Perceptions of Climate Change and Determinants of Adaptation Decisions of Smallholder Maize (Zea mays L.) Farmers in Tigray, Northern Ethiopia.

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Research Article

Keywords: Adaptation, Climate change, Maize, Multinomial Logit model, Smallholder farmers, Tigray

Posted Date: February 23rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1312735/v1

PERCEPTIONS OF CLIMATE CHANGE AND DETERMINANTS OF ADAPTATION DECISIONS OF SMALLHOLDER MAIZE (Zea mays L.) FARMERS IN TIGRAY, NORTHERN ETHIOPIA.

Abstract

Climatic calamities are posing serious challenges to smallholder maize (Zea mays L.) farmers in Ethiopia. Adapting to climate change is largely location-specific, and its success is influenced by local institutions and socioeconomic conditions. This study was done to understand maize farmers' perceptions of climate change, investigate its implications, identify local adaptation tactics used by maize farmers, and establish the elements that influence farmers' adaptation decisions, In Tigray, northern Ethiopia. Household surveys were used to acquire primary data from 250 maize producers. To evaluate the data on socioeconomic features and perceptions, descriptive statistics were used, as well as a multinomial logit model to determine the elements that influence farmers' adaption decisions. The majority (91.2%) of the farmers have perceived climate change and the main indicators of climate change were erratic (low) rainfall (88.4%), rising temperatures (83.2%), and increased frequency of drought (79.2%). Decreasing soil fertility (83%) and decreasing crop yields (78%) are the major impacts due to climate change. Hence, 92.8% of the farmers have made adaptation attempts mainly by using crop-livestock integration (24%) and the use of improved maize varieties (20.8%). The econometric analysis indicated that age, gender, education, farm size, livestock ownership, lack of access to credit services, and poor economic status were the key determinants that influenced the farmers' choice of adaptation decisions. It is critical to support maize farmers' indigenous adaptation techniques with a variety of institutional, policy, and technology tools at the farmer and farm level.

Keywords: Adaptation, Climate change, Maize, Multinomial Logit model, Smallholder farmers, Tigray.

1. Introduction

Climate change is the biggest challenge facing the planet (Murtaza *et al.*, 2019). Agriculture has been one of the most sensitive sectors to climate change since it relies on suitable environmental conditions to thrive (Bryant *et al.*, 2016; Olesen *et al.,* 2011; Papajorgji and Pardalos, 2009; Lobell and Burke, 2008). Climate change refers to any statistically significant variation in either the mean state of the climate elements, persisting for an extended period, typically decades or longer (Madhuri & Sharma, 2020). Climate variability is variations in the mean state of the climate on all temporal and spatial scales that occur within smaller time frames, such as a month, a season, or a year (ATPS, 2013).

Climate change is a worldwide phenomenon with far-reaching consequences (Shafer, 2017). Smallholder farmers in poor nations, on the other hand, are disproportionately affected by climate change because of their reliance on the environment and natural resources for food and income, as well as a lack of infrastructure for adaptation, notably in Africa (Mercy, 2021). Because agriculture in these countries is dominated by the presence of low-income earner farmers engaged in subsistence farming (Akinnagbe and Irohibe, 2015; IPCC, 2007), climate change has had a significant impact on agricultural activity in developing countries (Fadina & Barjolle, 2018), and it affects farming livelihoods by acting as a hunger risk multiplier by damaging harvests and lowering crop yields, thereby increasing poverty and food insecurity (Sathyan et al., 2018).).

Sub-Saharan Africa (SSA) is one of the regions of the world that would have severely hit by climate change (Ceci et al., 2021; Chijioke et al., 2011). The region's reliance on agriculture exacerbates SSA's vulnerability to climate change (Yohannes, 2016). As a result of poverty, bad weather, and a lack of government agricultural support (Fagariba et al., 2018), smallholder farmers in SSA are among the world's most vulnerable groups to climate change (Harvey et al., 2018).

Climate change's negative consequences on Ethiopia's agriculture are a key source of concern (Belay et al., 2017). Ethiopia is one of the most vulnerable countries to the consequences of climate change due to its heavy reliance on climate-sensitive sectors such as agriculture. According to Kassie et al. (2013), as cited by Belay et al. (2017), Ethiopian small-holder farmers are predominantly reliant on rainfed agriculture, which is very vulnerable to climate change and variability (CCV). Ethiopia's Tigray regional state is one of the most vulnerable regions to climate change. The rainfall pattern in Ethiopia has drastically decreased towards the north over the last half-century, and the northern section of Ethiopia is warming faster than the national average (Gebre et al., 2013). As a result, impoverished subsistence farmers, who account for 98% of total cropland and more than 90% of total agriculture output in Ethiopia, are the first to feel the effects of climate change (ATPS, 2013).

The impact of CCV on agriculture, and thus food security, necessitates biophysical and societal responses and modifications (ATPS, 2013). Adaptation can help mitigate the effects of climate change, but it can't fix the problem by itself (Belay et al., 2017), because climate change can't be avoided any longer. The process of making suitable adjustments to the actual or anticipated effects of climate change is known as adaptation (IPCC, 2014). Because international efforts to decrease greenhouse gas emissions are insufficient to eliminate the risk of climate change impacts, local adaptation is critical (NCCARF, 2017). Studies indicate that, although the developing countries are less able to adapt to climate change, many research outputs also indicated that subsistence farmers of Africa who are already experiencing the harsh effects of weather-related hazards (e.g. erratic rainfall patterns, crop and livestock epidemics, drought, etc.) are developing effective coping strategies such as the use of improved crop varieties, crop-livestock integration, adjusting of planting dates, changes in crop type, irrigation, use of soil and water conservation practices, agro-forestry and involvement in off-farm and non-farm activities (Bryant *et al.*, 2016; Ndamani & Watanabe, 2016; Akinnagbe and Irohibe, 2015; ATPS, 2013; Gebre *et al.,* 2013). However, rainfed farmers identified dependence on climate-sensitive activities, a lack of accurate information, falling production, a lack of agricultural technologies, poverty, labor, land, and money shortages, and the lack of existence and/or proper provision of institutional services (seed and inputs companies, rural credit institutes, and so on) as major barriers to adaptation strategies (Araro et al., 2019; Sathyan et al., 2018; Eyasu and Beek, 2015; Gutu, 2015).

The perception of the danger posed by the CCV is one of the first criteria that affects adaptation actions (ATPS, 2013), since if the farmer does not perceive the risk, he or she may not feel compelled to take action (Madhuri & Sharma, 2020). As a result, before we can even begin to discuss and analyze farmers' adaptation methods to CCV threats, we must first understand their true perspective of CCV (Bryant et al., 2016; Gutu, 2015). The most important factors that have significant effects on farmers' perceptions of CCV are age, gender, wealth, information on CCV, social capital, and agro-ecological settings (Deressa et al., 2008).

Adapting to climate change is mostly location-specific, and its effectiveness depends on local institutions and socioeconomic settings (Belay *et al.*, 2017). In developing countries, a wide array of adaptation options is available

(IPCC, 2007) and the adoption of such effective adaptation strategies can safeguard rural communities' livelihoods (Ceci *et al.*, 2021). Farmers in Tigray have a long history of employing a variety of risk-mitigation tactics to the effects of climate change, combining both traditional and recently developed adaptation options (Gebru et al., 2020). However, these local adaptations in developing countries have not been well valued and documented because there are barriers, limits, and costs that are not fully understood (IPCC, 2007), and yet efforts to support farmer adaptation are hindered by a lack of information on how they are experiencing and responding to such risky climatic changes. Despite the fact that maize (Zea mays L.) is the most important cereal grain crop cultivated in the study area and plays a vital role in poor farmers' lives, only a few studies in the Tigray region have been done to correlate maize production with climate change (Gebre et al., 2013). Therefore, the objectives of this study were to assess the perception of smallholder farmers towards CCV; to identify the major local adaptation strategies used by maize farmers, and to identify the factors that determine the farmers' choice of adaptation decisions in the Tigray region, northern Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The research was conducted in five districts of Tigray: Tselemti and Medebay Zana in the northwestern zone, Na'eder Adet and Qolla Tembien in the central zone, and Kilte Awla'elo in the eastern zone (Figure 1). The Tigray region's geography is separated into three agro-ecologies: 8% highland (>2500 masl), 39% mid-highlands (1500-2500 masl), and 52 percent lowland (500-1500 masl) (Kibru et al., 2020). Tselemti and Qolla Tembien districts are classified as lowlands, while Medebay Zana, Na'eder Adet, and Kiltie Awla'elo districts are classified as mid highlands. Rainfall patterns in the study districts are mono-modal, with rain beginning in June and ending in mid-September.

Over 80% of the Tigray population relies on mixed crop and livestock production as a source of income. Over 95% of Tigray's cultivated land is dominated by smallholder farmers who rely on rain-fed agriculture for survival (Kibru et al., 2020). The main crops grown are sorghum, maize, Tef, wheat, millets, and barley for family food consumption and sesame and cotton for the market. The studied districts' average land holding per household is 1.27 hectares (own data elaboration). Information on the area, population, latitude, longitude, altitude, rainfall, and temperature of the study districts is given in Table 1.

2.2. Sampling design and sample size

Three stages of purposive sampling (to select sample zones, districts, and *kebeles*) and random sampling (to select sample respondent households) were used. Zones, districts, and the *kebeles* were purposively chosen based on their maize production experience and availability of nearby meteorological data (Table 2).

The lists of households available at sampled kebeles were used as sampling frames. A total of 250 sample farmers were drawn from a list of 2807 maize farmers. 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 0.05. Then the total number of household heads (HHHs) per *kebele* (the smallest administrative unit in Ethiopia) was determined using the Probability Proportional to Size (PPS) sampling method (McGinn, 2004). Finally, individual farm HHHs were randomly selected from each *kebele* and a total of 250 HHHs were interviewed.

2.3. Data sources and collection methods

The survey was carried out between January 2019 and May 2019 and data were collected from 250 maize farming households. In order to collect data in the research region, a variety of data collection methods were used, including interviews, personal observation, group discussion, and document analysis. For the study, both primary and secondary data were gathered.

Primary data were collected using a structured interview, focus group discussions (FGD), and key informants' interviews (KII) (Gebru et al., 2020) on the topics of climate change, perceptions, potential impacts on maize farming, current adaptation practices, social constraints (determinants) of adopting adaptation, and barriers that prevent farmers from implementing the already available adaptation strategies. Structured (closed-ended) and semi-structured (both open and close-ended) questionnaires were used to collect primary data from the sampled maize producers. The household heads (HHHs) were interviewed since they are crucial decision makers in the home. In the event that the male HHH was unavailable, his spouse was interviewed in his place. Moreover, to double-check the information obtained from individual farmers, the study was supplemented with qualitative and quantitative data collected through (FGD) and (KII), as rapid rural assessment tools (Dhanya & Ramachandran, 2016). Five FGDs (one from each district) were used to generate information.

The participants for the FGD included community leaders, religious leaders, village elders, model farmers, women, youth, and children in each Kebele comprising of 6–10 individuals per group. The KII who were familiar with the farming community were carefully chosen to share views on climate change, its causes, its effects on food security, and viable community adaption measures. Interaction with the KII was guided by questions similar to those used in the FGDs. The participants for the KII included researchers, zonal and district agricultural experts, development agents, and religious leaders (Gebru et al., 2020). Before conducting the data collection at the individual household level, the questionnaire was initially pre-tested to check its appropriateness, validity, and applicability (Eshetu et al., 2021).

The interview questionnaire focused on the maize farmers' experiences with climate change and agricultural production; their capacity to cope with past and future threats; barriers to successful adaptation strategies with a greater focus on moisture (i.e., rainfall and temperature); and ways to reduce threats and improve livelihoods through individual and collective action.

During the survey, farmers were asked about what they see, feel, and believe in the face of climate change. To determine whether a farmer has correctly perceived climate change and variability, all five major parameters (rainfall, temperature, drought onset/end of the rainy season, and dry spell) 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).

To determine whether a farmer has correctly perceived climate change and variability, all five major parameters (rainfall, temperature, drought onset/end of the rainy season, and dry spell) 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). Moreover, the relevant secondary data for this analysis (historical daily climate data on rainfall, max, and min temperatures) for 30 years (1988-2018) were obtained from the National Meteorological Service Agency (NMSA) of Ethiopia and were used for climate trend analysis.

2.4. Methods of data analysis

2.4.1. Descriptive analysis

Farmers' perceptions of climate change are defined as an aggregated awareness of the trend of five major climatic parameters (rainfall, temperature, drought, onset/cessation of the rainy season, and dry-spell) derived from empirical meteorological records collected in the research area over the last 20 years (Amadou et al., 2015).

Statistical analysis was performed on the social data collected from the sample houses using IBM's Statistical Package for Social Science (SPSS) software version 20 (IBM, 2012) and MS Excel spreadsheets. To examine the demographic and socio-economic features of the respondents and to highlight the varying levels of adaptation to climate change and tactics used, descriptive statistical measures such as mean, standard deviation, percentage, and frequency of occurrence were used. The meteorological data was analyzed using gridded data from Ethiopia's NMSA, and so quality control was met (hence no missing data). Results of the analyzed data were presented using figures and tables. Content analysis was used to investigate the qualitative data collected using focus group discussions and key informant interviews (Gebru *et al.*, 2020).

2.4.2. Econometric (choice) analysis

In this study, the MNL model (the multinomial logit analysis) was used to examine factors influencing farmers' choice of different adaptation strategies applied by the farm-households in the study area. The MNL model is suitable for estimating the likelihood that a given option is more preferred than other available options, with the assumption that the available options are mutually exclusive (Gebre *et al.*, 2013).

According to Greene (2003), farmer ***i*** decides to use *the jth* 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.

The independent irrelevant alternative (IIA) assumption is required by the equation of the MNL model, according to Bryan et al. (2009), because the model suffers from problems of independence and works under the assumption of IIA, which states that the ratio of the probability of choosing any two alternatives is independent of the attributes of any other alternatives in the set of choices. Hausman test (Hausman & McFadden, 1984) was used to test the validity of the IIA assumption.

Normalizing the "no adaptation" strategy to climate change as a reference category for analysis was used to estimate the MNL model (Gebru et al., 2020). The MNL model's parameter estimates (called coefficients) only reveal the direction of the independent variables' effect on the dependent variable, not their magnitude or probabilities. As a result, marginal effects or marginal probabilities are functions of probability itself, measuring the expected change in the chance of a given choice being chosen in response to a unit shift in an independent variable from the mean, and are computed as:

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

The Variance Inflation Factor (VIF) technique was employed to detect the problem of multicollinearity for **continuous** explanatory variables; i.e., there must not be collinearity among the independent variables. To check this, the MNL model uses a test called VIF (variance inflation factor).

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

Where: VIF is 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 relation exists between the explanatory variables, then multicollinearity is a problem expected with a large value of R^2 in at least one of the test regressions.

The contingency coefficients were calculated as:

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

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

Finally, only statistically significant explanatory variables were discussed after the data used to analyze the hypothesized explanatory variables that were expected to affect the choice and adoption of adaptation strategies to climate change were subjected to the MNL regression model, embedded in the STATA-13 (StataCorp, 2015) econometric software.

2.4.3. Description of variables and their working hypothesis used in the MNL model

2.4.3. 1. Dependent variables

Due to a variety of socioeconomic, institutional, and environmental circumstances, the majority of smallholder farmers employ a combination of adaptation techniques, while some do not apply any adaptation strategies at all (Gebru et al., 2020). Six alternative adaptation options (five on-farms and one off-farm) and the no-adaptation option as a base category were employed as dependent variables in this study for use in the MNL model. The baseline category refers to a system's current state against which change is measured.

In this study, the dependent variable is whether a maize household has 'adopted' or 'not adopted' any climate change adaptation strategy (Table 3). Many research (e.g., Ndamani & Watanabe, 2016; Bila et al., 2015; Gutu, 2015) have found that, as a result of climate stress, African farmers employ a diverse spectrum of on-farm, off-farm, and non-farm coping techniques. However, socioeconomic characteristics and resource availability have been found to have an impact on farmers' climate change adaptation intentions and actions (Dang et al., 2014).

2.4.3. 2. Independent variables

In this study, the most essential set of explanatory variables that influence farmers' decisions to pick and implement among the numerous possible adaption strategies were examined. Table 3 summarizes and presents the list of these explanatory variables, as well as their projected working casual effects (signs). It was expected that these explanatory variables will impact farmers' adaption strategy choices and decisions.

3. Results and Discussions

3.1. Demographic characteristics of the respondents

According to the results of the survey, male families accounted for 89.6% of the 250 respondents, while female households accounted for 10.4%. (Table 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, with a minimum of 22 years and a maximum of 81 years; 24.8% were above 55 years old, making them particularly vulnerable to climatic stress (Pickson & He, 2021).

The agricultural production system differed, with 13.2% of farmers specializing in crop production and the majority (80%) of farmers relying on crop-livestock (mixed) farming as their primary source of income (Table 4). According to Robinson & Bernard (2015), integrating crops and cattle at the farm level maximizes nutrient cycling, boosts overall farm output, and improves diet quality. Off-farm revenue activities (e.g., local brewing, traditional gold mine, wage work, church service, hair dressing, guarding, blacksmith, petty trade, local house construction, traditional singer, charcoal making, and so on) are also used by maize farmers to supplement their income (Table 6).

Among the 250 sampled farmers, 30% are illiterate;; 33.2% have a primary education (1-4 years of schooling), and only 8.4% have a high school education (9-12 years schooling). The average year of education was 3.74 years, indicating that the majority of respondents did not finish primary school (4 years of schooling). Climate change sensitivity is reduced by education because it provides victims of climate change with alternate adaptation alternatives (Pickson & He, 2021). However, more than 53.2% of respondents had a poor level of education (less than four years of schooling), indicating that the farmers are especially vulnerable to climate change risks as a result of their lack of education (Pickson & He, 2021).

The average household size was 6.32 family members; 18.8% of respondents had up to four family members, and 71.2% had five to eight. In farming livelihoods, the size of a family member is considered as a work force (Ndamani & Watanabe, 2016). The average size of a farm per household was 1.27 hectares (highly affected by the larger landholding size of Tselemti district which is lowland). Farmers with more than 1 hectare of land are likely to have a positive impact on their perception and implementation of various climate change adaptation techniques (Assefa *et al.,* 2020). Increased land size, for example, encourages farmers to try out new agricultural practices like tree planting, livestock rearing, crop diversification, and so on (Tesfahunegn et al., 2016).

Farmers owned an average of 6.04 TLU and 1.56 oxen in terms of livestock. The majority (44.8%) of the farmers had a pair of oxen and only a few farmers (11.2%) had more than two oxen. In the study area, the livestock included cattle, shoats, equines, and poultry. TLU conversions do not include beehives. TLU is a direct measure of food security and household resilience, and having a larger quantity of livestock ensures alternate means of survival beyond the agriculture sub-sector (Gutu, 2015). In the study area, animal ownership is extremely important; not having any oxen is deemed unworthy of a farmer's livelihood.

3.2. Farmers' perceptions of climate change trends and adaptation strategies

The study focused on understanding if farmers' perceptions of climate change match with historical climate (mainly rainfall and temperatures) record for the period 1989 to 2018, and identifying determinants of adaptation in Tigray, northern Ethiopia.

3.2.1 Farmers' perception of annual and main season climate changes

According to the findings, 86.15% and 84.88% of farmers (averaged over the five study districts) saw an upward trend in mean annual and main season (summer) temperatures, respectively (Table 5). Furthermore, the findings found that 87.6% and 80.8% of farmers, respectively, believed that annual and main season rainfall patterns had reduced (Figure 2). The main season months for this research area are July, August, and September.

Concerning farmers' perception of rainfall during the main season, the majority (45.2%) of the farmers perceived that the late onset of rainfall during the main rainy season is the main indicator of climate change (Figure 3).

The descriptive results (Table 5, Figures 2 and 3) revealed that the majority of farmers in the study districts believed rainfall levels had decreased and temperatures had risen. In line with this, Tessema *et al.* (2013) reported that, the majority of Ethiopian farmers are aware that the temperature is rising, while Belay et al. (2017) observed that rainfall amounts have dropped.

3.2.2 Comparing farmers' perception of climate change with empirical climatological data

Climate change and variability were perceived by the majority of respondents (91.2%) in the research area during the past 15 years and beyond. Farmers' perceptions of long-term temperature and rainfall trends have been supported by recorded meteorological data from the stations. According to the findings, throughout the last 30 years, 88.4%, 83.2%, and 79.2 % of farmers observed less rainfall, increased temperatures, and increased frequency of drought, respectively, and as a result, the area became drier (Figure 2).

In this study, the farmers' most pronounced indicator of climate change is rainfall, followed by temperature. In line with this result, Amadou *et al.* (2015) reported that in climate change studies, farmers' perception of climate change is typically based on the perception of average change of rainfall and temperature which are the main climatic parameters utilized.

Furthermore, Belay et al. (2017) discovered that changes in rainfall distribution and amount have resulted in low precipitation and frequent drought, affecting Ethiopian agriculture. Moreover, according to Kahsay et al. (2019), 95.28 % and 77.5 % of families in Tigray, respectively, saw a drop in rainfall and an increase in temperature, and are thus aware of climate change and variability based on their local experiences.

According to the results of meteorological data analysis, temperature (Tmax. and Tmin.) increased in trend over the study period (1989-2018), and farmers' perceptions of an increased temperature trend were compatible with true historical records (figure 5). However, the meteorological data for the annual rainfall indicated a decreasing trend which was not statistically significant.

Farmers' perceptions of decreased rainfall during the last 30 years, on the other hand, are at odds with the findings of rainfall data analysis and earlier publications (Waongo et al., 2015). Differences in research periods and drought interpretation, with an emphasis on meteorological drought rather than farmers' assessment of agronomic droughts, may explain the divergence between public perception and historical meteorological records on rainfall changes. Scientists often examine climate data at different timescales than those relevant to farmers and agricultural growth, potentially leading to differences in farmers' perceptions and observable data (Limantol et al., 2016). Most of the technical support necessary for effective farmer adaptation arrives either too late or in some cases not at all. As a result of this situation, many farmers now lack credible climate adaptation information, particularly regarding the arrival and cessation of rainfall (Antwi-agyei et al., 2012).

Analysis of historical temperature data (1989-2018) from the nearby observatory stations revealed that both annual and seasonal temperatures in the study areas had an increasing trend (Figure 5). In addition, an increasing trend of annual temperature has been observed. Similarly, Gebrehiwot and van der Veen (2013) depicted that for the period 1954-2008, both mean minimum and maximum temperatures in Tigray had increased.

3.2.3 Farmers' perception of causes of climate change

According to the findings (Figure 6), the primary reasons of climate change as viewed by farmers are Devin's anger (36.8%), growing human population (32.8%), deforestation (13.6%), and harmful human behaviors (11.2%). The majority of farmers felt that the primary cause of climate change is God's wrath on human sins as a symbol of punishment for disobedience and unfaithfulness to His rules.

The farmers also believe that they are often at the mercy of natural forces they cannot control, especially drought which is caused by the season to season and year to year change in rainfall. This is consistent with the findings of Debela *et al.* (2015), who found that a large number (45%) of Borana smallholders in Southern Ethiopia believe humanity is cursed and those supernatural powers are the principal cause of climate change. Similarly, Thistlethwaite (2010) indicated that when talking about the causes of climate change, most farmers have often been considered it as "acts of God". However, this perception indicates a lack of proper scientific understanding because climate change occurs primarily as a result of human activities (Murtaza *et al.*, 2019); through the emission of greenhouse gases (GHGs) released mainly by the burning of fossil fuels and forests.

3.2.4. Farmers' perceptions on climate change-induced hazards

Drought (36.8%), new incidences of crop and animal diseases, insects (stem and root borers in maize), and weed species (24.4%), flood (18%), hailstorm (12.8%), and water logging (8%) were the most commonly stated climate change threats in the study region (Table 6). Drought, brought on by rising temperatures and a gradual decrease in rainfall, impacted agricultural production, putting farmers' food security at risk. According to Kassie *et al.* (2013), as referenced by Belay et al. (2017), changes in the distribution and amount of rainfall have impacted Ethiopian farmers, resulting in low precipitation and frequent droughts. Furthermore, according to Thistlethwaite (2010), the world is experiencing the effects of climate change: water and air temperatures are rising at alarming rates; the devastation caused by severe droughts and floods is increasing; new diseases are emerging and old diseases are spreading; people's health is being harmed and deaths are on the rise; and hunger is expected to escalate.

Farmers are directly affected by climate change through extreme weather patterns known as hazards (e.g., drought, flooding, and pest and disease-friendly conditions) and indirectly through changes in water, air, food (quantity and quality), ecosystems, agriculture, and the economy (FAO, 2016; Thistlethwaite, 2010). Another source of sensitivity to climate dangers is smallholders' inadequate risk management skills.

Farmers of the study area have experienced a lot of extreme weather hazards**,** for a long time, particularly droughts. Accordingly, the respondents claimed that climate change-induced shocks have resulted in depletion in soil fertility (83%), a decline in livestock feed (82.6%), biodiversity loss (82.4%), a decline in surface water sources (80%), and crop yield reduction (78%) (Figure 7). Moreover, the respondents have indicated that climate change had caused a high incidence of pests (seriously maize stem and root borers) and diseases, which negatively affected both livestock and crop production, which are manifested by low productivity which directly influences food security. This is in line with the findings of Maya *et al.*, (2019) and FAO (2016) which reported that higher and fluctuating temperatures and changes in rainfall caused by climate change and extreme weather events have reduced crop production; lead to shortages of drinking water, an increased incidence of crop and livestock pests and diseases, and changes in their distribution and transmission.

The results of FGDs and KIIs also revealed that climate change-induced shocks have resulted in a variety of losses: rains have become more erratic, and when they did come, they were often in heavy fall, causing floods, resulting in a decrease in soil nutrients and an increase in erosion during the main rainy season. Crop yields are declining as a result of climate change, insect impact on crops is increasing, rainfall are becoming more unpredictable and torrential when they do arrive, malaria is back, and dengue illness is now year-round, according to Shafer (2017). Maize farmers in Tigray have recently reported lower crop yields due to climate change, which has been exacerbated by high temperatures and limited precipitation (Figure 6). This is consistent with Gebrehiwot's (2013) results, which said that droughts of varied intensity and duration occur in semi-arid parts of northern Ethiopia. As a result, greater utilization of available rainfall, understanding the effects of climate variability, and soil and field management on agricultural production are critical to increasing crop yields and reducing production risks.

3.2.5 Climate change adaptation strategies practiced by maize farmers

To combat the effects of climate change and variability, the maize farmers pursued crop-livestock integration (24%), use of improved crop seeds (20.8%), changing crop type and/or adjusting cropping calendar (16.8%), involvement in irrigation activities (15.6%), implementation of SWC practices (9.2%) and involvement in off-farm activities (6.4%) as the most dominant and frequent adaptation measures (Table 6). This is in line with the findings of Gebru et al. (2020), who found that the least followed adaptation option in Tigray is switching from the prevalent crop-livestock integration practice to either pure crop production or pure livestock husbandry. Only 3.2% of farmers (Table 4) have no livestock at all and rely only on crop production, but this is due to poverty rather than a conscious decision to specialize in crop cultivation.

For the sake of profit maximization, farmers frequently employ a limited set of adaption options. In many cases, farmers in the study region have adopted many coping strategies to adapt their farms to the effects of climate change and variability. However, the application of any adaptation method varies from farmer to farmer and from location to location. As a result, maize producers utilized a variety of adaptation measures to mitigate the detrimental effects of climate change.

Based on discussions held with FGDs, KIIs, review of the literature, and field observations, the widely practiced adaptation strategies identified included: crop-livestock integration (24%), use of improved crop varieties (20.8%), changing crop type, and/or adjusting planting/harvesting dates (16%), irrigation (15.6%), SWC practices (9.2%), and involvement in off-farm activities (6.4%) (Table 6). Many research findings in SSA support this; for example, farmers in Tigray showed better participation in farm diversification (manuring, ridging, and terracing) and crop-livestock integration (Gebru *et al.,* 2020); farmers in Ethiopia's rift valley have used agricultural production approaches to boost crop productivity under climate change through the application of modern agricultural inputs, primarily improved crop varieties, agronomic practices, and crop-livestock integration (Sime and Aune, 2018).

3.2.6. Barriers to the use of adaptation practices by maize farmers

Farmers' perceived constraints that make it harder for them to plan on using adaptation strategies to climate change have resulted in the identification of eight primary constraints (Table 7). The major ones are the high cost of farm inputs (88.4%), lack of access to water for irrigation (86.6%), lack of capital (84%), and the unpredictability of weather (83.2%). This agrees with the findings of Gebru *et al.*, (2020) who identified that low technical skills on the application of the adaptation measures, lack of capital, shortage of farm-land, high population pressure, lack of coordination, and follow-up to work together were pointed out as core reasons for the low application of the adaptation actions to climatic change in Tigray. Farmers also reported that the high cost of farm supplies exacerbated their problems. This is backed by FAO (2016) research findings, which showed that smallholders suffer particular difficulties in overcoming barriers to the adoption of new technology and practices due to financial constraints. Smallholder farmers are unable to afford the transaction costs of adaption measures due to a lack of finance facilities, and the lack of water resources (e.g. dams and dug-outs) makes irrigation practice unfeasible, according to Ndamani and Watanabe (2016).

3.2.7 Determinants (social constraints) of adaptation choices to climate change

The MNL model was used to analyze the determinants of farmers' choice of adaptation techniques to climate-related shocks using discrete dependent variables with livelihood factors as multiple choices. The estimated coefficients of the MNL model, as well as their levels of significance, were determined by combining the use of adaptation tactics by smallholder farmers (Table 7). Normalizing the "no adaptation" strategy to climate change as a reference category for analysis was used to estimate the MNL model. The Chi-square statistics suggested that the maximum likelihood ratio statistics were highly significant ($p< 0.0001$), indicating that the model has a good explanatory power (Gebru et al., 2020).

An important assumption of the MNL model is the Independence of Irrelevant Alternatives (IIA) and the model was tested using the Hausman test to see if it fulfills the assumption. The Hausman test supported that the IIA is not violated because $\chi2$ ranged from -31.02 up to 8.88 with probabilities almost equal to 1.0. Moreover, to make sure that the continuous explanatory variables do not create the problem of multicollinearity, auxiliary regression was fitted and VIF was calculated. All the VIF values were less than 10 (1.05 up to 1.41), indicating no serious problem of multicollinearity (Gebru *et al.*, (2020) and it is safe to assume the absence of multicollinearity. Similarly, the contingency coefficient was calculated and checked for the categorical independent variables to detect if a problem of strong association exists. The results of all the coefficients were less than 0.75., indicating an absence of a strong association among the explanatory variables in the model estimation as described by Gujarati (2004) and Feleke *et al.* (2016). Therefore, all the hypothesized continuous and categorical explanatory variables were well included in the model.

The results of the MNL model tests also showed that both tests failed to reject the null hypothesis of independence of the climate change adaptation options, suggesting that the MNL specification is appropriate to model climate change adaptation practices of smallholder farmers. Thus, marginal effects, which measure the expected change in the probability of a particular choice being made concerning a unit change in an independent variable were calculated and presented (Table 7).

The regression coefficients, average marginal effects (ME), and their significance levels (p-values) were calculated using the MNL model results to determine the likelihood of a given adaptation method for a unit change in the independent variables (Table 8). The regression coefficient parameter estimations only show the direction of the effect of the independent variables on the dependent variables, i.e., a decrease (-ve sign) or an increase (+ve sign), but not the actual magnitude of change in probability. As a result, marginal effects were calculated and reported in, which measure the magnitude of change in the probability of making a certain decision for a unit change in an independent variable (Table 8).

Gender, age, family size, farm size, education, farm income, access to climate information, livestock ownership, and access to credit were significantly affected using one of the alternative climate change adaptation strategies identified by the maize farmers. As a result, certain variables that have a considerable influence on the choice of climate change adaptation decisions are examined and discussed below.

Gender of the household: The gender of the household head is one of the most important HHH factors that determines farmers' choice and execution of agricultural adaptation techniques to mitigate the negative effects of climate change. The results of the MNL model revealed that being a male HHH improved climate change adaptation, i.e., when the household is led by a male, the likelihood of altering crop variety, planting and/or harvesting date, and SWC activities as a climate change adaptation strategy increased (Table 8). These SWC practices are well acknowledged to be problematic for female-headed households due to their labor-intensive nature. As a result, for one unit increase in a household being male-headed, adopting these two adaptation strategies increases by 8.1% and 7.2% respectively at a 5% significant level. This result is in line with the research findings of Nordhagen & Pascual, (2013) who found that larger HHHs headed by males were more likely to use crop-related adaptation strategies (e.g. purchase of seeds). Similar studies by Kom *et al.* (2020), Tadesse *et al.*, (2009) and Tazeze *et al.*, (2012) found that households headed by older males were more likely to implement crop adaptation measures. This may be due to the fact that men execute the majority of farming tasks while women are more involved in processing, giving male-headed households an advantage in terms of farming experience and understanding of various adaptation strategies (Asfaw et al., 2019; Tazeze et al., 2012). According to Gebre et al. (2013), having a male head of household increases the ability and variety of climate change coping mechanisms.

Age of the household: Because the HHH's age indicates experience, the farmer is supposed to gain greater experience and skills in farming as he or she becomes older. The MNL model revealed that the HHH's age had a positive and significant impact on the adoption of mixed farming (crop-livestock integration) and irrigation activities as adaptation measures to mitigate climate change's negative effects (Table 8). That is, as the household head's age rises by one year, the likelihood of these two adaptation techniques being utilized by maize farmers rises by 1% at $p< 0.1$ and $p< 0.05$, respectively. Antinuke & Mebrat (2016) observed that the age of the household head was positively and significantly connected with crop diversification, which supports this finding. Similarly, Misganaw et al. (2014) found that as people get older, they gain more farming expertise, which improves farmers' ability to respond to climate change dangers.

Changing crop type and/or planting date, on the other hand, had a negative correlation with HHH age, i.e., a unit increase in HHH age negatively (-0.077) affected and significantly reduced the probability of using this adaptation strategy by 1.2% at $p<0.05$, implying that older farmers are less likely to use this adaptation strategy due to their old age and lack of energy to do so actively. This result is consistent with Antinuke & Mebrat (2016), who found that older household heads were less likely than younger ones to employ labor-intensive activities as an adaptation measure.

Educational level: Education is linked to the development of problem-solving abilities. The MNL model revealed that education had a considerable beneficial impact on the use of improved crop varieties and irrigation methods as climate change adaptation strategies (Table 8). That is, as the education level of the household head increased by one year, the probability of using the use of improved crop varieties as an adaptation strategy by the household increased by 3.7% (at $p < 0.05$) and irrigation practices as adaptation strategies by 1.3% (at $p < 0.1$). Farmers with a higher level of education were more likely to use improved crop types and irrigation techniques. This means that literate farmers are more likely to respond to changes by weighing options that best suit their knowledge, interests, and talents. In agreement with this result, Tadesse et al. (2009) also found that households with more education were more likely to undertake crop adaptation strategies.

Family size: The family member is regarded as a work force for farm operations such as livestock care, plowing, weeding, terracing, fertilizer or seed application, and so on, all of which increase production and, as a result, it raises their income and livelihood. As shown in Table 8, family size positively affected and significantly increased the probability of crop-livestock integration (mixed farming) by 1% ($p<0.01$) and involvement in off-farm activities by 0.7% ($p<0.001$) as adaptation strategies to reduce the negative impacts of climate change. Farmers benefit from the size of their families since it provides them with a supply of labor that allows them to complete farming tasks on time and efficiently. This is consistent with the FGD and KII replies, which said that young rural-to-urban migration in quest of wage labor is a key feature of the research areas. Similarly, according to a study by (Ndamani & Watanabe (2016), the visible tendency of larger households to adjust to climate change is likely owing to their higher labor endowment.

However, household size negatively affected and significantly reduced the probability of using most of the adaptation strategies, e.g., use of improved crop variety, changing crop type and/or planting and/or harvesting date, and SWC practices. This negative association could be due to the fact that a household with more dependent members (e.g., under-age children) may rely primarily on outside wage labor (Tesfahunegn et al., 2016); or households with large families may be forced to divert part of their labor force to off-farm or non-farm activities in an attempt to earn income in order to alleviate the consumption pressure imposed by a large family rather than adopting the other adaptation strategies (Tazeze et al., 2012).

Farm size: According to the MNL model results, the HHH farm size was found to be positively and significantly linked with the majority of the maize farmers' adaption strategies (Table 7). Except for SWC practices and participation in off-farm activities, increasing farm size by one hectare per household would improve the likelihood of implementing most of the adaptation options. Hence, as the farm size of the household increased by one hectare, it positively and significantly increased the probability of adoption of crop-livestock integration by 17.2% (at $p<0.001$), use of improved crop varieties by 1.9%, changing crop type and/or planting date by 1.2% and practicing irrigation activities by 0.1%, all at $p<0.1$, as adaptation strategies to reduce the negative effects of climate change. The positive correlation is most likely due to the fact that larger farms allow farmers to engage in a variety of agricultural activities (Eshetu et al., 2021). In line with this finding, Westengen & Brysting (2014) found a strong positive relationship between farm size and maize producers' utilization of improved crop varieties.

Household income: Farmers' employment of adaptation strategies is influenced by a variety of factors, including economic factors, because any adaptation investment requires capital that must be recouped with a minimum amount of profit (Gilbert, 2012). From the results of the MNL model shown in Table 8, household income has positively and significantly increased the probability of adoption of crop-livestock integration (mixed farming), irrigation practices, and involvement in off-farm activities as adaptation strategies to reduce the impacts of climate change on maize production, i.e., as the income level of the household head gets increased by one unit (i.e., 1000 ETB), the probability of choosing 'crop-livestock integration', 'irrigation practices', and 'involvement in off-farm activities' instead of the baseline category *("no adaptation")* rises by 8.4 (at $p<0.05$), 6.2 (at $p<0.05$), and 1.2 (at $P< 0.01$) percent points, respectively. This finding is consistent with previous findings that wealthier farmers are more likely to use adaptation practices in response to climate change than poor farmers (Ndamani & Watanabe, 2016); households with higher income were more likely to undertake crop adaptation strategies (Tadesse et al., 2009); and when the household farmer's main source of income increases, farmers tend to invest in productivity smoothing options such as irrigation (Tazeze et al., 2012).

Livestock ownership (TLU): Farmers' preferences for climate change adaptation strategies are influenced by the number of TLUs held by the household head (Alem et al., 2016). As shown in Table 8, household livestock ownership has a good and significant effect on crop-livestock integration (mixed farming) and SWC practices as adaptation techniques. That is livestock owners are more likely to practice crop-livestock integration and SWC practices than those without livestock; as the number of TLU of the household increased by one unit, the probability of using these adaptation strategies to minimize the negative effects of climate change by the maize farmer household increased by 0.5% (at $p<0.05$) and by 1% (at $p<0.01$), respectively. This finding is consistent with Tazeze et al. (2012), who stated that livestock plays a significant role in soil fertility management by supplying traction (particularly oxen) and manure, as well as serving as a source of revenue to acquire improved crop varieties. This is also in agreement with Mensah (2011), who stated that poor farmers in SSA tend to use manure or other on-farm fertility alternatives for maize production because they cannot afford the high cost of fertilizers; thus, livestock ownership is the best means of farmers' livelihood in the study area.

However, owning cattle has a negative and considerable impact on the likelihood of using most of the other adaption alternatives. For example, a unit increase of the number of TLU by the household significantly reduced the probability of changing crop type and/or adjusting planting date by 1.1% (at $p<0.01$), practicing irrigation activities by 0.2% (at $p<0.05$) and involvement in off-farm activities by 0.1% (at $p<0.01$). This is likely due to farmers' inclination to focus on the care of their cattle rather than alternative adaption measures that may yield a lower return on investment.

Access to climate information: The MNL model's results (Table 8) revealed that the household head's access to climatic information is favorably and significantly associated to modifying the crop/planting/harvesting date, as well as participation in off-farm activities. Farmers with access to climate information were more likely to change crop/planting/harvesting dates and participate in off-farm activities as CC adaption methods. Even though service on climate information delivery is not formal, access to getting information about seasonal forecasts and climate change from different sources has positively and significantly affected the use of changing the crop/ planting/ harvesting date by 16.8% ($p<0.1$) and involvement in off-farm activities by 14.4% ($p<0.05$) as adaptation strategies to reduce the impacts of climate change on maize production. This result is supported by a study conducted by Tazeze et al., (2012), who stated that having better climate information allows farmers to compare alternative adaptation strategies and so choose the ones that will help them cope better with climate change in their location. Pickson and He (2021) also found that supplying farmers with climate information increases their knowledge of weather threats; but, because most farmers do not have access to these services, they may have a limited ability to react to climate change (Pickson & He, 2021).

Credit access: The study's findings (Table 8) revealed that higher access to credit facilities increases the likelihood of households using improved crop varieties, shifting crop/planting/harvesting dates, and using irrigation activities as climate change adaptation methods. That is, as the household's access to credit services increases by one unit, it significantly increases the probability of using these three activities as an adaptation strategy by 16.5% ($p<0.1$), 11.7% ($p<0.05$), and 19.8 % ($p<0.01$) respectively. This result is consistent with earlier findings that access to affordable financing improves farmers' financial resources and their capacity to meet transaction expenses connected with various adaptation choices they may choose to pursue (Nhemachena and Hassan, 2008). Similarly, Ndamani & Watanabe (2016) found that farmers that receive institutional services are more likely to use adaptation strategies because they can share information, address difficulties, share ideas, and make joint decisions. This finding suggests that improved institutional support is critical in encouraging the use of adaptation strategies to mitigate the negative effects of climate change (Tazeze et al., 2012).

4. Conclusion and Recommendation

The findings of this study revealed that farmers were aware of the features of climate change, its causes, and its impacts on agriculture, and that they had perceived it, as evidenced by temperature and drought increases, as well as a decrease in rainfall amount. The most significant climatic shock influencing maze productivity has been drought. Divine's wrath and the ever-increasing population number, according to the majority of farmers, were the primary reasons of climate change. Climate change is causing maize producers to confront substantial challenges such as decreased crop yields, decreased soil fertility, and higher incidences of new diseases, insects, and weed species. Crop-livestock integration, the use of improved maize cultivars, changing crop type, adjusting cropping calendar, participation in irrigation activities, implementation of soil and water conservation practices, and participation in off-farm activities were the most common adaptation strategies used by the farmers to adapt to climate change.

Gender, age, credit availability, education, wealth, family size, and climatic information were some of the primary socio-economic characteristics that influenced farmers' perceptions and decisions about employing adaptation measures. Despite knowing the need of various adaptation tactics in maize farming, the majority of farmers do not fully implement them. Poverty, the unpredictability of weather, a lack of/limited farmland, a lack of reliable weather information, 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) were among the major obstacles to their struggle to adapt to climate change.

This research provides empirical evidence of subsistence agriculture in a rapidly changing climate and an urgent need for solutions. As a result, the farmer should be the beginning point for finding a clear and real response to the issues posed by climate change. At both the farmer and farm level, government agricultural policies and investment strategies must play a vital role in addressing the climate crisis.

Government and non-government organizations should focus their investments on providing direct support to these subsistence farmers, such as training and the provision of yield-increasing crop technology packages, integrated use of on-farm and off-farm fertilizers, credit access, education, improving farmers' access to irrigation water, and improving farmers' access to weather forecasting information. Furthermore, developing capacity for off-farm income-generating activities is critical because it allows farmers to engage in activities that are less vulnerable to climate change. As a result, it is critical to assist farmers' indigenous adaptation techniques from a variety of institutional, policy, and technology perspectives.

Abbreviations:

CC: contingency coefficient; **FGD**: focus group discussions; **HHH**: household head; **IIA**: independence of irrelevant alternatives: **KII**: key informants' interviews; **ME**: marginal effect; **MNL**: multinomial logit model; **NMSA**: national meteorological service agency; **TLU**: tropical livestock unit; **VIF**: variance inflation factor.

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Figures

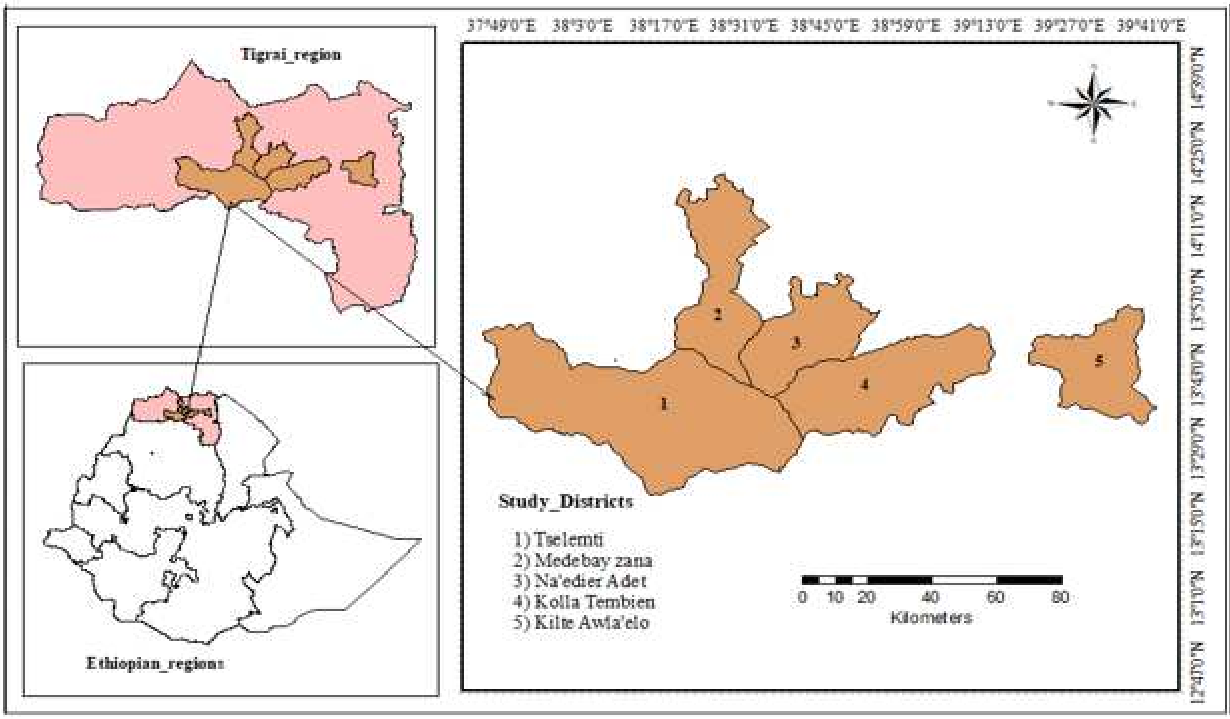

Figure 1

Location map of the study districts

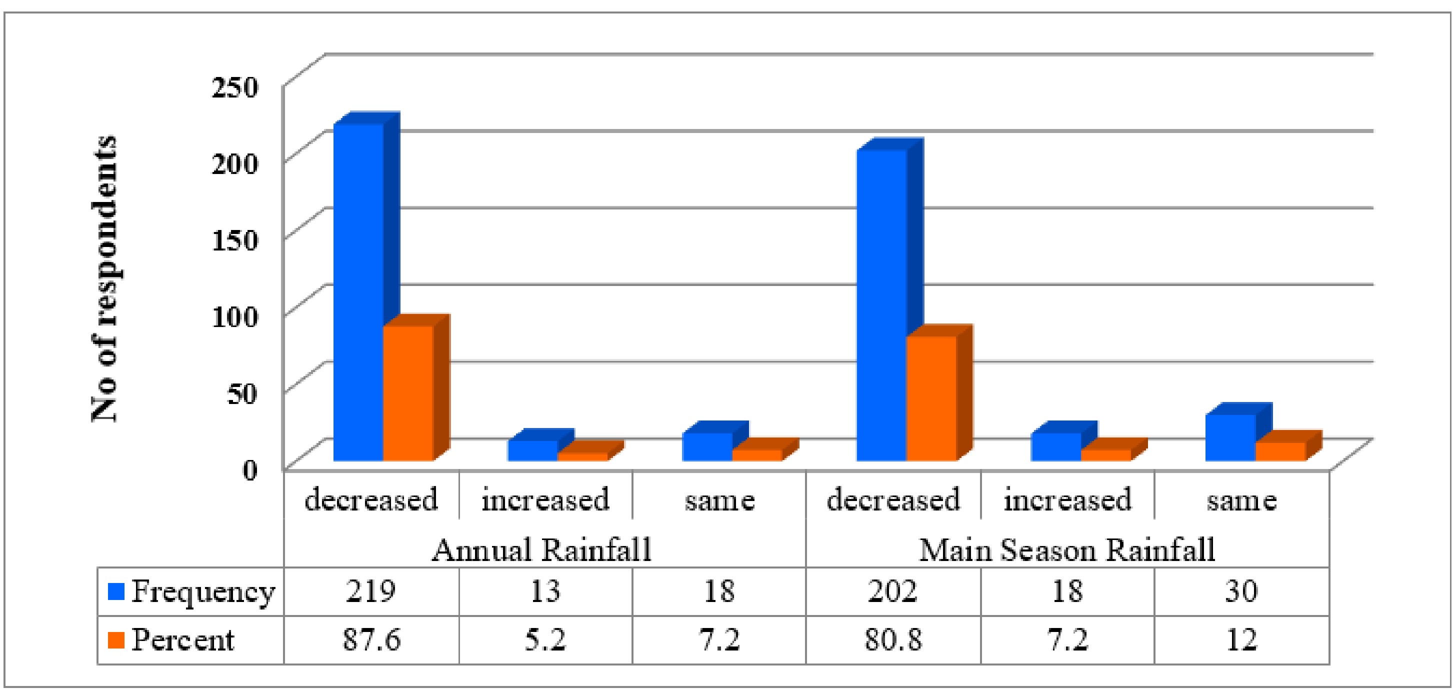

Figure 2

Farmers' perceptions on annual and main season rainfall patterns (N=250).

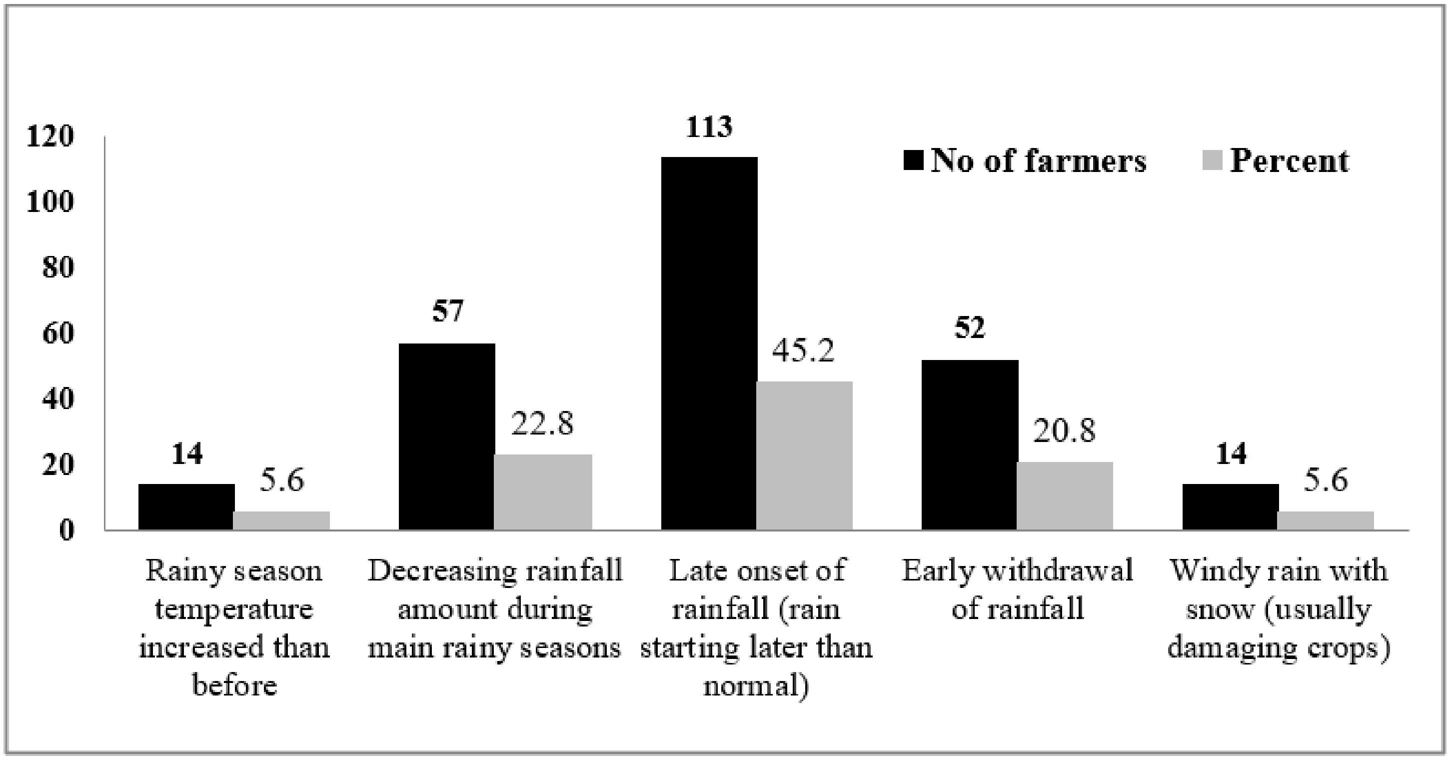

Figure 3

Farmers' perception of the major rainfall features during the main season (N=250).

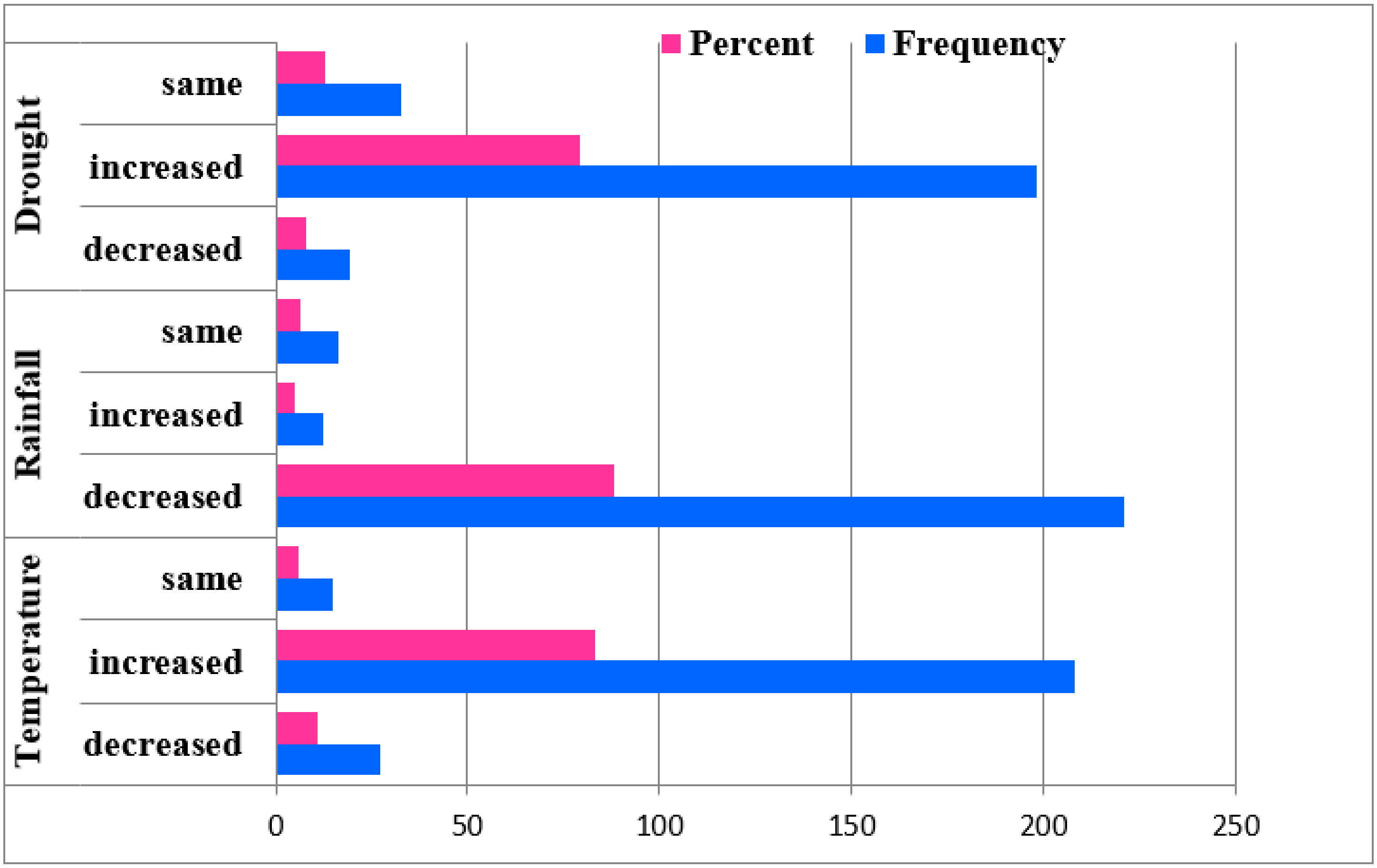

Figure 4

Farmers' perception of long-term climate change and indicators of change in Tigray.

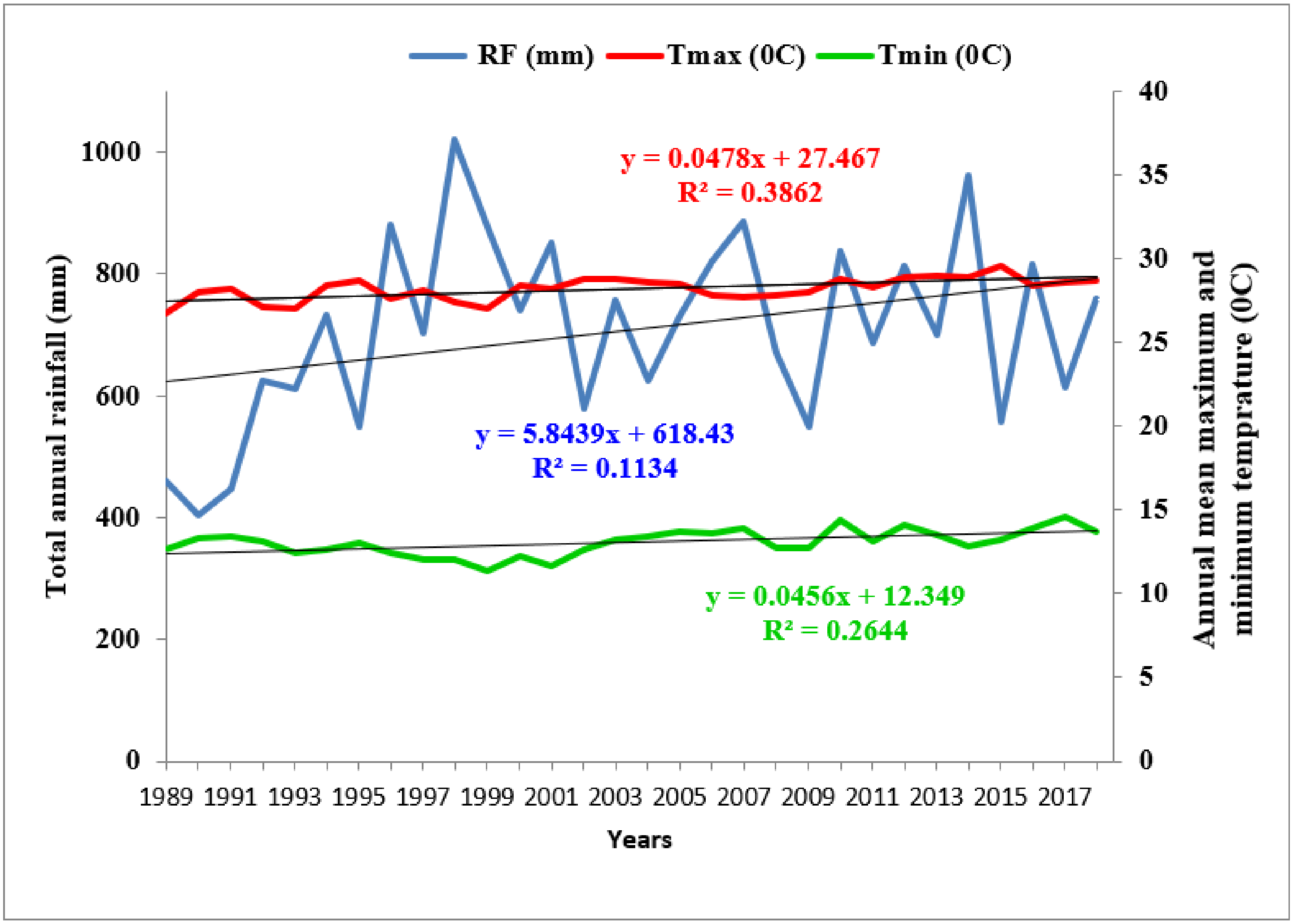

Figure 5

Trends of annual rainfall and temperature of the study area (1989-2018)

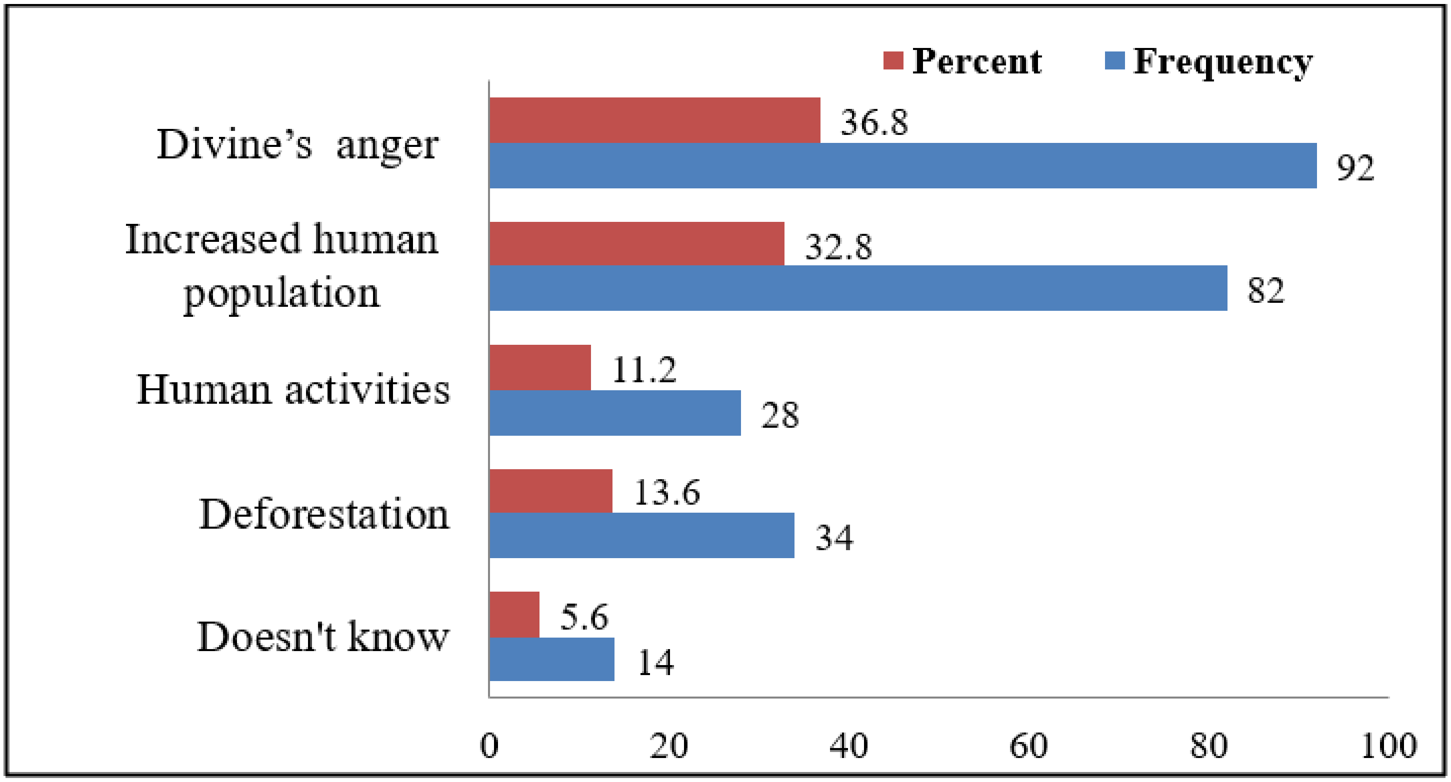

Figure 6

Farmers' perception of causes of climate change

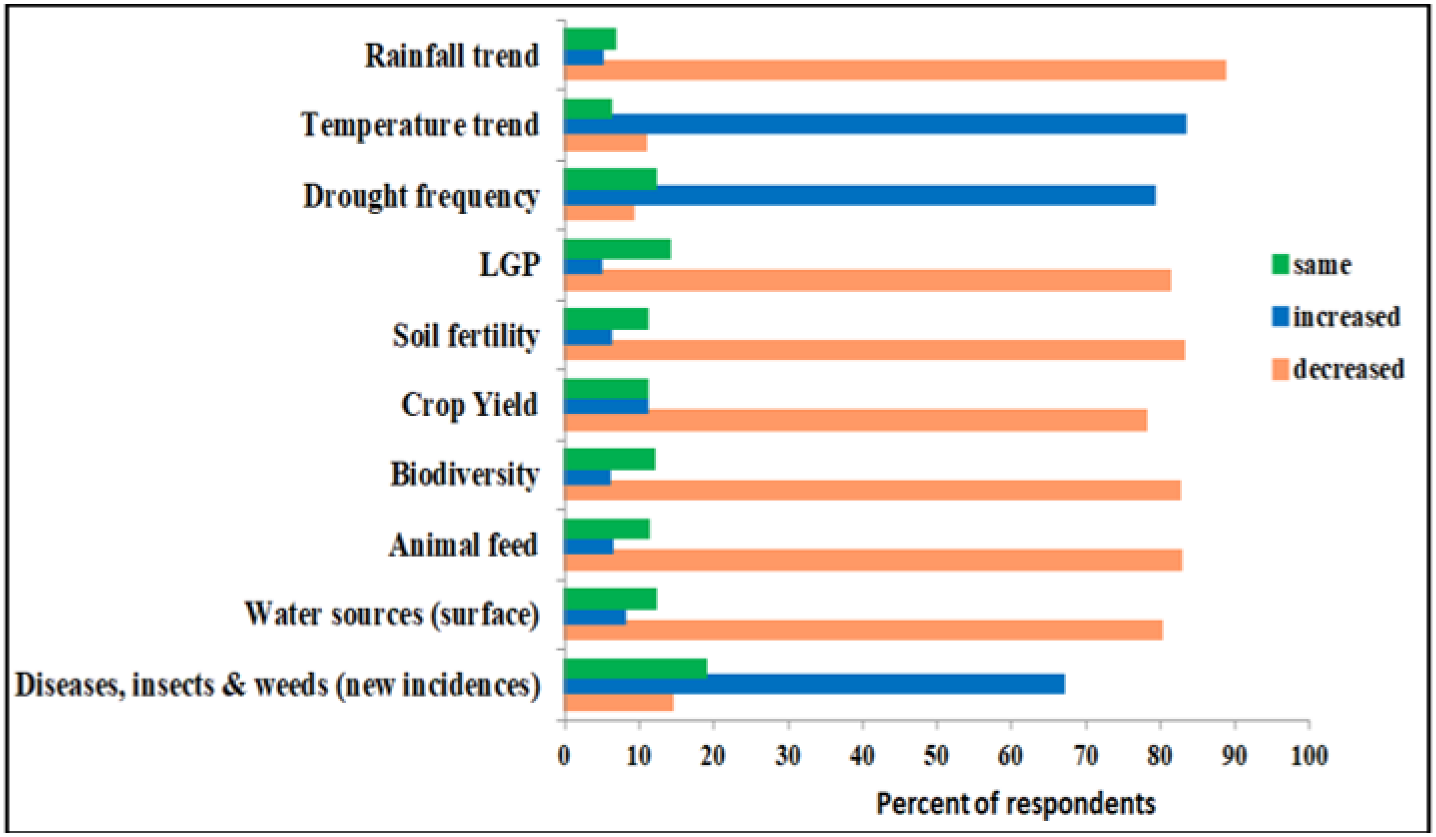

Figure 7

Farmers' perception of climate change impacts. LGP: length of the growing period.

Supplementary Files

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- Tables.docx