	Type	Description	Code of Variables
Adaptation response	Dummy	Response variables	No = 0 Yes = 1
Age	Continuous	Predictors	Years
Sex	Dummy	Age of HHH	Female = 0 Male = 1
		Sex of HHH	No formal education = 0 Formal education = 1
Education	Dummy	Education of HHH	No = 0 Yes = 1
Access to extension	Dummy	Access of HHH to extension service	No = 0 Yes = 1
Access to market	Dummy	Access of HHH to market	No = 0 Yes = 1
Farming experience	Continuous	Experience of HHH	Years

contact to extension services, and access to market.

#### Analytical methods

The study used a mix of econometric models and descriptive statistics to analyze the data. Both descriptive and inferential statistical methods were used in the analyses. Demographic and socioeconomic information, as well as the details gathered from the household survey, were summarized using descriptive statistics like mean, percentages, and frequency distribution.

The econometric Binary Logistic Regression Model (BLRM) was employed in the study to ascertain the variables persuading farmers' decisions to adapt to climate change using the statistical package for social sciences (SPSS) version 20. To check for significant outliers and multi-collinearity, a preliminary analysis was conducted. The explanatory (independent) variables were examined for multicollinearity using a correlation test. The fitness and accuracy of the model were examined using an omnibus test of model coefficients. The connection among the likelihood of selecting a specific adaptation option and the group of explanatory variables is described by the binary logistic regression model (BLRM) for the selection of adaptation approaches. The dependent variable in this research was represented by the model's suitability, represented by the numbers 0 and 1. To estimate the probability that farmers would adjust to climate change, the odds ratio was used. The variables used in the binary logistic regression model are displayed in Table 2. The model was individually applied to each of the six adaptation approaches that farmers in the research area had come up with. Three indigenous practices, such as reducing social and religious rituals, reducing food intake, and selling livestock, are included in the adaptation practices. Improved adaptation practices were improved farming, improved crop varieties, and soil and water conservation practices.

#### Discussions of the findings

##### The respondents' socioeconomic profile

The socioeconomic characteristics of the household respondents were indicated in Table 3 below.

##### Barriers to implementing climate change adaptation plans

Table 4 below shows barriers that hinder stallholder farmers' choices to adjust to climate change. The lack of non-farm employment for the vast majority of households (90.25 %) has an adverse effect on how well the households are able to adapt to climate change. Agricultural inputs that aid in climate change adaptation by increasing agricultural productivity were difficult to use for more than half of the households (58.5



**Table 3**

Socioeconomic characteristics of the respondents.

Sex of HHH	Male	Female				
Frequency	388	12				
Percentage	97	3				
Education	Non-formal	Formal educ.				
Frequency	93	307				
Percentage	23.2	76.8				
Agro-ecology	Highland	Mid-land	Low-land			
Frequency	134	133	133			
Percentage	33.5	33.25	33.25			
Marital status	Single	Married	Divorced	Widowed		
Frequency	–	399	–	1		
Percentage	–	99.75	–	0.25		
Family size	1–3	4–6	7–9	10–12	13–15	
Frequency	7	146	188	54	5	
Percentage	1.75	36.5	47	13.5	1.25	
Age years	31–40	41–50	51–60	61–70	71–80	81–90
Frequency	40	183	130	32	13	2
Percentage	10	45.75	32.5	8	3.25	0.5
Farm experience	10–20	21–30	31–40	41–50	51–60	61–70
Frequency	47	211	105	30	6	1
Percentage	11.75	52.75	26.25	7.5	1.5	0.25

**Table 4**

Barriers hindering climate change adaptation by the smallholder farmers.

Determinant issues	Yes		No	
	Frequency	Percent	Frequency	Percent
Lack of non-farm employment	361	90.25	39	9.75
Limited access to market	234	58.5	166	41.5
Shortage of finance	355	88.75	45	11.25
Lack of agricultural credits	270	67.5	130	32.5
Limited access to extension services	225	56.25	175	43.75
Lack of training and demonstration	386	96.5	14	3.5
Lack of weather forecasting and early warning	356	89	44	11
Lack of crop insurance	400	100		
Lack of access to media	283	70.75	117	29.25
Shortage of agricultural inputs	277	69.25	123	30.75
Lack of irrigation agriculture	303	75.75	97	24.25
High cost of farm inputs	349	87.25	51	12.75
High cost of farm labor	318	79.5	82	20.5
Reliance on single rain season	340	85	60	15

%) because of their limited market access. The study's findings also showed that 88.75 % and 67.5 % of the respondents, respectively, faced financial constraints and lacked access to agricultural credit for their farming operations. On the other hand, the study showed that 56.25 % of the respondents had only a limited amount of contact to extension services. Further, the majority of the respondents (96.5 %) lack access to training and demonstration, which could have an adverse influence on how farmers adapt to climate change. In terms of having contact to weather predicting and early warning methods for their farming activity, 89 % of the respondents did not have access which makes it difficult for them to plan ahead for adaptation.

There is no crop insurance against climate shocks during crop failure for all of (100 %) the respondents. According to the study, 70.75 % of the respondents lack access to contemporary mass media. This is partly as a result of the study area's rural setting lacking infrastructure such as electricity and other services. Further results from the research showed that 69.25 % of the household respondents lacked access to agricultural inputs. The majority of household respondents (75.75 %) do not use irrigation agriculture. This demonstrates how the respondents' subsistence agriculture-based way of life is dependent on natural rainfall. The vast majority of farmers in the study area rely on intermittent rain-fed agriculture, which is the foundation of their economy (Teka, Girma, & Alemayehu, 2022a). A further factor that made 85 % of the farmers

**Table 5**

Indigenous adaptation strategies employed by smallholder farmers.

Indigenous adaptation practices	Responses	
	Yes (%)	No (%)
Temporary migration (labor migration) to wage labor	43.5	56.5
Application of traditional irrigation agriculture	26.8	73.2
Mixed farming (local crop and livestock)	94.25	5.75
Mixed cropping	96.5	3.5
Use of prayer (Praying)	77.2	28.8
Using local short season crops	76.2	23.8
Seed and grain storage	60.2	39.8
Sold livestock	81.2	18.8
Reduced food amount	85.2	14.8
Reduce social and religious ceremonies	95.8	4.2
Indigenous weather forecasting	65.2	34.8

vulnerable to climate change was their reliance on just one rainy season, the summer. Farmers' attempts to adapt to climate change were hampered by the high cost of farm inputs (87.5 %) and farm labor (79.5 %). The findings of this study agree with other research which identified poor climate change information, high cost of farm inputs, credit constraints and income constraints as major factors constraining farmers from adapting to climate change impacts (Ozor, Madukwe, Enete, & Amaechina, 2010).

#### *Strategies used by smallholder farmers to adapt to climate change*

##### *Indigenous adaptation strategies*

The key indigenous adaptation techniques created by the smallholder farmers as a defense against climate change are presented in Table 5 below. The study's findings showed that, in order of highest to lowest prevalence, respondents engaged in mixed cropping (96.5 %), reduced social and religious ceremonies (95.8 %), mixed farming (94.25 %), reduced food consumption (85.2 %), sold livestock (81.2 %), prayed (77.2 %), used local short-season crops (76.2 %), indigenous weather forecasting (65.2 %), seed and grain storage (60.2 %), labor migration (43.5 %), and traditional irrigation agriculture (26.8 %). Farmers rely more heavily on native adaptation techniques than on improved adaptation technologies. Over the past century, indigenous knowledge has aided rural farmer households in overcoming climate stressor challenges and improving decision-making for adaptation (Kom, Nethengwe, & Mpandeli, 2022).

**Table 6**

Improved adaptation approaches used by smallholder farmers.

Improved Adaptation strategies	Response	
	Yes (%)	No (%)
Buying weather/climate related crop insurance	–	100
Application of chemical fertilizers	88	12
Using different agrochemicals (pesticides and herbicides)	76	24
Using improved crop varieties	34.2	65.8
Application improved irrigation system	–	100
Improved mixed farming (improved crop and livestock)	16.8	83.2
Improved agroforestry system	27	73
Soil and water conservation techniques	68	32
Integrated disease and pest management	6.8	93.2
Improved weather forecasting system	7.8	92

*Improved adaptation technologies employed by smallholder farmers*

In order to determine the type of adaptation practices on which farmers relied most, the study divided the farmers' adaptation strategies into indigenous and improved technologies. Regarding the improved adaptation technologies, all of the respondents (100 %) did not have crop insurance for risks related to the climate, as shown in the Table 6 below. Additionally, the majority of farmers did not make use of improved adaptive technologies like improved crop varieties (65.8 %), improved irrigation systems (100 %), improved mixed farming (83.2 %), enhanced agroforestry (73 %), enhanced integrated disease and pest management (93.2 %), and improved weather forecasting and early warning systems (92 %). The farmers employed more native adaptation techniques in comparison to the improved adaptation technologies.

*Factors influencing farmers' decisions regarding climate change adaptation**Factors influenced the reduction of social and religious rituals as a response to climate change adaptation*

The binary logistic regression model was used to determine the factors that affected farmers' decisions regarding their adaptation strategies to climate change. The relationship between the outcome and the predictors is displayed in Table 7 below. The probability of the outcome changes by Exp (B) for every unit change in the predictor, which is represented by Beta (B), the predicted change in Log Odds. According to the likelihood test (chi-square statistics), the model has a significant ability to predict outcomes ( $X^2 = 23.165$ ,  $df = 6$ ,  $p = 0.001$ ). According

**Table 7**

Binary logistic regression for predictors of reduction of social and religious rituals.

Variables	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	–0.016	0.050	0.107	0.744	0.984	0.892	1.085
Sex (1)	18.563	11.784	0.000	0.999	11.828	0.000	.
Farm experience	–0.045	0.052	0.742	0.389	0.956	0.863	1.059
Education (1)	–0.087	0.788	0.012	0.912	0.916	0.196	4.293
Access to market(1)	–1.952	0.822	5.645	0.018*	0.142	0.028	0.710
Access to extension (1)	2.454	1.043	5.535	0.019*	11.637	1.506	89.909
Constant	6.338	2.405	6.944	0.008	565.692		

**Table 8**

Binary logistic regression for predictors of reduction of food amount.

Variables	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	–0.078	0.028	7.604	0.006*	0.925	0.876	0.978
Sex(1)	0.854	1.073	0.633	0.426	2.348	0.287	19.226
Education(1)	–0.187	0.428	0.191	0.662	0.830	0.359	1.918
Farm experience	0.058	0.032	3.273	0.070	1.059	0.995	1.128
Access to Market (1)	0.222	0.328	0.456	0.499	1.248	0.656	2.376
Access to extension (1)	1.632	0.388	17.712	0.000*	5.114	2.392	10.937
Constant	3.563	1.246	8.179	0.004	35.255		

to the findings of the binary logistic regression model analysis, among the other explanatory variables, access to the market had a negative and significant ( $p < 0.05$ ) influence on respondents' decisions to scale back social and religious rituals in reaction to climate change adaptation with (coefficient =  $-1.952$ ;  $p = 0.018$ ; odds ratio =  $0.142$ ). This suggested that farmers with limited market access were more likely to adapt to climate change by reducing social and religious rituals as a response to climate change adaptation than those with greater market access. The only explanatory factor that significantly and favorably affected how smallholder farmers adapted to climate change was access to extension services with (coefficient =  $2.45$ ,  $p = 0.019$ , odds ratio =  $11.637$ ). According to the findings, farmers who had contact to extension services were  $11.637$  times more probable to adjust to climate change than those who had less or no access to these services. This can be ascribed to the fact that the development agents (DA) in the research area provided farmers technical assistance so they could modify their farms to adjust to the changing climate. Many studies have also demonstrated that access to extension services improves smallholder farmers' adaptation to climate change (Asfaw et al., 2013; Maponya & Mpandeli, 2013; Shongwe et al., 2014; Sani & Haji, 2016).

The study's findings also revealed that the household heads' age, sex, farm experience, and level of education had no statistically significant influence on the smallholder farmers' adaptation decision. Farmers' adaptation strategies were negatively impacted by their age and farm experience with (coefficient =  $-0.016$ ;  $p = .744$ ; odds ratio =  $0.984$ ) and (coefficient =  $-0.045$ ;  $p = .389$ ; odds ratio =  $0.956$ ), respectively. This demonstrated that younger and less experienced farmers were more probable to adapt to climate change than their more experienced counterparts. This can be described by the possibility that younger farmers are more familiar with climate information as a result of contemporary media and education. The study's results also showed that compared to female farmers, male farmers were more probable to adjust to climate change. With (coefficient =  $-0.087$ ;  $p = .912$ ; odds ratio =  $0.916$ ), education had a negative impact on respondents' decision to reduce social and religious ceremonies in response to climate change adaptation. This suggests that respondents without formal education were more traditional and valued social and religious rituals.

*Factors influenced farmers to reduce food amounts as a response to climate change adaptation*

A summary of the variables that affected farmers' decisions to

**Table 9**

Binary logistic regression for predictors of selling livestock.

Variables	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	−0.008	0.026	0.088	0.766	0.992	0.942	1.045
Sex (1)	0.400	0.797	0.252	0.616	1.492	0.313	7.113
Education (1)	0.327	0.360	0.824	0.364	1.387	0.685	2.809
Farm experience	−0.009	0.029	0.092	0.762	0.991	0.937	1.049
Access to market (1)	−0.743	0.307	5.860	0.015*	0.476	0.260	0.868
Access to extension (1)	0.605	0.282	4.599	0.032*	1.832	1.053	3.186
Constant	2.114	1.099	3.699	0.054	8.285		

decrease food consumption in reaction to climate change adaptation is provided in Table 8 below. An omnibus test of the model's coefficients revealed the likelihood test (chi-square statistics):  $X^2 = 35.498$ ,  $df = 6$ ,  $p = 0.000$ , indicating that the model is significant for predicting farmers' climate change adaptation. The outcome demonstrated that only household head's contact to extension services had a significant and favorable influence on smallholder farmers' decision to reduce the amount of food as a strategy to adjust to climate change with (coefficient = 1.632,  $p = 0.000$ ; odds ratio = 5.114). According to the findings, farmers who had contact to extension services were 5.114 times more probable to adapt to climate change than farmers who had less or no access to these services. It can be concluded that the respondents' practices for coping with climate change were influenced by the development agents' close collaboration with farmers. Farmers' decisions to reduce the amount of food in reaction to climate change adaptation strategies were negatively and significantly influenced by the respondents' ages with (coefficient = −0.078;  $p = .006$ ; odds ratio = 0.925). This suggested that younger farmers were more probable to decrease food than their more experienced counterparts in an effort to adjust to climate change. In comparison to their female counterparts, male farmers were 2.348 times more likely to reduce food consumption in an effort to adjust to climate change.

Access to formal education had a negative impact on farmers' decisions to reduce food amount in reaction to the effects of climate change with (coefficient = −0.187;  $p = .662$ ; odds ratio = 0.830). This suggested that farmers with formal education were less likely than those without formal education to reduce food amount as a means of coping with climate change. Farmers who had more farm experience were 1.059 times more probable to reduce their food intake as a strategy of coping with climate change, while farmers who had access to markets were 1.248 times more likely to do so.

#### Factors influencing farmers to sell their livestock to adapt to climate change

The factors in Table 9 below are what influenced farmers' decisions to sell their livestock in an effort to adjust to climate change. The model is significant in examining farmers' performance in adjusting to climate change, according to the likelihood test of model coefficients, which revealed the following results:  $X^2 = 13.921$ ,  $df = 6$ ,  $p = 0.031$ . The study's results demonstrated that, among the other explanatory variables, respondents' decisions to sell their livestock in response to climate change adaptation were positively and significantly ( $p < 0.05$ )

influenced by contact to extension services. Smallholder farmers' decisions to sell their livestock in an effort to adapt to climate change were significantly and negatively impacted by household heads' access to market with (coefficient = −0.743,  $p = .015$ ; odds ratio = 0.476). Farmers' decisions to sell their livestock as a form of climate change adaptation were also negatively impacted by the age and farming experience of the household heads. This implied that because of the cultural significance of livestock, older respondents were valued more highly than younger respondents for their livestock. Male farmers had a 1.492 times higher likelihood of adapting to climate change than their female counterparts. In comparison to those who had not attended any formal education at all, respondents who had attended formal education were 1.387 times more probable to sell their livestock as a response to climate change adaptation.

#### Factors influenced farmers to practice improved mixed farming as a strategy for climate change adaptation

Table 10 below shows issues that influenced farmers' decisions to practice improved farming as a response to climate change. According to the likelihood test (chi-square statistics), the model's performance in making predictions is significant with ( $X^2 = 100.620$ ,  $df = 6$ , and  $p = 0.000$ ). The outcomes of the binary logistic regression model demonstrated that, among the explanatory variables, farm experience and access to extension services significantly and positively influenced the farmers' choice to practice improved mixed farming as a response to climate change with (coefficient = 0.228,  $p = .000$ ; odds ratio = 1.256) and (coefficient = 2.657,  $p = .000$ ; odds ratio = 14.258), respectively. The adoption of improved mixed farming was significantly and negatively impacted by the age of the farmers with (coefficient = −0.164,  $p = .000$ ; odds ratio = 0.849). This suggested that younger farmers would be 0.849 times more probable than older farmers to engage in improved mixed farming. This might be due to the fact that younger farmers were exposed to different climate information than their elderly counterparts, and that the latter were less receptive than the former. Farmers who received formal education were 2.277 times more likely to practice improved farming than farmers who did not receive formal education. Farmers with market access were 1.014 times more likely to adopt improved farming than farmers with no or limited market access. This meant that farmers who had access to the market were more likely to receive superior agricultural technologies than those who did not.

**Table 10**

Binary logistic regression for predictors of improved mixed farming practice.

Variables	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	−0.164	0.035	21.711	0.000*	0.849	0.793	0.910
Sex (1)	−0.054	0.733	0.006	0.941	0.947	0.225	3.986
Education (1)	0.823	0.526	2.442	0.118	2.277	0.811	6.389
Farm experience	0.228	0.042	29.420	0.000*	1.256	1.156	1.363
Access to market (1)	0.014	0.362	0.001	0.970	1.014	0.499	2.060
Access to extension (1)	2.657	0.543	23.955	0.000*	14.258	4.920	41.326
Constant	2.684	1.155	5.403	0.020	14.642		



**Table 11**

Binary logistic regression for predictors of soil and water conservation practices.

	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	0.023	0.023	1.003	0.317	1.024	0.978	1.072
Sex (1)	0.037	0.691	0.003	0.958	1.037	0.268	4.022
Education (1)	−0.038	0.304	0.016	0.901	0.963	0.531	1.746
Farm experience	−0.014	0.025	0.296	0.587	0.986	0.938	1.037
Access to market (1)	0.581	0.239	5.930	0.015*	1.788	1.120	2.855
Access to extension (1)	−0.679	0.225	9.130	0.003*	0.507	0.327	0.788
Constant	−0.006	0.932	0.000	0.995	0.994		

**Table 12**

Binary logistic regression for predictors of decision to practice improved crop variety.

	B	S.E.	Wald	Sig.	Exp(B)	95 % C.I. for EXP(B)	
						Lower	Upper
Age	0.059	0.025	5.570	0.018	1.061	1.010	1.115
Sex (1)	0.188	0.631	0.088	0.766	1.206	0.350	4.156
Education (1)	0.298	0.345	0.746	0.388	1.347	0.685	2.647
Farm experience	−0.098	0.029	11.366	0.001	0.907	0.857	0.960
Access to market (1)	0.248	0.261	0.903	0.342	1.282	0.768	2.139
Access to extension (1)	−1.662	0.261	40.425	0.000	0.190	0.114	0.317
Constant	−0.582	1.000	0.339	0.561	0.559		

*Factors affecting soil and water conservation for climate change adaptation*

A summary of the factors influencing farmers' decisions to employ soil and water conservation techniques can be found in Table 11 below. The likelihood test (chi-square statistics) revealed that the model has a significant prediction performance to use with ( $X^2 = 20.617$ ,  $df = 6$ , and  $p = 0.002$ ). According to the findings of the binary logistic regression model, farmers' decisions regarding soil and water conservation practices in response to climate change adaptation were positively and significantly ( $p < 0.05$ ) influenced by access to the market. The decision-making of respondents regarding soil and water conservation practices was negatively and significantly influenced by their access to extension services (coefficient =  $-0.679$ ,  $p = .003$ ; odds ratio =  $0.507$ ). Additionally, farmers' decisions regarding soil and water conservation practices were negatively impacted by their farm experience (coefficient =  $-0.014$ ,  $p = .587$ ; odds ratio =  $0.986$ ). Comparing male and female farmers, male farmers were 1.037 times more likely to practice soil and water conservation as a form of climate change adaptation. In comparison to younger farmers, older farmers were 1.024 times more probable to practice soil and water conservation. The farmers' educational background and farm experience had a negative impact on their choice to practice soil and water conservation. This meant that farmers with less farm experience and less formal education were more likely to pursue soil and water conservation.

*Factors influencing farmers to practice improved crop variety to adapt to climate change*

The factors that influence farmers' choices of improved crop varieties are compiled in Table 12 below. The likelihood test (chi-square statistics) revealed that the model has a significant prediction performance to use with ( $X^2 = 79.577$ ,  $df = 6$ ,  $p = 0.000$ ). The study found that farmers' decisions to use improved crop varieties as a response to climate change adaptation were positively and considerably ( $p < 0.05$ ) influenced by the respondents' ages with (coefficient =  $0.059$ ,  $p = .018$ ; odds ratio =  $1.061$ ). Farmers' decision to practice improved crop variety was negatively and strongly influenced by respondents' farm experience and access to extension services with (coefficient =  $-0.098$ ,  $p = .001$ ; odds ratio =  $0.907$ ) and (coefficient =  $-1.662$ ,  $p = .000$ ; odds ratio =  $0.190$ ) respectively.

Farmers' decision to practice enhanced crop variety was positively influenced by access to formal education with (coefficient =  $0.298$ ,  $p = .388$ ; odds ratio =  $1.347$ ). Farmers who had access to the market were

1.282 times more likely than those who did not to use improved crop varieties in response to climate change. Improved crop varieties were used by older farmers 1.061 times more frequently than by younger farmers. In response to climate change, male farmers were 1.206 times more probable than female farmers to use improved crop varieties.

**Conclusions**

The study examined stallholder farmers' strategies for adapting to climate change, as well as the obstacles they faced and the variables that affected those decisions. The findings showed that farmers encountered numerous difficulties in their attempts to adapt to climate change. The main obstacles were the inability to find non-farm employment, the high cost of farm labor and inputs, and their reliance on rain-fed sustenance farming, which is very vulnerable to climate change. As opposed to improved adaptation technologies, the majority of farmers had more experience and confidence in indigenous adaptation strategies like reducing food consumption, reducing social and religious rituals, and growing a variety of crops (local varieties). They resisted using more advanced adaptation technologies due to access issues and the associated expense. The outcome of the binary logistic regression model showed that access to extension services by farmers had a positive and significant influence on their methods of coping with climate change, in comparison to other explanatory factors. This demonstrated that farmers' capability to adjust to climate change was positively impacted by the presence of development agents nearby in rural areas. Based on its main conclusions, the study recommends that farmers be assisted in adapting to the changing climate and for the sustainable production of food crops by reducing the challenges of climate change they face and by lowering the cost and increasing the accessibility of farm inputs.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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