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Maize Farmers' Perceptions of Climate Change and Determinants of Adaptation Decisions in Northern Ethiopia

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Abstract

Rain-based agriculture is highly vulnerable to climate variability and change. Farmers' decisions about how to adapt to climate change are influenced by socioeconomic setups and local institutions. The objectives of this study were to evaluate farmers' perceptions of climate change, identify the local adaptation techniques they used, and pinpoint the major socio-economic challenges they faced when putting those strategies into practice. 250 maize farmers were used as samples for the collection of primary data. Descriptive statistics were used to evaluate the data on socioeconomic characteristics, and the multinomial logistic model was used to identify the factors influencing farmers' decisions to adapt. The majority of households (91.2%) believed that climate change is occurring, and its main symptoms include unpredictable rainfall (88.4%), warming temperatures (83.2%), and more frequent droughts (79.2%). The findings show that farmers' perceptions of rising temperatures and weather data matched; however, there was a discrepancy between perception and rainfall records. Reduced maize yields (78%) and declining soil fertility (83%) were the two biggest effects of climate change perceived by the farmers. Accordingly, 92.8% of farmers have developed their best adaptation, primarily through the combination of crops and livestock (24%) and the adoption of enhanced maize varieties (20.8%). The econometric model's findings showed that the primary variables influencing farmers' decisions were age, gender, education, farm size, animal ownership, and poverty. The study recommends supporting the indigenous adaptation techniques of maize farmers from a variety of institutional, policy, and technological angles, both at the farmer and farm levels.

Keywords: adaptation, climate variability and change, Ethiopia, maize, MNL model, perception, smallholder farmers

1. Introduction

Achieving agriculture's fundamental purpose of feeding the world's population is getting harder and harder due to multiple challenges, with climate change being the greatest problem the world is currently facing (Murtaza *et al*., 2019). The effects of climate variability and change (CVC) are more noticeable in agriculture than in any other sector (Bryant *et al*., 2016; Olesen *et al*., 2011) because CVC directly and negatively impact food security (Murtaza *et al*., 2019). Climate change is a global issue; however, it disproportionately affects smallholder farmers in developing countries, particularly in Africa (Mercy, 2021), by reducing crop and livestock yields, which leads to an increase in poverty and food insecurity. The main causes of this are poverty, unfavorable weather, and a lack of government agricultural support (Sathyan *et al*., 2018).

Now that CVC has an impact on agriculture and poses a threat to food security, biophysical and societal responses and modifications known as adaption strategies are required (Belay *et al*., 2017; ATPS, 2013). Local adaptation is crucial since global efforts to reduce greenhouse gas emissions fall short of completely eliminating the likelihood of CVC effects (Mercy, 2021; NCCARF, 2017). How farmers view the threats presented by the CVC is one of the primary elements determining the decision on how to adapt (ATPS, 2013). Furthermore, the perception of CVC by farmers is significantly influenced by variables like age, gender, wealth, financial availability, understanding of the climate, social capital, etc. (Deressa *et al*., 2009).

Perceptions are not always an accurate depiction of reality. However, farmers, especially those in developing countries, react to CVC in large part based on how they perceive changes in climatic variables and concerns that have an influence on their livelihoods (Simelton *et al*., 2013). Farmers' perceptions of the local weather are vital in their decision-making and the use of autonomous adaptation measures in these nations because there is a dearth of reliable meteorological data (Etana *et al*., 2020). Due to the fact that perception influences behavior, failing to perceive CVC as a threat to livelihoods may lessen concern and impede action. Farmers' perspectives are crucial for managing climate risk and enhancing agriculture when properly assessed (Hasan and Kumar, 2019; Gebre *et al*., 2013).

Depending on how they see the challenges brought up by CVC, farmers respond in a wide variety of ways. The convergence of perception with and divergence from observed trends both influence the type and timing of taking actions. Agricultural decisions and adaptation strategies are more likely to be successful when subjective assessments and objective measurements are in agreement (Etana *et al*., 2020). However, because farmers' perceptions are based on short-term experiences and memories and climate change is a long-term process, it can be difficult for farmers to appropriately identify changes in climate variables (Hasan and Kumar, 2019). Studies on whether farmers can accurately detect changes in local climate variables have produced conflicting results in light of these difficulties (Etana *et al*., 2020). Farmers' views of rising temperatures and meteorological information largely agree, although investigations reveal a discrepancy between perception and rainfall records (Foguesatto *et al*., 2020; Gebre *et al*., 2013). For example, a study by Meze-Hausken (2004) that looked at farmers' views of the CVC in northern Ethiopia discovered a contradiction between farmers' beliefs of continuously decreasing rainfall and the actual rainfall measures.

Most Ethiopians (around 85%) rely on agriculture for their livelihood, which also accounts for 50% of the nation's GDP and more than 80% of its foreign exchange revenues (Elias & Ganewo, 2020). The second-largest agricultural crop in Ethiopia after teff is maize (*Zea mays L.*) in terms of area covered, total national output, and yield per hectare (CSA, 2015). Moreover, maize is the most significant cereal crop in the study area, which is largely farmed for subsistence purposes and gives smallholder farmers a source of food, animal feed, and revenue.

Rainfed agriculture in Ethiopia is incredibly vulnerable to CVC (Belay *et al*., 2017; Yohannes, 2016). Farmers who primarily rely on rain-fed agriculture report that a lack of accurate information, a lack of agricultural technologies, poverty, a lack of labor, a lack of land, a lack of money, and the absence or improper provision of institutional services are their biggest barriers to making decisions about alternative adaptation strategies (Sathyan *et al*., 2018; Eyasu & Beek, 2015; Gutu, 2015). Despite Ethiopia's significant reliance on a rain-based economy, there aren't many studies connecting farmers' perspectives to meteorological data due to a paucity of crucial data. Additionally, the accuracy of farmers' subjective assessments was not generally confirmed with meteorological data. The present study gains new insights from the combination of farmers' opinions and real meteorological data that go beyond merely showing the proportion of farmers who are correct or incorrect (Etana *et al*., 2020).

There are numerous adaptation techniques that can help maintain rural populations' livelihoods in developing nations (Ceci *et al*., 2021; IPCC, 2007), including both traditional and innovative adaptation strategies (Gebru *et al*., 2020). However, because local adaptations in underdeveloped countries involve costs, constraints, and obstacles that aren't fully understood, they haven't been valued or thoroughly documented; moreover, a lack of information limits efforts to aid farmers in adapting (IPCC, 2007). For example, maize growers lack trustworthy information on climate difficulties, particularly on accurately forecasting the start and cessation of the rainy season so they can employ the appropriate corn varieties. Despite the fact that maize is the most significant crop farmed in the research area and is essential to farmers' livelihoods, only a few studies have attempted to connect maize farmers' perceptions of climate change (Gebre *et al*., 2013). Therefore, the goals of this study were to assess the effects of CVC on maize output, determine the most important local adaptation strategies, and assess the variables that influence farmers' judgments about adaptation choices in northern Ethiopia.

2. Materials and Methods

2.1 Description of the Study Area

Five districts in Tigray (Tselemti, Medebay Zana, Na'eder Adet, Qolla Tembien, and Kilte Awla'elo) were involved in this study (Figure 1). The study districts' rainfall patterns are mono-modal, with rain starting in June and ending in September. More than 85% of the Tigray population lives in rural areas, with livelihoods basically dependent on mixed crop and livestock farming (Kibru *et al*., 2020). The major crops grown include maize (*Zea mays L.*), sorghum (*Sorghum bicolor*), wheat (*Triticum aestivum*), teff (*Eragrostis teff*), finger millet (*Eleusine coracana*), and barley (*Hordeum vulgare*), faba bean (*Vicia faba*), field pea (*Pisum sativum*), and chickpea (C*icer arietinum).* Subsistence farming is a common agricultural practice. Food insecurity is common, and hence the majority of the population depends on emergency food aid. Food insecurity is a problem in the study area because of decreased agricultural output brought on by unfavorable climatic circumstances, as well as other socio-economic issues such as a lack of farmland, land degradation, and restricted use of advanced agricultural technologies (Etana *et al*., 2020). The vulnerability of maize farmers to the impacts of CVC is further exacerbated by deforestation, population pressure, a lack of alternatives to the current way of life, and inadequate rural infrastructure.

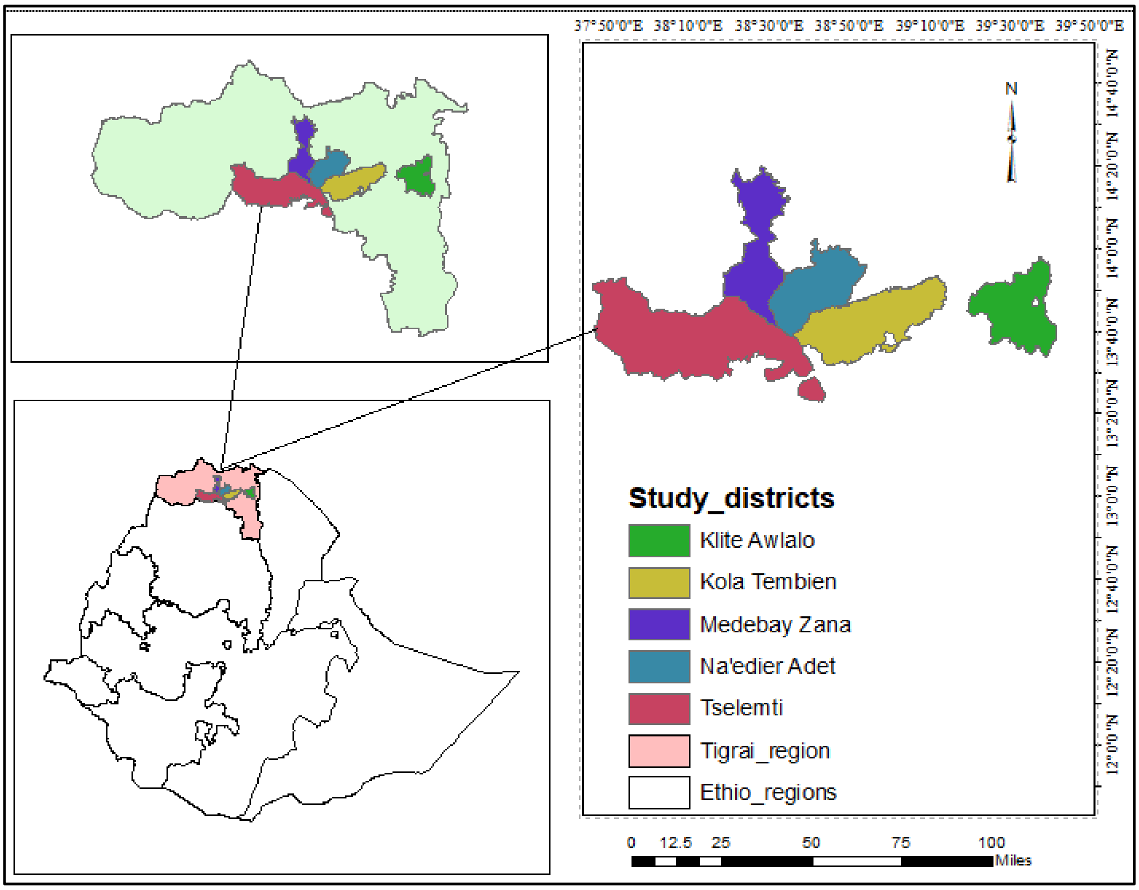


Figure 1. Location map of the study districts

2.2 Sampling Design and Sample Size

Both random and purposeful sampling methods were used to choose samples from various zones, districts, and kebeles and to select maize households. The lists of households that produce maize in each sampled kebele were utilized as sampling frames. The zones, districts, and kebeles were carefully chosen based on their prior experience in maize production and the accessibility of nearby meteorological stations.

The sample size was determined as per the procedure determined by Yamane, (1967):

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

Where, n = sample size; N= population size; e = level of precision at 0.06. The sampling method Probability Proportional to Size (PPS) (McGinn, 2004) was used to determine the total number of household heads (HHHs) per *kebele* (the smallest administrative unit in Ethiopia). A total of 252 sample farmers were picked from a list of 2807 maize growers; however, two households gave similar answers and hence 250 sample households were considered and interviewed (Table 1).

Finally, the use of gridded meteorological data in this study allowed for the investigation of both short-term seasonal variations and long-term annual changes. Data on precipitation, lowest temperature, and maximum temperature for 30 years (1989–2018) were gathered from Ethiopia's National Meteorological Service Agency (NMSA). Both the notions of weather and climate are used in this study.

Table 1. The sample size of the respondent HHHs for the study area

SN	Zone	District	Kebele	No of HHHs	No of respondents using the PPS method	Percent
1	North western	Tselemti	Seqotta Silasse	191	17	6.8
			Serako	135	12	4.8
			Medhane Alem	168	15	6.0
			Tsa’eda Qerni	168	15	6.0
		Medebay Zana	Mes’hil	146	13	5.2
			Debre Kerbe	124	11	4.4
			Nefasit	124	11	4.8
			Bahra	135	12	4.4
2	Central	Na’eder Adet	May Timket	167	15	6.0
			Addi Selam	135	12	4.8
			Siekha	157	14	4.8
			Dag’na	135	12	5.6
		Qolla Tembien	Merere	135	12	4.8
			Worqamba	146	13	5.2
			Begashekha	157	14	5.6
			Adha	124	11	4.4
3	Eastern	Kilte Awla’elo	Abraha Atsbeha	146	13	5.2
			Mesanu	101	9	3.6
			Tahtay Addi Kisandid	112	10	4.0
			La’elay Addi Kisandid	101	9	3.6
Total	**3**	**5**	**20**	**2807**	**250**	**100**

Source: Agricultural offices of each district (2020).

2.3 Data Sources and Collection Methods

Data from 250 maize-growing households were collected between January 2020 and May 2020. We used a variety of data collection methods, such as interviews, private observations, focus groups, and document analysis. For this inquiry, both primary and secondary data were gathered.

The primary data were collected via structured interviews, focus group discussions, and key informant interviews (KII) (Gebru *et al.*, 2020). To collect primary data, structured (closed-ended) and semi-structured (both open and closed-ended) questionnaires were administered to the sampled maize growers. Because they have a significant influence on household decision-making, the HHHs were questioned. If the male HHH was unavailable, his wife assumed his position and was questioned. Moreover, the study included qualitative and quantitative data collected by FGD and KII as rapid rural assessment techniques to supplement the information gained from individual farmers (Dhanya & Ramachandran, 2016). The questionnaire focused more on moisture (rainfall and temperature) and asked questions about the maize farmers' experiences with climate change and agricultural production, their capacity to deal with current and potential threats, barriers to effective adaptation strategies, and ways to reduce risks and improve livelihoods through both individual and group action.

Farmers' opinions and attitudes regarding CVC were probed during the study. To determine whether a farmer has accurately perceived CVC, all the five major parameters—rainfall, temperature, drought, onset/end of the rainy season, dry spell, and dry spell period—must agree that there is a decrease in rainfall, increase in temperature, late-onset/early cessation dates of the rainy season, increase in drought frequency, and increase in dry spell period (Amadou *et al*., 2015). Additionally, the National Meteorological Service Agency (NMSA) of Ethiopia provided the pertinent secondary data for this analysis (historical rainfall and temperature data) for 30 years (1989-2018), which were used for a climate trend analysis.

2.4 Methods of Data Analysis

2.4.1 Descriptive analysis

According to Amadou *et al*. (2015), farmers' perceptions of climate change are defined as an overall awareness of the trend of five key climatic parameters: rainfall, temperature, drought, the start and end of the rainy season, and dry spell over the past 20 years. The social data gathered from the sample homes were statistically analyzed using MS Excel spreadsheets and IBM's Statistical Package for Social Science (SPSS) software, version 20 (IBM, 2012). Descriptive statistical metrics including mean, standard deviation, percentage, and frequency of occurrence were used to analyze the respondents' demographic and socioeconomic characteristics and to highlight the various degrees of adaptation to climate change and strategies employed. Quality control was met by using gridded data from Ethiopia's NMSA to assess the meteorological data (hence no missing data). The results of the analyzed data were presented using figures and tables.

2.4.2 Econometric (Choice) Analysis

The multinomial logit analysis (MNL) model was utilized in this study to investigate the factors impacting farmers' choice of the various adaptation strategies employed by farm-households in the research area. The MNL model is ideal for assessing the likelihood that a certain option will be selected above other alternatives since it makes the assumption that the available options are mutually exclusive (Gebre *et al*., 2013).

According to Greene (2003), farmer *i* decides to use *the* j^{th} adaptation option if the perceived benefit from option *j* is greater than the utility from other available options (say, k) depicted as:

$$U_{ij}\left(\beta_j' X_i + \varepsilon_j\right) > U_{ik}\left(\beta_j' X_i + \varepsilon_k\right), k \neq j$$

where $\boldsymbol{U_{ij}}$ and $\boldsymbol{U_{ik}}$ are the perceived utility by farmer *i* of adaptation options *j* and k, respectively; X_i is a vector of explanatory variables that influence the choice of the adaptation option; β_j and β_k are parameters to be estimated, and ε_j and ε_k are the error terms.

According to Bryan *et al*. (2009), the MNL model suffers from independence issues and operates under the independent irrelevant alternative (IIA) assumption, which states that the ratio of the probability of selecting any two alternatives is independent of the characteristics of any other alternatives in the set of choices. To determine if the IIA assumption was valid, the Hausman test (Hausman & McFadden, 1984) was applied. For this study, the MNL model was estimated by standardizing the "no adaptation" strategy to climate change as a reference category (Gebru *et al*., 2020).

The parameter estimates—also known as coefficients—for the MNL model only display the direction, not the magnitude or the likelihood, of the independent variables' effects on the dependent variable. The projected change in chance of making a certain choice in response to a unit deviation of an independent variable from the mean is therefore measured by marginal effects or marginal probabilities, which are functions of probability themselves and are calculated as:

$$\frac{\partial P_j}{\partial X_k} = P_j\left(\beta_{jk} - \sum_{j=1}^{j-1} P_j \beta_{jk}\right)$$

The MNL model uses a test called VIF (Variance Inflation Factor) to detect the problem of multicollinearity for continuous explanatory variables; i.e., there must not be collinearity among the independent variables.

$$VIF = \frac{1}{1 - R_j^2}$$

Where: VIF is the variance inflation factor; R_j^2 is the adjusted square of the multiple correlation coefficients that result when one explanatory variable (j) is regressed against all others. If an approximately linear relationship exists between the explanatory variables, then multicollinearity is a problem with a large value of R^2 in at least one of the test regressions.

The contingency coefficients were calculated as (Gebru *et al*., 2020):

$$C = \sqrt{\frac{x^2}{n - x^2}}$$

where C is Contingency Coefficient, $\chi 2$ = Chi-square test, n= total sample size.

Finally, the MNL regression model, integrated into the STATA-13 (StataCorp, 2015) econometric software, was used to analyze the data used to analyze the hypothesized explanatory variables that were anticipated to influence the choice and adoption of adaptation strategies to climate change. Only statistically significant explanatory variables were discussed here.

2.4.3 Description of Variables Used in the MNL Model

For a variety of socioeconomic, institutional, and environmental reasons, the majority of smallholder farmers use a combination of adaptive measures. Some people, however, do not employ any adaptive strategies at all (Gebru *et al*., 2020). Six different adaptation choices (five on-farm and one off-farm) were employed as dependent variables for the MNL model in this study, with the no-adaptation option serving as the base category. The baseline category refers to the state of a system against which change is measured.

In this study, the dependent variable is whether a maize household has "***adopted***" or "***has not adopted***" any climate change adaptation strategy. The availability of resources and socioeconomic conditions, however, have been found to have an impact on farmers' intents and behaviors related to climate change adaptation (Dang *et al*., 2014). Additionally, the most crucial set of independent factors that affect farmers' decisions to choose and put into practice among the several potential adaptation methods was looked at. The explanatory variables were anticipated to have an impact on farmers' decision-making regarding their choice of adaptation options. The list of these explanatory variables, as well as their projected working causal effects (signs), were summarized and presented in Table 2.

Table 2. Description of variables used in the econometric (MNL) model

Variables	**Description**	**Measurement**	**Type**	**Effect**
Dependent:				
CLI	Crop-livestock integration	1 if HH adopted CLD, 0 otherwise	Dummy	
VAR	Use of improved crop variety	1 if HH uses VAR, 0 otherwise	Dummy	
CCTPHD	Changing CTPHD	1 if HH shifts to CCTPHD, 0 otherwise	Dummy	
IRR	Irrigation	1 if HH uses IRR, 0 otherwise	Dummy	
SWC	Soil and water conservation	1 if HH chooses SWC, 0 otherwise	Dummy	
NFA	Non-farm activities	1 if HH involved in NFA, 0 otherwise	Dummy	
Independent:				
Socioeconomics variables:				
Age	Age of the respondent	years	Continuous	±*
Gender	Gender of the respondent HHH	(1= male, 0 = female)	Dummy	±*
Education	Educational level of the HHH	years (grade levels)	Continuous	+
Family	Family (household) size	number	Continuous	±*
Income	Annual income	ETB	Continuous	+
Household assets:				
Farm	Farm size	ha	Continuous	+
TLU	Livestock ownership	number	Continuous	+
Institutional/policy variables:				
Extension	Access to extension contact	(1= yes, 0 = no)	Dummy	+
Credit	Access to credit services	(1= yes. 0= no)	Dummy	+
Climate variable:				
ClimInfo	Access to climate information	(1= yes, 0 = no)	Dummy	+

Cannot be signed a priori (+ or -); CTPHD: crop type and/or planting and/or harvesting date

3. Results and Discussion

3.1 Demographic Characteristics of the Respondents

Male-headed households accounted for 89.6% of all households (Table 3), while female-headed households accounted for 10.4%. This is due to sociocultural circumstances in Ethiopia that allow a more male-headed family to tackle agricultural-related difficulties (Tesfahunegn *et al.*, 2016). The respondents' average age was 48; 24.8% were over 55 years old, making them particularly vulnerable to climatic stress (Pickson & He, 2021). 80% of farmers relied on mixed crop-livestock farming as their primary source of livelihood. The majority of farmers in Africa are engaged in mixed farming because it maximizes nutrient cycling, increases total farm productivity, and enhances diet quality (Robinson & Bernard, 2015). Farmers also use small trade, traditional gold mining (TGM), and other off-farm revenue sources to supplement their income (Table 3). More than 53.2% of respondents had less than 4 years of education, demonstrating that these farmers are especially vulnerable to CVC hazards as a result of their ignorance (Pickson & He, 2021). In terms of livestock, farmers owned an average of 1.56 oxen and 6.04 TLU.

The agricultural production system varied, with the majority of farmers (80%) depending on crop-livestock (mixed) farming as their main source of income and 13.2% of farmers specializing in crop production (Table 3). This is consistent with Robinson & Bernard's (2015) findings, according to which farmers benefit from combining crops and livestock at the farm level. Maize farmers also use off-farm money-generating activities (such as local brewing, traditional gold mining, wage jobs, church service, hairdressing, guarding, blacksmithing, etc.) to boost their income (Table 4).

The majority of respondents did not complete primary school (4 years of schooling), as seen by the average length of education, which was 3.74 years. On the other hand, more than 53.2% of respondents had little to no education (less than 4 years of formal education), demonstrating that these farmers are particularly vulnerable to the hazards of climate change as a result of their ignorance (Pickson & He, 2021). There were up to four family members for 18.8% of respondents, and 71.2 percent had five to eight. There were 6.32 family members in the average home. The size of a family is seen as a workforce in agriculture (Ndamani & Watanabe, 2016).

In terms of livestock, farmers held an average of 1.56 oxen and 6.04 TLUs (tropical livestock units). Only a small percentage of farmers (11.2%) possessed more than two oxen, with the bulk of farmers (44.8%) owning just a pair. Having more cattle means having income sources other than the crop-dominated farming system (Gutu, 2015). In the study area, owning animals is crucial; a farmer is not deemed deserving of a living if he or she does not have any oxen.

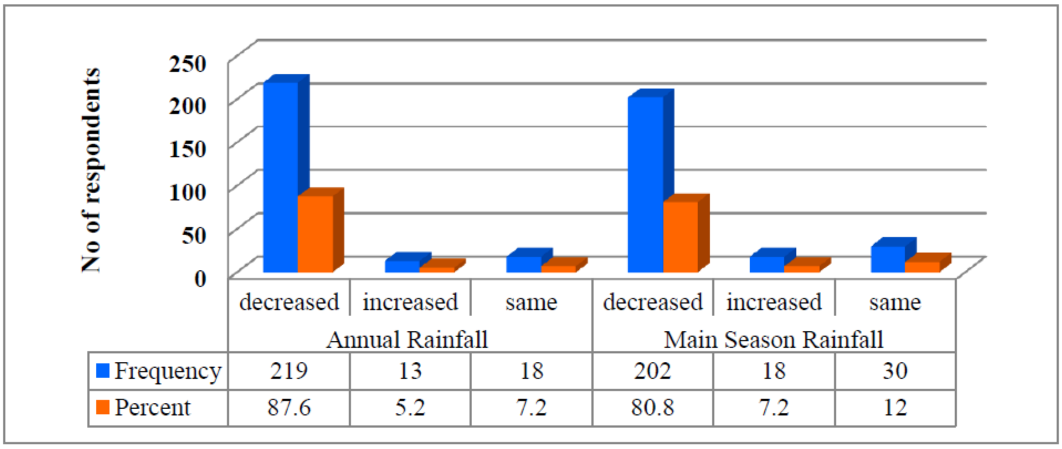
Table 3. Descriptive statistics on the characteristics of the maize HHHs in Tigray, (N= 250)

Farmers' Characteristics	**Respondents' Categories**	**Maize farmers**		**Range**		**Mean**	**SD**
		N	**%**	**Min.**	**Max.**		
Gender	Male	224	89.6	-	-	-	-
	Female	26	10.4				
Age (years)	≤35	42	16.8				
	36-45	64	25.4	22	81	48.16	11.91
	46-55	82	32.8				
	>55	62	24.8				
Formal Education (years of schooling)	Illiterate	75	30	0	14	3.74	3.45
	1-4	83	33.2				
	5-8	66	26.4				
	9-12	21	8.4				
	> 12	5	2.0				
Family size	Small (below 4)	47	18.8	2	12	6.32	1.92
	Medium (5-8)	178	71.2				
	Large (>8)	25	10.0				
Main source of income	Crop production	33	13.2				
	Mixed farming	200	80.0				
	Casual labor	6	2.4				
	Petty trade	3	1.2				
	Salary	3	1.2				
	TGM	5	2.0				
Farmland size (ha)	no farm land	3	1.2	0	3	1.27	0.59
	<1ha	144	57.6				
	1-2ha	90	36.0				
	2-5ha	13	5.2				
TLU (number)	0	8	3.2	0	24.56	6.04	4.37
	1-10	209	83.6				
	11-20	30	12.0				
	> 20	3	1.2				

Source: Field survey, 2019 (Authors' construct). TGM: Traditional gold mining; TLU: Tropical livestock unit.SD: Standard deviation; HHHs: Household heads

3.2 Farmers' Perception of Annual and Main Season Climate Changes

According to the findings, farmers believed that yearly and main season rainfall patterns had dropped by 87.6% and 80.8%, respectively (Figure 2). According to the descriptive data, the majority of farmers in the study districts believed that the temperature had increased and the amount of rainfall had decreased. Accordingly, Belay *et al*. (2017) found that rainfall levels have decreased, while Tessema *et al*. (2013) revealed that most Ethiopian farmers are aware that the temperature is rising.



	Annual Rainfall			Main Season Rainfall		
	decreased	increased	same	decreased	increased	same
🟦 Frequency	219	13	18	202	18	30
🟧 Percent	87.6	5.2	7.2	80.8	7.2	12

Figure 2. Farmers' perceptions of annual and main season rainfall patterns

3.3 Comparing Farmers' Perception with Empirical Climate Data

The majority of respondents (91.2%) said that CVC had occurred over the past 30 years, and as a result, 88.4%, 83.24%, and 79.24% of them saw a decrease in rainfall, an increase in temperature, and more frequent droughts, respectively. These changes caused the area to become drier (Figure 3). Rainfall and temperature were the two most visible indicators of climate change for the farmers in this study. This is consistent with a study by Amadou *et al*. (2015) who found that farmers' assessments of CVC are typically based on average changes in rainfall and temperature, which are the main climatic indicators utilized in climate change research. Furthermore, according to Kahsay *et al.* (2019), 95.28% and 77.5%, respectively, of Tigray families saw a drop in rainfall and an increase in temperature; as a result, these families are aware of CVC based on their local experiences.

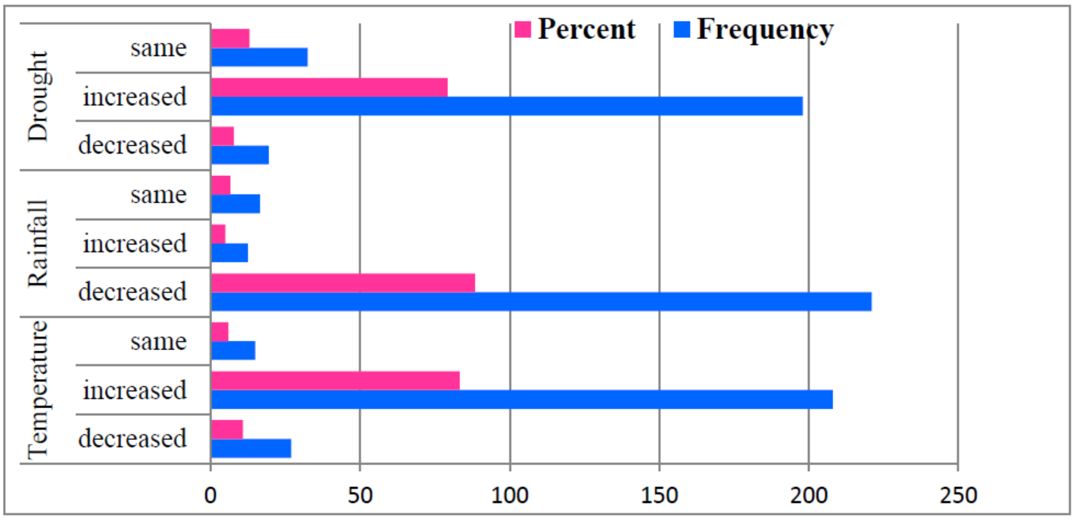


Figure 3. Farmers' long-term perceptions of climate change

Figure 3 displays farmers' assessments of long-term climate trends and seasonal variations. The analysis of meteorological data revealed an increase in temperature over the study period (1989–2018), and farmers' opinions of this trend were consistent with the results (Figure 4). In agreement with this, Gebrehiwot and van der

Veen's (2013) investigation found that the mean Tmax and Tmin had both risen in northern Ethiopia. The annual rainfall meteorological data did, however, show a rising trend (positive slope), although it was not statistically significant (figure 4).

According to a study by Bewket (2012), farmers in Ethiopia's central highlands firmly believed that the temperature was rising and that the amount of rain was dwindling. However, Limantol *et al*. (2016) and Waongo *et al*. (2015) reported that because scientists frequently examine climate data at different timescales than those relevant to farmers, it is possible that this could lead to differences in farmers' perceptions and observable data. Farmers' perceptions of decreased rainfall for long periods of years are at odds with the findings of the real rainfall data analysis.

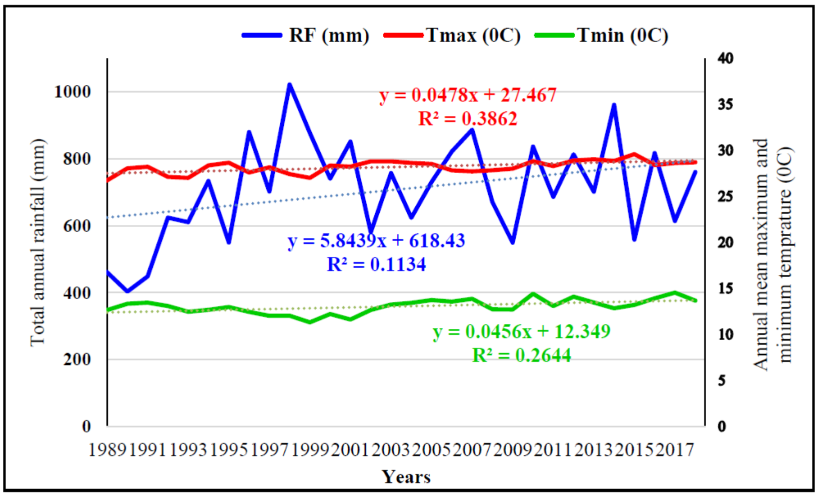


Figure 4. Annual rainfall and temperature trends in the studied area (1989-2018)

3.4 Farmers' Perceptions on Climate Change-induced Hazards

The main CVC-induced shocks were (Figure5): depletion of soil fertility (83%), a decline in livestock feed (82.6%), biodiversity loss (82.4%), and crop yield reduction (78%). In agreement with this, Maya *et al.*, (2019), FAO (2016) and Thistlethwaite (2010) have reported that higher temperatures and fluctuating rainfall caused by CVC, have reduced crop production; lead to shortages of drinking water, the devastation caused by severe droughts is increasing; new diseases are emerging and old diseases are spreading and hunger is expected to increase.

Farmers in the study area have noticed lower corn yields, mostly as a result of moisture loss brought on by CVC (Figure 5). This is consistent with Gebrehiwot's (2013) finding that droughts of various intensities and lengths have affected crop output in northern Ethiopia. Making efficient use of the available rainfall and understanding the effects of soil and field management are therefore necessary for reducing the production risks associated with maize.

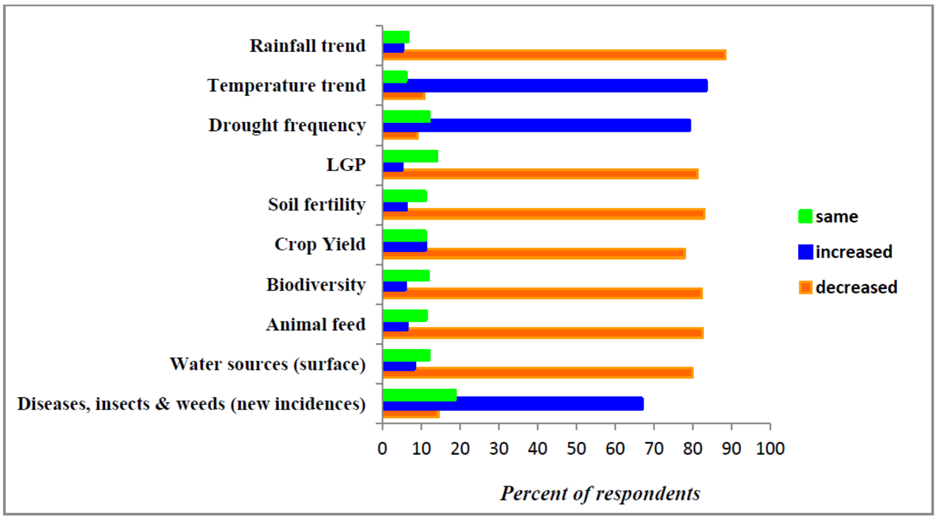


Figure 5. Farmers' perspectives on the effects of climate change

3.5 Maize Farmers' Adaption Tactics to Climate Variability and Change

The most prevalent and regularly employed adaptation techniques by the maize farmers to counteract the effects of CCV were crop-livestock integration (24%), adoption of enhanced crop seeds (20.8%), changing crop type, and/or shifting the cropping calendar (16.8%) (Table 4). For instance, Tigray farmers demonstrated better participation in farm diversification (manuring, ridging, and terracing) and crop-livestock integration (Gebru *et al.*, 2020); farmers in Ethiopia's Rift Valley have applied modern agricultural inputs, primarily improved crop varieties, agronomic practices, and crop-livestock integration (Sime and Aune, 2018).

Table 4. Major CVC adaptation tactics used by maize producers in Tigray (N=250)

Adaptation practice	**Freq.**	**%**	**Actual adaptation activities**
Crop-livestock integration	60	24	intercropping, crop rotation, rearing of cattle, shoats, equines, poultry, etc.
Use of improved crop varieties	52	20.8	Use of early maturing, high yielding, drought-tolerant, etc.
Changing crop type	42	16.8	Use of other crops (e.g., planting sorghum instead of maize or vice versa) based on the goodness of the rain.
Irrigation	39	15.6	Dry season gardening
SWC practices	23	9.2	Terracing, mannuring. tillage, tie-ridging, hoeing, etc., as water harvesting techniques
Off-farm activities	16	6.4	Local brewing, pottery, wage labor, church service, guarding, *traditional* gold mining, petty trade, traditional singer, etc.

3.6 Determinants of Adaptation Tactics to Climate Change

Combining smallholder farmers' use of adaptation tactics with the expected coefficients and levels of significance of the discrete dependent variables from the MNL model are indicated in Tables 5 & 6. The maximum likelihood ratio statistics were extremely significant ($p<0.0001$) according to the Chi-square statistics, demonstrating the model's strong explanatory ability (Gebru *et al.*, 2020). Because $\chi2$ varied from -27.94 to 0.31 with a probability equal to 1.0, the Hausman test demonstrated that the IIA (independence of irrelevant alternatives) is not violated (Table 5).

To make sure that the continuous explanatory variables did not contribute to the multicollinearity problem, auxiliary regression was fitted and VIF was calculated. Given that there were no substantial multicollinearity problems and that all of the VIF values were less than 10 (1.05 to 1.41), it is safe to conclude that multicollinearity does not exist (Gebru *et al.*, 2020). To determine whether there is a problem with strong association, the contingency coefficient for the categorical independent variables was calculated and evaluated. As a result, none of the coefficient results were greater than 0.75, indicating that the explanatory variables in the model estimation did not strongly correlate with one another (Gujarati, 2004). As a result, the model adequately incorporates all of the suggested explanatory elements.

Table 5: MNL model results for Hausman tests of IIA assumption

Omitted Variables	**Chi-square**	**df**	**p>chi-square**	**evidence**
Crop-livestock integration	-20.783	41	1.000	for *Ho*
Improved variety	-24.415	42	1.000	for *Ho*
Changing crop type	-27.923	41	1.000	for *Ho*
Irrigation	0.311	41	1.000	for *Ho*
SWC practices	-27.938	41	1.000	for *Ho*
Off-farm activities	-24.464	41	1.000	for *Ho*
No Adaptation	-18.103	51	1.000	for *Ho*

Ho: Odds (Outcome-J vs Outcome-K) are independent of other alternatives.

The MNL model was used to calculate the marginal effects (ME) and their significance levels (p-values) to assess the likelihood of a particular adaptation strategy for a unit change in the independent variables. Therefore, only explanatory variables with statistical significance and a significant influence on the choice to use CVC were investigated and discussed below (Table 6).

Gender of the household: The MNL model's findings showed that having a male HHH improves climate change adaptation; specifically, when the household is headed by a male, there is a higher possibility that crop variety, planting and/or harvesting date, and SWC activities will be changed as a climate change adaptation strategy (Table 7). The labor-intensive nature of these SWC activities is well known to provide a challenge for families headed by women. As a result, adoption of these two adaptation techniques increases by 8.1% and 7.2%, respectively, at a 5% significant level, for each additional unit of male-headed households. According to Nordhagen & Pascual's (2013) research, larger HHHs headed by males were more likely to employ crop-related adaptation techniques. Their findings are supported by this outcome (e.g., purchase of seeds). Households headed by older males were shown to be more likely to undertake agricultural adaptation methods, according to studies by Kom *et al.* (2020), Tadesse *et al.*, (2009), and Tazeze *et al.* (2012). This may be due to the fact that men perform most agricultural chores, while women are more involved in processing, giving male-headed households an edge in terms of farming expertise and comprehension of various adaptation tactics (Asfaw *et al.*, 2019; Tazeze *et al.*, 2012).

Age of the household: Age reveals experience. The likelihood that maize farmers will adopt crop-livestock integration and irrigation as adaptation approaches increased by 1% at $p < 0.1$ and $p < 0.05$, respectively, as the household head's age rose by one year (Table 6). According to Atinkut & Mebrat (2016), crop diversification was favorably and significantly correlated with the age of the HHH. On the other hand, changing crop type and/or planting date had a negative correlation with HHH age; i.e., a unit increase in HHH age negatively (-0.077) affected and significantly reduced the likelihood of using this adaptation strategy by 1.2% at $p < 0.05$, indicating that older farmers are less likely to use it because of their older age and lack of energy to do so actively.

Educational level: Problem-solving skills can be developed through education. The findings (Table 6) revealed that the likelihood that the household would use enhanced crop varieties as an adaptation strategy increased by 3.7% (at $p< 0.05$) and irrigation practices as an adaptation strategy by 1.3% (at $p< 0.1$) as the household head's educational level increased by one year. In other words, farmers who had more expertise were more likely to use better crop varieties and irrigation techniques. Tadesse *et al*. (2009) showed that households with higher levels of education were more likely to implement agricultural adaptation measures, which is consistent with this finding.

Table 6. Estimates of the MNL model parameters for household adaption techniques

Indep. Variable	**Crop-livestock integration**		**Improved variety**		**Changing crop type**		**Irrigation**		**Soil and water conservation**		**Off-farm activities**	
	Coeff.	ME (dy/dx)	Coeff.	ME (dy/dx)	Coeff.	ME (dy/dx)	Coeff.	ME (dy/dx)	Coeff.	ME (dy/dx)	Coeff.	ME (dy/dx)
Sex	0.893	-0.108	1.501	0.052	2.206**	0.081	1.378	0.011	2.612**	0.072	2.197	0.024
Age	0.063*	0.010	0.014	-0.002	-0.077**	-0.012	0.079**	0.010	0.014	-0.001	-0.069	-0.003
Education	-0.079	-0.047	0.252**	0.037	0.176	0.006	0.204*	0.013	0.096	-0.003	0.176	0.0027
Family size	0.299*	0.010	-0.337**	-0.001	-0.419**	0.010	0.312	0.005	-0.55***	0.019	0.528**	0.007
Farm Size	2.033***	0.172	1.206*	0.019	1.368*	0.012	1.269*	0.001	0.752	-0.046	0.004	-0.047
TLU	0.198**	0.005	-0.118	0.015	-0.25***	-0.011	-0.156**	0.002	0.28***	0.010	-0.197*	0.001
Income	1.082**	0.084	0.619	-0.028	0.324	-0.049	1.080**	0.062	0.249	-0.041	1.022*	0.012
Climate Info.	0.223	0.199	-1.145	0.053	2.254*	0.168	-1.221	0.020	-1.409	-0.006	3.074**	0.144
Credit Acc.	0.095	-0.139	1.425*	0.165	2.092**	0.117	2.623***	0.198	-1.114	-0.265	-0.131	-0.035
Constant	-12.588**		-5.694		1.699		-14.365**		2.612		-3.029	
Alternative variables:					Adaptation methods (6)							
Base category:					No adaptation							
MNL model (Multinomial logistic regression) test:					No. of obs. = 250							
					LR $chi^2(60) = 210.65$***							
					Prob. > $chi^2 = 0.0000$							
					Pseudo $R^2 = 0.2285$							
					Log likelihood = -355.54878							

, ** and * indicate statistically significant at 1%, 5%, and 10%, respectively; ***ME: marginal effect

Household income: Table 6 demonstrated that the probability of choosing "crop-livestock integration," "irrigation practices," and "involvement in off-farm activities" over "no adaptation" increased by 8.4% ($p<0.05$), 6.2% ($p< 0.05$), and 1.2 % ($P< 0.01$) points, respectively, as the income level of the HHH increased by one unit (i.e., 1000 ETB). This result is consistent with earlier findings that more affluent farmers are more likely to use adaptation practices in response to CVC than less affluent farmers (Ndamani & Watanabe, 2016); households with higher incomes were more likely to engage in crop adaptation strategies (Tadesse *et al*., 2009); and farmers tend to invest in productivity smoothing options like irrigation when their household's main source of income rises (Tazeze *et al*., 2012).

Livestock ownership (TLU): According to Table 6, people who own livestock are more likely to engage in crop-livestock integration and SWC practices than people who don't; as the number of TLU in the household increased by one unit, the likelihood that the maize farmer would use these adaptation strategies increased by 0.5% ($p< 0.05$) and by 1% ($p< 0.01$), respectively. This finding is in line with that of Tazeze *et al*. (2012), who claimed that animals play a vital role in managing soil fertility by providing traction (especially oxen) and manure, as well as acting as a source of income to buy better crop varieties.

Credit access: The results (Table 6) showed that the likelihood of choosing a better crop variety, switching to a different crop type, and using irrigation as an adaptation strategy increased by 16.5 % ($p< 0.1$), 11.7% ($p< 0.05$), and 19.8% ($p< 0.01$), respectively, as the HHH's credit availability improved by one unit. According to Nhemachena and Hassan (2008), access to cost-effective loan systems increases farmers' financial resources and their ability to select and employ a variety of adaptation options. Similar results were reported by Ndamani & Watanabe (2016), who found that farmers who receive institutional services are more likely to apply adaptation tactics because they can share information, resolve issues, exchange ideas, and work together to make decisions.

4. Conclusions and Recommendations

Climate variability and change (CVC) and how well farmers comprehend these changes have a substantial impact on agricultural activities and the viability of the livelihood options they have selected. According to this study's findings, farmers are aware of the characteristics of climate change, its causes, and its effects on agriculture. Increases in warmth, drought and a decrease in rainfall all reflect their impression of it. Farmers believe that drought has been the primary climatic shock affecting maze productivity. Climate change was mostly caused by divine anger and the ever-growing population. Due to climate change, maize farmers are confronted with a number of challenges, such as declining crop yields, decreased soil fertility, and a rise in the incidence of new diseases, insects, and weed species.

Climate change and its impacts can never be avoided, hence farmers in the study area are adapting to it using different adaptation strategies. The most frequently used adaptation strategies by maize farmers are crop-livestock integration, utilizing improved maize cultivars, moving crop kinds, changing the cropping calendar, and participating in non-farm activities. Farmers may find it difficult to use the existing adaptive mechanisms, for a variety of reasons. Some of the main socioeconomic factors that influenced farmers' opinions and decisions regarding using adaptation methods were gender, age, loan availability, education, and wealth. Their struggle to adapt to climate change was hampered by poverty, unpredictable weather, a lack of/limited farmland, a lack of farm labor, a lack of water for irrigation, a lack of major institutional services (extension, seed and input suppliers, rural credit institutes), poor soil fertility, and the high cost of off-farm inputs (fertilizers, pesticides, and improved maize seeds).

This study presents concrete proof of subsistence maize growing in a rapidly changing climate, as well as desperately required solutions. Plans for farming are impacted in several different ways by the observed fluctuations in climatic variables. To decrease the effects of climate change, it is also required to identify and implement adaptation strategies that are specifically adapted for the climate characteristics of each agro-ecological site. For example, the requirement for water management and the need for seeds that can be harvested rapidly or endure water stress are highlighted by variations in rainfall patterns. Due to the recurrence of climatic unpredictability and catastrophic events, it is furthermore necessary to expand alternative climate-resilient livelihood options to ensure food security.

Finding a clear and practical response to the problems posed by climate change should start with the farmer. In order to increase maize yields and lower production risks, it is essential to better utilize the available rainfall by applying trustworthy climate information on maize cultivation. To encourage farmers to use adaptation strategies to lessen the negative effects of CVC, institutional, policy, and technological perspectives from both the farmer and farm levels should be considered in both governmental and NGO agricultural policies and investment strategies. This will help support the indigenous adaptation strategies used by maize farmers.

This is because determining how local climate factors are changing is necessary for developing efficient adaptation strategies and boosting agricultural productivity. Furthermore, as it enables farmers to engage in activities that are less impacted by climate change, the development of skills and training opportunities for off-farm income-generating activities for farmers is essential. Decisions regarding adaptation and the choice of adaptation decisions alter over time and among diverse regions as a result of the geographical and temporal changes in climate variables. Future studies should therefore concentrate on the dynamic relationships between climatic variables, household vulnerability, local viewpoints, and farmer decision-making on adaptation options.

Abbreviations

CVC: climate variability and change; **FGD**: focus group discussions; **HHH**: household head; **IIA**: independence of irrelevant alternatives: **KII**: key informants’ interviews; **ME**: marginal effect; **MNL**: multinomial logit model; **PPS**: Probability Proportional to Size; **TLU**: tropical livestock unit; **VIF**: variance inflation factor.

Competing Interest

The authors declare that they have no conflict of interest.

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