Research Article

Socio-economic and Institutional Determinants of Farmers' Adaptation Strategies to Climate Change and Variability in Sidama Region, Ethiopia

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Abstract

The fact that climate has been changing in the past and continues to change in the future implies the need to understand how farmers perceive climate change and adapt to guide strategies for adaptation. This study aimed to identify determinant factors that influence farmers' choice of adaptation in response to climate change. Multi-stage sampling techniques were used to select the study area purposely and systematic sampling to select 149 households. Primary and secondary data collection methods were used. descriptive statistics and multivariate probit model were used to analyze quantitative data. To detect the trend of climate change and variability, Mann-Kendall's trend test was used as a tool. The result shows that annual and 'belg' rainfall show a statistically significant decline trend ($p<0.05$) whereas both minimum and maximum temperature indicate significantly increasing trend ($p<0.001$). Multivariate probit model shows that the major climate change adaptation strategies in the study area include soil and water conservation, planting trees, use of improved crops and livestock varieties and use of crop diversification were 77.8%, 70.4%, 61.03% and 50.3%, respectively. The joint probability of using all adaptation strategies was 42.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. Multivariate probit model revealed that the household head age, family size, educational level, farm income, off/non-farm income, tropical livestock unit, access to extension and access to climate information were among the significant determinants of choice of climate change adaptation strategies. Government policies should be initiated to improve household income, literacy status, access to extension services, credit, and information, that would enhance and diversify farmers' knowledge of climate change to improve their adaptation strategies.

Keywords: Adaptation; Climate change; Multivariate probit model

1. Introduction

Scientific evidence indicates that the earth's climate is rapidly changing, owing to increases in greenhouse gas emissions (Stern, 2008; IPCC, 2014). The increased concentration of greenhouse gases has raised the average temperature and altered the amount and distribution of rainfall globally (IPCC, 2007, 2014). There are growing facts that extreme events, such as droughts and floods, have been common incidences (IPCC, 2014). Sub-Saharan Africa is expected to experience decreased precipitation and increased temperatures in future predicted climate scenarios, which will cause production instability amongst small-scale farmers. With rain-fed agriculture being the most practiced form of agriculture in sub-Saharan Africa, variations and changes in temperature and

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rainfall will pose a serious problem to the mostly agriculture-reliant economies of this region.

According to the Inter-Governmental Panel on Climate Change (IPCC), vulnerability to climate variability and change is a function of exposure to extreme climate events, sensitivity to the events and adaptive capacity of the affected community (IPCC, 2007). The high vulnerability of these small-scale farmers completely wears away their resilience when faced with an increasingly variable and changing climate (FAO, 2010). The amount and seasonal distribution of rain vary annually and are difficult to predict, while the temporal distribution of rainfall during the growing season is an important factor influencing crop yield. Rains can be delayed by several weeks or stopped during critical germination periods, leading to short and long-term droughts with crop failures, food shortages and famines (Abebe, 2007). Increasing temperature and rainfall variability in different parts of Ethiopia adversely influence the agricultural production of smallholder farmers.

To minimize the shock of climate change on smallholder farmers' adaptation strategy is an essential instrument. The main significant points such as social, economic, technological, and environmental trends enable smallholder farmers to perceive and adapt to climate change (Temesgen *et al.,* 2009). In addition, knowledge of the adaptation method and determinants of farmers' choice of adaptation strategies are enhancing efforts directly towards tackling the impact of climate change. Micro-level studies at the farm level on how rural farmers perceive these changes and how they are responding to the effects of a changing climate are limited in the study area. The objective of this study was to assess socioeconomic and institutional factors (age, gender, education, household size, farming experience, off/non-farm income, extension service, access to credit facilities, etc) that influence smallholder farmers' adaptation strategies to climate change in Loka Abaya woreda Sidama Region

2. Empirical Literature on the Determinants of Farmers' Adaptation Strategies to Climate Change

In three Tigrai districts in northern Ethiopia, a study by (Tagel, 2013) used a multinomial logit model to examine how farmers perceived climate change and what factors influenced their decision to choose adaptation strategies. The findings showed that a farmer's choice of adaptation is influenced by a variety of factors, including education level, age, and wealth of the household's head, access to credit for agricultural services, and climate information. Additionally, the main barriers preventing adaptation to climate change are a lack of information about adaptation strategies and finance.

The finding of Belaineh *et al*. (2013) in a similar study in Doba district, western Hararghe, Ethiopia, found that agro-ecological location, sex, family size, plot size, off-farm income, livestock holding, frequency of extension contact, and training are the determinant of factors influencing adaptation strategies. The study also identified crop diversification, the use of soil and water conservation techniques, integrated crop, and livestock diversification, participating in off-farm income activities, and rainwater harvesting as common adaptation strategies.

According to Asrat and Simane (2018), the use of improved crop varieties, agroforestry practices, soil conservation practices, irrigation practices, and adjusting planting dates are the most important adaptation strategies by smallholder farmers. However, adaptation decision is location-specific and influenced by key drivers such as socioeconomic, environmental, and institutional factors.

3. **Materials and methods**

3.1 Description of the area

The study was carried out in Loka Abaya woreda at the western border of the Sidama region located about 62 km southwest of Hawassa and 337 km from Addis Ababa. The woreda is situated at 6°26'0″- 6°48'0″N latitude and 37°59'0″- 38°21'0″ E longitude (Figure 1). The total area is 1,190 km^2 and it represents moist *kol*a agroecology in Sidama region with altitude ranging from 1170 up to 1500 meters above sea level (m.a.s.l.). Annual rainfall for Loka Abaya ranges between 670-1050 mm and the temperature ranges from 26–33 ^{0}C (USAID, 2005). According to the projected population by CSA (2019), the total population of the woreda is 123,705, of which 63,107 are male and 60,598 are female. Mixed crop-livestock is the main farming system in the woreda.

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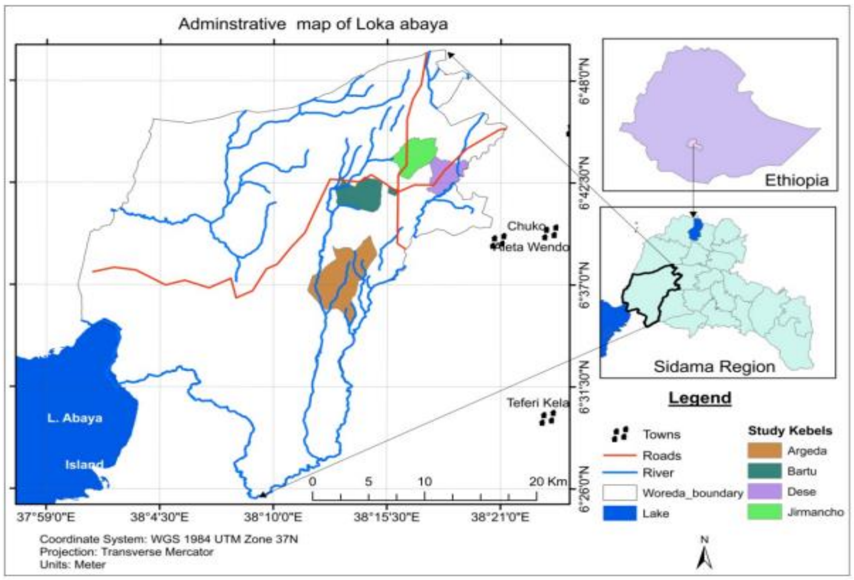

Figure 1. Map of the study area, Loka Abaya woreda

3.2 Data collection method

To meet the objectives of the study, both primary and secondary data were collected and utilized by employing qualitative and quantitative methods. This study employed a multi-stage sampling procedure. In the first stage, Loka Abaya woreda was selected purposely because it is the most climate change-affected area in the Sidama region. In the second stage, four kebeles were selected randomly out of the total 26 rural kebeles in the woreda since the kebeles are in a relatively similar agroecological zone (almost lowland kebeles); characterized by hot conditions and experienced climate-induced risks (USAID, 2005). In the third stage, about 149 sample households were selected using a systematic random sampling technique (Israel, 1992).

$$n=N/1+N\ (e)^2$$

This study was based on a cross-sectional household survey, consisting of 149 sample households. It was the collection of data mainly using questionnaires to capture quantitative or qualitative data at a single point in time. Qualitative data from 10 key informant interviews and 4 focus group discussions were transcribed, categorized, looked for relationships and interpreted.

3.3 Methods of Data Analysis

Quantitative data was entered into Statistical Package for Social Sciences (SPSS) 20.0 version. This kind of data was analyzed using descriptive statistical methods such as frequency, percentage, tables and mean with the help of Microsoft Excel. A multivariate probit model was used to explain the different determinants of the sample respondent households with STATA version 14.4.

Mann-Kendall Trend Test

The Mann-Kendall statistical test was used to analyse the monthly, seasonal and annual rainfall and temperature data trends at 0.1%, 1% and 5% level of significance. Climate data trend analysis determines whether the measured values of a variable increase or decrease during the period. As recent study indicates that the most widely used method is the non-parametric Mann-Kendall test (Mann, 1945).

The Mann-Kendall test statistic(S) is calculated according to:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sgn\left(x_{j-x_i}\right)$$

Where: N the is number of data points. Assuming$\left(x_{j-x_i}\right)$ = θ, the value of sgn (θ) is computed as follows:

$$\mathrm{Sgn}(\theta) \begin{cases} 1 & \text{if } \theta > 1 \\ 0 & \text{if } \theta = 1 \\ -1 & \text{if } \theta < 1 \end{cases} \quad i$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal distribution with the mean and the variance as follows: E[S] = 0

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{K=1}^{n} t_k(t_{k-1})(2t_{k+5})}{18}$$

Where: n is the number of tied (zero difference between compared values) groups and t_k is the number of data points in the k^{th} tied group.

Econometric Model Specification

The empirical specification of choice decisions over the four categories of climate change adaptation can be modeled in two ways, by either multinomial logit regression or multivariate regression analysis. One of the underlying assumptions of multinomial logit regression models is the independence of irrelevant alternatives that is error terms of the choice equations are mutually exclusive (Surabhi and Mamta, 2015). However, the choices among the adaptation strategies are not mutually exclusive as farmers are using more than one adaptation strategy at the same time and therefore the random error components of the adaptation choice may be correlated. So, using a multivariate probit model allows for the possible at the same time correlation in the choice to access the four different adaptation strategies simultaneously. Addressing the correlations of the error terms among unobserved adaptation choices, the multivariate model ensures statistical efficiency in the estimations of available choices (Lin *et al.* 2005). Empirically the model can be specified as follows:

$$Y_{ij} = \begin{cases} 1 \\ 0 \end{cases} \text{if } Y^*_{ij} > 0 \text{ otherwise}$$

Where i = farmer ID, Yi1 = 1, if the farmer uses soil and water conservation practice (0 otherwise), Yi2 = 1, if the farmer uses improved crop and livestock varieties (0 otherwise), Yi3=1, if the farmer uses crop diversification (0 otherwise), Yi4 = 1 if the farmer uses planting trees (0 otherwise) and *n* is the number of observations. The hypothesis can be tested by running four different independent binary probit or logit models by assuming that error terms are mutually exclusive. However, the decision to use different strategies may be correlated, thus the elements of error terms might experience stochastic dependence. In this situation, a multivariate probit model of the following form is used to test the hypothesis.

$Yij = X\ ij\beta j + \varepsilon_{ij}$

where Yij (j =1… 4) represent the four different adaptation option faced by the i[th] farmer (i=1,…, 1,149), X′ ij is a 1 x k vector of observed variables, $\beta_{1,+}\ \beta_{2\dots}\ \beta_n$ are conformable parameters that affect the adaptation choice decision of farmer βj is a k x 1 vector of unknown parameters (to be estimated), and ε_{ij} is the unobserved error term, $\varepsilon_{1,}\ \varepsilon_{1\dots}\ \varepsilon_n$ are distributed as multivariate normal distribution with zero means. The unknown parameters in Equation (2) are estimated using simulated maximum likelihood.

4. Results and discussion

4.1 Demographic and Socio-economic Characteristics of Respondent

For this study, primary data were collected from a total of 149 sampled households. Out of the total sample households surveyed, 82.6% were male-headed and 17.4% were female-headed. This result indicated that the majority of respondents in the study area were male. Out of the total sample HHs, the majority 85.9% were married and 7.4% were single. Regarding the education status, 45.6% of the respondents did not attend school while 4% of the respondents were college or university graduates. Most respondents (74.5%) have farm experience between 11-30yrs. Concerning landholding, the majority of respondents (60%) owned land size of < 1 ha and 9.4% owned > 2 ha (Table 1).

Table 1. Distribution of respondents by their socioeconomic characteristics in the study area

Variables	Frequency	Percent
Gender		
Male	123	82.6
Female	26	17.4
Marital status of household		
Single	11	7.4
Married	128	85.9
Divorced	4	2.7
Widowed	6	4.0
Educational level of household		
Cannot read and write	68	45.6
Primary school	53	35.6
Secondary school	22	14.8
College and university	6	4
Farm experience of household		
5-10yrs	17	11.1
11-20yrs	62	41.6
21-30yrs	49	32.9
Above 31yrs	21	14.1
Farmland size in hectares		
<0.5ha	44	29.5
0.5-1ha	46	30.9
1-1.5ha	29	19.5
1.5-2ha	16	10.7
Above 2ha	14	9.4

The mean age of the household heads was 44.09 years with a maximum of 65 and 28 years as a minimum (Table 2). This suggests that working age or active labor dominates farming activities indicating the potential for implementation of climate change adaptation practices. Farmers in the study area are engaged in mixed farming activities, including crops like chat, and coffee, and rearing of domestic animals such as cows, oxen, goats, sheep and chickens. Moreover, the survey result revealed that the mean livestock holding of the sampled households in terms of tropical livestock unit (TLU) was 4.47, and minimum and maximum values range from 0 to 16.37 TLU, respectively (Table 2). Farm income of the surveyed households ranges from 0 to 113,000.00 birr with an average of 24,488.59 birr per annum. Major sources of income in the study area are on-farm activities mainly from the sale of crops, sales of livestock and livestock products (milk and butter). Regarding this, maize, chat, coffee, and haricot beans are the most common sources of on-farm income in the study area. Non-farm income refers to non-agricultural income sources, either in secondary and tertiary sectors (Barrett *et al.*, 2001). Non-farm activities relate to all other activities that are not related to crop and livestock production, e.g., petty trading in non-agricultural activities, barbering, building construction, etc (Kankam-Boadu,2023). Surveyed farmers' income from off/non-farm activities ranged from 0 to 16,200.00 birr with an average of 4,209.73 birr per annum (Table 2). On the other hand, petty trading, daily labor, handcraft, remittance, and government/NGO aid are sources of off-farm income for some of the sample households. The survey data indicated that the household size of the sampled households varies from 1 to 12 with an average household size of 5.27, which is higher than the national average family size of 4.93 (CSA, 2007). The mean distance from the market center of the sample households at the time of the survey was about 7.23 km. Market access minimizes risks that occur due to the distance for transporting agricultural inputs and their production.

Table 2. Distribution of socio-economic characteristics of respondents

Variable	Minimum	Maximum	Mean	Std. Deviation
Age of household	28	65	44.0940	7.99691
Household size	1	12	5.2752	2.01300
On-farm income	0	113,000	24,488.59	29,432.97
Off/non-farm income	0	16,200	4,209.73	5,465.67
Livestock (TLU)	0	16.37	4.4753	4.23739
Distance of market (km)	4	10	7.2315	2.19299

4.2 Climate Data Analysis

4.2.1 Changes in the rainfall and temperature in Loka Abaya woreda

Climate is determined by rainfall, temperature, wind, and clouds. However, temperature and precipitation are major elements of weather. The rainfall and temperature data of the one station were obtained from Ethiopia Meteorological Agency for the aim of this study (1990-2019).

4.2.2 Annual and seasonal rainfall variability

The coefficient of variation is used to classify the degree of variability of rainfall events into three less (CV < 20), moderate (20 < CV < 30) and high (CV > 30) inter-annual variability of rainfall (Asfaw *et al.*, 2018). The data obtained from Ethiopia Meteorological Agency revealed that the coefficients of study area were 28.16, 31.04 and 21.57 for *kiremt* (local in *Hawado)*, *belg* (local in *Badheessa)* and annual rainfall, respectively, which indicate that there was moderate to high inter-annual variability of rainfall between 1990-2019 (Table 3). The degree of variation in the amount of rainfall for *kiremt* season is less than *belg* (Table 3). The finding is consistent with Kassie (2014), who reported moderate to high concentrations of rainfall in the Central Rift Valley of Ethiopia. Besides, the year-to-year of *belg* rainfall variability over the study area is high compared to the year-to-year variability of annual and *kiremt* rainfall.

Table 3. Descriptive statistics of seasonal and annual rainfall for the period 1990–2019

Parameters	*Kiremt*	*Belg*	Annual
Maximum rainfall	574.30	601.10	1309.6
Minimum rainfall	107.66	139.40	406.3
Average	376.22	379.71	949.16
SD	107.66	117.89	204.80
CV %	28.61	31.04	21.57

4.2.3 Annual and seasonal rainfall trend analysis

The annual rainfall in Loka Abaya woreda over the past 30 years decreased by about 11.9 mm annually (Figure 2). This is also confirmed by the respondents on the trend of rainfall. According to the data obtained from the National Meteorological Agency, the *kiremt* rainfall in the study area decreased by 1.69 mm. The trend line shows that about sixteen years of rainfall amount is below average and fourteen years the amount of *kiremt* rainfall is above the average. In general, it is believed that within these sixteen years, there was less amount of rainfall than the other fourteen years within thirty years. This result is in line with Getenet (2013) who confirmed decreasing trends. of rainfall volume in western and eastern arid and semi-arid areas of the country. The *belg* rainfall in Loka Abaya woreda over the past 30 years decreased by 6.76 mm (Figure 2). More than sixteen months have shown below average *belg* rainfall in the study area.

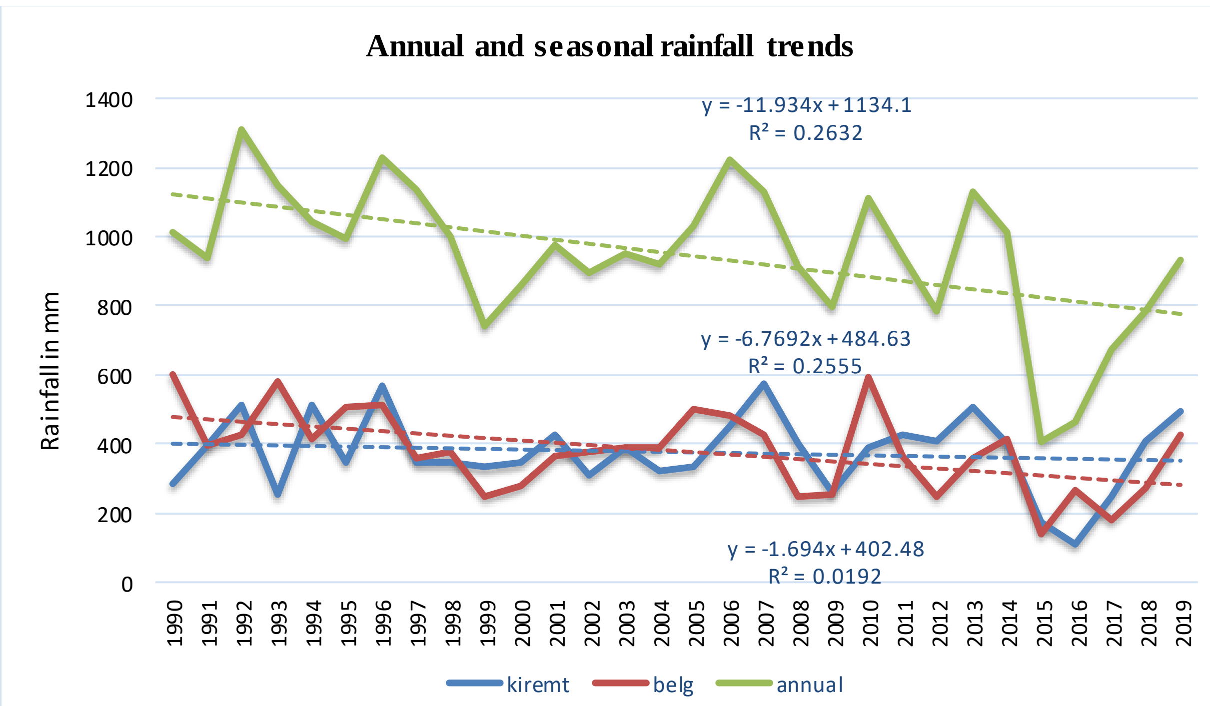

Figure 2. Trends of annual and seasonal rainfall variability in the study area.

4.2.4 Annual and seasonal Mann-Kendall trend test of rainfall analysis

According to the Mann–Kendall trend test, seasonal trend analysis results showed significant decreasing trend of *belg* rainfall at α=0.05 significant level. The Sen's slope estimator indicated that the *belg* rainfall decreased by 6.63 mm per season (Table 4). Generally, the most important rainfall season in the study is *belg*, which showed a tendency of decreasing trends for the period 1990-2019 but not in *kiremt*. The result agrees with the findings of (Nater, 2010; Jury and Funk, 2013;) who indicated decreasing trends of spring season rainfall in Ethiopia. The annual rainfall trend also showed significant decreasing trend at α=0.001 and rainfall decreased by 10.17 mm per year. Annual and seasonal rainfall at Loka Abaya generally exhibited a slight decline over 1990-2019. From the Mann-Kendall trend test, annual rainfall and *belg* season rainfall in Loka Abaya woreda were significantly decreasing. The result is inconsistent with (Eshetu *et al.*, 2016), which pointed out that a non-significant trend in annual and seasonal rainfall was reported in in high rainfall area of southwestern Ethiopia. The outcomes FGD and key informant interviews also revealed that rainfall amount, particularly the *belg* rains, is declining and the distribution has been erratic (for details see the section on farmers' perception on climate change and variability). On the other hand, the *kiremt* rainfall indicated a non-significant increase. In all, such seasonal and inter-annual variability in rainfall amount could negatively affect the ability of farmers to mitigate the effects of climate change and variability (Ayalew *et al.*, 2012).

Table 4. Mann-Kendall results of seasonal and annual rainfall

Parameters	*Kiremt*	*Belg*	Annual
Mann-Kendall	0.04	-2.46*	-2.64***
Sen's Slope	0.140	-6.633	-10.178

*** 0.001 significance level, *0.05 significance level

4.2.5 Trends of temperature in the study area (1990-2019)

The average yearly maximum temperature of the woreda was 25.35 °C, while the average minimum temperature was 12.4 °C. As indicated in Figure 3, the maximum temperature of Loka Abaya woreda over the past 30 years increased by about 0.064 °C annually. This result is in line with the survey results of respondents regarding the increment in temperature over the past thirty years.

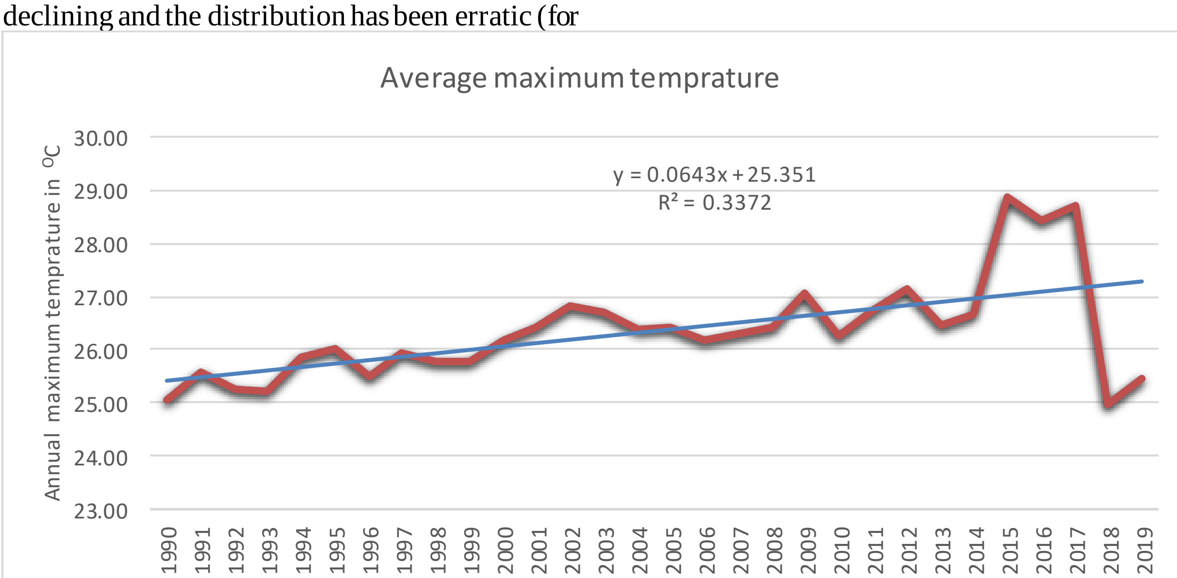

Figure 3. Trend of maximum temperature

The trend analysis of the meteorological data record of temperature for the period (1990-2019) also showed that increasing trend in yearly minimum temperature over the past thirty years. Figure 4 indicates that the average annual minimum temperature increased by 0.04 ^{0}C per year.

4.2.6 Annual Mann-Kendall trend test of maximum and minimum temperature

The Mann-Kendall test showed that a significant increasing trend of annual mean maximum temperatures was observed at 0.069 °C per year (Table 5). This result is in line with the finding of Fenta (2017) who reported an increasing trend of annual maximum temperatures at Amibara and Gewane districts in the Afar region, Ethiopia. The annual mean minimum temperature also indicates an increasing trend at a rate of 0.062°C per year. This result exceeds the findings reported by NMSA (2001) which showed that the mean annual minimum temperature in Ethiopia increased by 0.025 °C per year. Hence, the study area was warming at a faster rate than the country's warming trend. Furthermore, according to studies in Ethiopia, it is assumed that the temperature has been increasing annually at the rate of 0.2 °C over the past five decades (Yohannes *et al.*, 2009). Table 5 indicates that the annual minimum temperature increased by 0.062 ^{0}C per year.

4.3 Farmers' Perception on Climate Change and Variability

Climate change will bring about substantial welfare losses especially for smallholders whose main source of livelihood derives from agriculture (Asrat and Belay, 2018). Despite the policy provisions and institutional (re)arrangements, climate change-induced impacts have been undermining the national economic performance and the country's endeavor to reduce poverty (Echeverría and Terton, 2016). The households were asked whether they have perceived changes and variability of climate mainly in terms of rainfall and temperature in the study area. Accordingly, 79.9% of the respondents perceived a changing

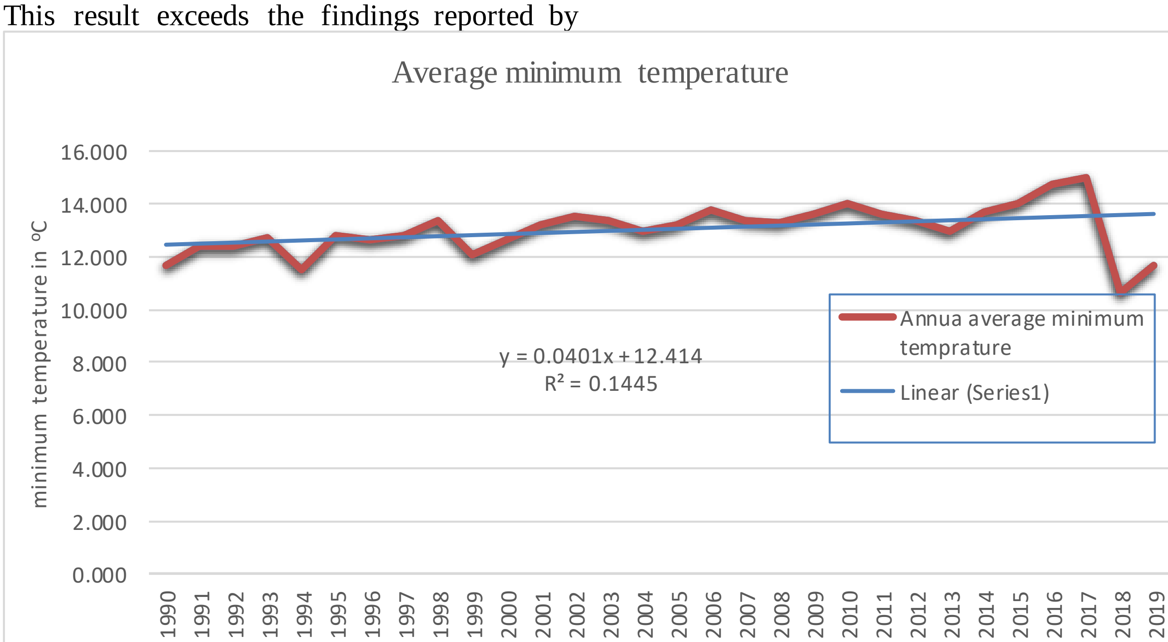

Figure 4. Trend of minimum temperature

climate, 11.4% have not noticed any changes and 8.7% don't know whether there is a change in the climate or not. Addison (2006) confirmed that understanding the local people's perception on climate change and variability is important to designing appropriate adaptation and coping strategies for many poor countries that are highly vulnerable to the impact of climate change and variability is important to designing appropriate adaptation and coping strategies for many poor countries that are highly vulnerable to the impact of climate change and variability. About 81.7% of the respondents perceived an increase in temperature while only 9% noticed the contrary or decrease in temperature 8.7% noticed no observable change and 3.4% of the respondents did not perceive any temperature change. This result is similar to Deressa *et al*. (2008), who indicated that the majority of farmers in Ethiopia are aware of climate change and perceive an increased temperature. The FGD participants and interviews with key informants also confirmed the presence of increased temperature during recent periods to recent past. As the survey indicated, 65.1% said that rainfall decreased, 12.8% increased, 20.8% fluctuated and 2.3% did not perceive the change (Table 6). Thus, the result of this study indicated that farmers' perception was in line with the meteorological data analysis.

Table 5. Annual Mann-Kendall results of maximum and minimum temperature for 1990-2019

Parameters	Mann-Kendall	significance	Sen's slope
maximum temperature	3.96	***	0.069
Minimum temperature	3.62	***	0.062

NMA, Ethiopia (2019); *** = 0.001 level of significance

Table 6. Pattern of perceived temperature, and rainfall in the study area

Variable	Frequency	Percent
How do you perceive climate change in your district?		
Changed	119	79.9
Not changed	17	11.4
Don't know	13	8.7
Pattern of temperature		
Increasing	122	81.7
Decreasing	6	9
No observable change	13	8.7
I don't know	5	3.4
Pattern of rainfall		
Increasing	19	12.8
Decreasing	97	65.1
Fluctuating	31	20.8
I don't know	2	2.3

4.4 Climate Change Adaptation Strategies

Soil and water conservation:

In addition to reducing soil erosion and runoff, soil and water conservation practices help keep nutrients on the field. Physical and biological soil and water conservation measures increase water-use efficiency (increasing soil moisture by reducing the speed of the runoff and using water harvesting structures which is useful in drier areas) and protect water quality. Surface residue and plant cover improve soil carbon concentration and provide additional environmental benefits. Considering the magnitude of the moisture stress in the woreda, soil and water conservation techniques are widely adopted by farmers. Out of the total sampled households, 77.8% used soil and water conservation as an adaptation strategy to reduce the adverse effect of climate change on farm productivity. According to focus group discussions, soil and water conservation practice includes soil erosion protection, management, and care of the soil in order to make it suitable for their crops, conservation of rainwater for watering the crops in times of too little rain, groundwater harvesting and agro-forestry to reduce soil loss from farm plots, preserving critical nutrients and increasing crop yields. The result is similar to Tibebu *et al.* (2018) who assessed soil erosion control efficiency of land management practices implemented through free community labor mobilization in systematically selected watersheds of Ethiopia.

Planting trees: Through photosynthesis, trees absorb and store atmospheric carbon dioxide (CO2), making them natural carbon capture and storage devices. For this reason, tree planting is frequently praised as an important solution to climate change. In the study area, planting trees on bare and eroded land is one of the best adaptation options in combination with other options. About 70.4% of respondents prefer and used planting trees for own uses and as adaptation option to reduce the negative effect of climate change. Discussion of focus group emphasized that planting trees is recognized as farmers believe that planting trees can attract rainfall and can increase water retention by reducing runoff. The other scenario is that trees provide natural shade for their livestock when the temperature is hot. Temesgen *et al.* (2009) identified tree planting to be one of the major methods used by farmers to adapt to climate change in the Nile Basin of Ethiopia

Improved crop and livestock varieties: Improved crop varieties in the context of climate change adaptation offer higher and more stable yields, increased tolerance or resistance to pests, diseases, drought, heat, and other stress factors, and therefore strengthen the resilience of rural farmers to climate change. Improved crop varieties were used as adaptation options in combination with other options and about 61.03% of respondents used them to reduce the negative effects of climate change. The farmers are practicing mixed farming that is crop and animal husbandry. During the focus group discussion farmers indicated the criteria for selecting to use improved crop variety which has different qualities that help to adapt to the changing climate such as productive, early maturing variety, disease and pest resistance and crops that have more product for their livestock feed. Yield performance, yield stability and drought tolerance are particularly important variety properties (Macholdt and Honermeie, 2016). Key informant interviews said that the government is supplying improved varieties of crops, livestock, and inorganic fertilizer to cope with the adverse effects of climate change.

Crop diversification: Crop diversification is the practice of cultivating more than one variety of crops belonging to the same or different species in a given area in the form of rotations and or intercropping and enhances crop productivity and consequently resilience in rural smallholder farming systems (Makate *et al.*, 2016). Crop diversification (mixed cropping, intercropping) is a common practice in the study area. The system is commonly practiced in the woreda where cereals (maize), legumes (haricot beans, soybeans) and vegetables (pepper) are grown together. From Focus Group Discussions made with farmers, it was noted that they have a wide knowledge of the advantages of mixing crops with varying attributes in terms of maturity period, drought resistance, input requirements and end use of the product. Of the total sampled households, 50.3% use crop diversification as adaptation strategy to reduce the adverse effect of climate change on farm productivity (Table 7). This is why Michler and Josephson (2017) revealed that crop diversification is the best strategy for households as a source of income, risk reduction, and poverty alleviation. As an adaptation option, it is used to cope with the hostile effects of climate change.

Table 7. Summary of common adaptation strategies used by farmers in the study area.

Adaptation strategies	Frequency	Percent	Ranking
Soil and water conservation	116	77.8	1st
Planting tree	105	70.4	2nd
improved crop and livestock varieties	91	61	3rd
Crop diversification	75	50.3	4th

4.5 Determinants of Farmers' Choice of Adaptation Strategies

Results from the multivariate probit model of determinants of choice adaptation measures using data from a cross-sectional survey of 149 sample households are presented in Table 8. The correlation coefficients are statistically different from zero in 3 of the 6 cases, confirming the appropriateness of the multivariate probit specification and choice of climate change adaptation strategies are not mutually independent. The results on correlation coefficients of the error terms indicate that there is complementarity (positive correlation) and substitutability (negative correlation) between the two adaptation options being used by farmers. Multicollinearity was tested by using the variance inflation factor (VIF), so the mean value of 1.89 proved the absence of multicollinearity between covariates. The result of multivariate probit model shows that the likelihood of households adopting soil and water conservation, planting trees, using improved crop and livestock varieties and crop diversification were 77.8%, 70.4%, 61.03% and 50.3% respectively. The result also shows that the joint probability of using all adaptation strategies was 42.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. This implies that most farmers in study areas used more than one adaptation choice to minimize the adverse effect of climate change.

The simulated maximum likelihood (SML) estimation results suggested that there was positive and significant interdependence between household decisions to use soil and water conservation and using the improved crop and livestock varieties, soil and water conservation and planting trees, using improved crop and livestock varieties, and crop diversification.

Age of household head: The age of the household head is a key variable affecting adaptation decisions at the farm level. The age of the household head is usually taken as a proxy for experience with farming. A farmer's age may influence adoption in one of several ways. The direction of influence is not, however, very clear and there are always mixed results from empirical analysis (Admassie and Ayele, 2010). In this study, an increase in the age of a household head was positive and significantly increased the use of improved crop and livestock varieties as an adaptation strategy to reduce the impact of climate change. This result is also consistent with the findings of (Aemro *et al.*, 2012; Taruvinga *et al*., 2016). Contrary to the findings of this study, the age of the household head is negatively related with the implementation of adaptation measures indicating that older farmers are less likely to change their farming system in response to perceived climate change (Waibel et al. 2018).

Educational level: The education level of the farmer increases the probability of uptake of adaptation options to climate change. As can be observed in Table 8, education level significantly increases improved livestock and crop varieties as an adaptation method in the study area. Moreover, the coefficient of improved crop and livestock varieties is positive indicating a positive relationship between education and improved crop and livestock varieties as adaptation methods to climate change. This result is consistent with findings by (Getachew *et al.*, 2014; Seid *et al.,* 2016).

Household size: The model result shows that family size has positive and significant impact on the likelihood of improved crop and livestock varieties as adaptation strategy to reduce the negative impact of climate change. The possible reason is that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks that are labor-intensive. Croppenstedt *et al.*, (2003) argue that households with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages. Nonetheless, family size has negative and significant effects on the likelihood of soil and water conservation practices as adaptation strategies to reduce the negative effects of climate change. The reason is that soil and water conservation practices require more labor. This could be as households with large families from this study area migrate to urban areas (Addis Abeba) to engage in non-farm activities to earn income and ease the consumption pressure imposed by a large family. This result is consistent with the findings of (Gbetibouo, 2009; Belaineh *et al.*, 2013 and Taruvinga *et al.*, 2016).

On-farm income: It has a positive and significant impact on soil and water conservation practices and planting trees as an adaptation strategy. Higher farm income significantly increased the probability of conducting measures such as soil and water conservation and planting trees. In addition to this, higher income allows farmers to adopt measures, especially soil and water conservation are expensive and probably more effective responses to climate change. Furthermore, income is normally found to contribute positively to the adaptation of agricultural technologies. This result is consistent with (Deressa *et al.,* 2009; Temesgen *et al.*, 2008).

Off/non-farm income: The term off/non-farm refers to economic activities that are not directly related to agricultural activities. For instance, handicrafts, spinning of cotton or wool, cloth weaving, pottery, distilling local brews, masonry, blacksmiths, woodwork/carpentry, house construction, petty trade, etc (Tafesse *et al.*, 2015). The result of the model indicates that off/non-farm income significantly and negatively affects the uptake of soil and water conservation and planting trees as adaptation strategies to climate change. However, off/non-farm income is associated with crop diversification significantly and positively. This indicates that when farmers have non/off-farm incomes, they can afford the cost by using fewer practices such as soil and water conservation techniques and can buy improved crop and livestock varieties which increases productivity. On the other hand, off/non-farm income showed a negative relationship with adaptation by using tree planting with other measures. In short words, the existence of non-farm income serves as adaptation measure by itself and may delay other responses. This result is similar to (McNamara *et al.*, 2001) who confirmed that off-farm employment may pose a constraint to adoption of technology because it competes for labor and time needed for on-farm activities. Therefore, in this study, the variable off-farm employment was found to be negatively related to climate change adaptation. The result does not confirm the hypothesis which states that off/non-farm income has a positive influence on the SWC and planting trees and the result contradicts the findings of Aemro *et al*. (2012 and Legesse *et al.* (2013). In general, the probability of engaging in non-farm activities is higher for younger, better-educated, household heads who have better contact with extension agents and who have access to microfinance (Asfaw *et al.*, 2017)

Tropical Livestock Unit (TLU): The result of the model indicates that livestock holding has positive and significant effect on the likelihood of using improved crop and livestock varieties as adaptation strategies. In this case, livestock is considered a source of income for the farmers to purchase improved crop and livestock varieties by providing draft power (like oxen, horses, etc.) and their manure essential for soil fertility maintenance. Similarly, other studies concluded that farmers who have large number of livestock significantly increases the ability and choice of climate change adaptation strategies (Chilot, 2007; Aschalew, 2014; Francis *et al*., 2016).

Access to extension service: Extension visit has significant positive effect on climate change adaptation options like improved crop and livestock varieties. Farmers frequently visited by development agents had a high likelihood of participating in climate change and adaptation. The finding is in line with (Temesgen *et al.*, 2009; Belaineh *et al.*, 2013). Moreover, agricultural extension service is the main source of information concerning agricultural activities and natural resource conservation for farming households (Deressa *et al,* 2010; IPCC, 2014).

Access to climate information: Even though service on climate information delivery is not formal. Access to information from different sources has significantly and positively influenced the adaptation combination of improved crop and livestock varieties. The availability of better climate information helps farmers make comparative decisions among alternative adaptation practices and hence choose the ones that enable them to cope better with climate change. This indicates that the information on weather or climate forecasting increases the likelihood of adaptation to climate change. This finding is consistent with other studies (Baethgen *et al.*, 2003; Jones, 2003; Temesgen *et al*. 2009).

Table 8. Multivariate probit model results for households' choice of adaptation strategies.

Explanatory variables	Soil and water conservation	Improved crop and livestock varieties	Crop diversification	planting trees
	Coef.(St. Err)	Coef. (St. Err)	Coef. (St. Err)	Coef.(St. Err)
Age	-0.022 (-0.045)	0.085** (0.0371)	0.044(0.028)	-0.006 (0.031)
Gender	-0.0525 (0.804)	0.0396 (0.481)	0.707 (0.436)	-0.552 (0.484)
Education level	-0.4002(0.290)	0.5174* (.0.304)	0.125 (0.242)	0.284(0.221)
Household size	-0.418*(0.217)	0.238* (0.141)	0.178(0.123)	-0.016(0.117)
Farm experience	0.346 (0.409)	0.122 (0.359)	-0.331(0.277)	0.185 (0.279)
On farm income	0.000**(0.000)	-0.000 (0.000)	9.28e-06 (0.000)	0.000**(9.04)
Off/non-farm income	-0.0001*(0.000)	0.000(0.000)	0.000***(0.000)	-0.000*(0.000)
Land size	-0.531 (0.333)	0.326 (0.287)	0.017 (0.252)	0.177 (0.222)
TLU	-0.082 (0.086)	0.479**(0.237)	-0.088 (0.077)	-0.056 (0.069)
Distance	-0.068 (0.177)	-0.017 (0.088)	-0.017 (0.088)	-0.086(0.096)
Extension service	-0.038 (0.731)	1.184*** (0.4403)	0.1909 (0.346)	0.551 (0.406)
Climate information	-0.954 (0.626)	0.859* (0.445)	-0.103 (0.381)	0.223(0.391)
Credit	0.267 (0.509)	-0.418(0.379)	-0.167 (0.321)	0.1510 (0.329)
_cons	2.997(3.205)	-5.11** (2.115)	-1.224(1.783)	0.342 (1.872)
Rho21	-0.705** (0.322)			
Rho31	0.216 (0.276)			
Rho41	0.571**(0.238)	-0.171(0.302)		
Rho32			0.116*(0.259)	

Rho42				0.020(0.239)
Rho43				
Predicted probability	0.778	0.740	0.6103	0.503
Joint probability (success)			0. 4226	
Joint probability (failure)			0.0006	
Number of observation			149	
Number of simulation			5	
Waldchi2 (56)			77.16	
Log likelihood			-130.368	
Likelihood ratio test of Rho ij=0, $p>x^2$			0.0017**	

Note: *= p<0.1(10%), **= p<0.05(5%), ***=p<0.01(1%); coif. =coefficient and St. Err=standard error

5. Conclusion and recommendation

Climate change highly affects smallholder farmers' agriculture as the consequence of higher temperature and increased rainfall variability that reduces crop production. A better understanding of the local dimensions of adaptation is, therefore, essential to develop appropriate adaptation measures that tackle the adverse effects of climate change impacts. This study attempted to identify factors affecting the choice of climate change adaptation strategies by farmers. The model allows for the simultaneous identification of the determinants of all adaptation options, thus limiting potential problems of correlation between the error terms. Multivariate probit model displayed that the likelihood of households to adopt soil and water conservation, planting trees, use of improved crop and livestock varieties and crop diversification were 77.8%, 70.4%, 61.03% and 50.3%, respectively. The joint probability of using all adaptation strategies was 62.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. The model also confirms that household size, off/non-farm income and on-farm income have a significant impact on the use of soil and water conservation as climate change adaptation strategy. Likewise, age, educational level, household size, livestock holding, access to extension service and access to climate information significantly affect the use of improved crop and livestock varieties to adapt to climate change. In addition, off/non-farm income significantly influenced practicing crop diversification. Moreover, on-farm income and off/non-farm income significantly affect farmers' use of planting trees to adapt to climate change impacts whereas some variables in the findings such as gender, marital status, farm experience and distance to market were insignificant in this study. Thus, the results of the study provide information to policymakers and extension workers on how to improve farm-level adaptation strategies and identify the determinants for adaptation strategies.

It appears that improving educational status would do most to hasten adaptation and increase households' decision-making regarding the key adaptation strategies. Livestock holding which influences farmers' likelihood of adopting adaptation measures should be harnessed and properly utilized. Building the capacity of agricultural extension systems and making climate change education a priority through Information and Communication Technologies (ICT) innovations is crucial. Improving farm and off/non-farm income-earning opportunities is needed for smallholder farmers. Access to media should be strengthened to ensure accurate information is available and widely distributed.

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