Heliyon 6 (2020) e03867

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia

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ARTICLE INFO

Keywords:
Climate change
Adaptation strategies
Binary logistic regression
Gondar zuria district
Agricultural science
Environmental science
Earth sciences
Biological sciences
Sociology

ABSTRACT

Climate change is a major environmental and socioeconomic challenge in Ethiopia in recent decades. The study site is one of the climate change prone areas affected by climate variability and extreme events. Therefore, a better understanding of area-specific and adaptation is crucial to develop and implement proper adaptation strategies that can alleviate the adverse effects of climate change. Therefore, this work was aimed to identify determinants of farmers' adoption of climate change adaptation strategies in Gondar Zuria District of northwestern Ethiopia. Primary data were collected through semi-structured questionnaires, observation, and interviews. Besides, the secondary data were also obtained from journal articles, reports, governmental offices, and the internet. The Multinomial and Binary logistic regression models with the help of the Statistical Package for Social Sciences (SPSS) (21th edition) were used to analyze the data. The multinomial logistic regression model was used to estimate the influence of the socioeconomic characteristics of sample households on the farmer's decision to choose climate change adaptation strategies. The result showed that age, gender, family size, farm income, and farm size had a significant influence on the farmers' choice of climate change adaptation strategies. The result also revealed that crop failure, severe soil erosion and shortages of water are major climate change-related problems than others. In order to alleviate these problems, farmers have implemented mixed farming, mixed cropping, early and late planting (changing sowing period), use of drought-resistant crop varieties, application of soil and water conservation techniques, shifting to non-farm income activities and use of irrigation. In contrast, access to climate information, total annual farm income, and market access variables are significant adoption determinants of climate change adaptation strategies by farmers' in the study site. Therefore, we recommend future adaptation-related plans should focus on improving climate change information access, improving market access and enhancing research on the use of rainwater harvesting technology.

1. Introduction

The agricultural sector in sub-Saharan Africa is believed to be negatively affected by climate change (Deressa, 2007). The impact of climate change is more pronounced on smallholder farmers who are highly dependent on agriculture. Land degradation, frequent floods, and droughts are among the manifestations of climate change leading to productivity losses. Hence, efforts made to minimize the adverse effects of climate change on smallholder farmers in particular and agriculture in general are very crucial (Hassan and Nhemachena, 2008). Adaptation has been considered by many as the most efficient way of reducing the negative impacts of climate change. Adaptation enables farmers to maintain food, income and livelihood security while facing changes in climate and socio-economic conditions (Kandlikar and Risbey, 2000).

Currently, Ethiopia is one of the most vulnerable countries to climate change and variability which is frequently affected by climate-based hazards such as floods and drought (Burnett, 2013; Rovin et al., 2009). Similarly, seven major severe droughts have occurred in Ethiopia, five of which have led to food shortages and famines in the early 1980s (World Bank, 2010). Furthermore, six major flood occasions have occurred in different parts of the country in the year's interval from 1988 to 2006 (Bizuneh, 2013). However, the vulnerability of populations living under different social, economic, political, institutional and environmental conditions is not the same because of differences in adaptive capacity, exposure, and sensitivity.

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https://doi.org/10.1016/j.heliyon.2020.e03867
Received 14 December 2019; Received in revised form 29 February 2020; Accepted 24 April 2020

Subsistence farming in most parts of Ethiopia is dependent on rain-fed agricultural production. However, the rainfall is characterized by its erratic and unreliable nature. As a result, the inadequate rainfall and its associated drought are the main causes of famine and food shortages nationwide (Admassie et al., 2008; Gebremicheal et al., 2014). Moreover, the increase in climate change vulnerability in the country is mainly caused by rapid population growth, high dependency on rainfall based agriculture, severe poverty, chronic food insecurity, frequent natural drought and extreme environmental degradation (Rovin et al., 2009). The northern part of Ethiopia is characterized by the fragile landscape where rain-fed agriculture is the key source of livelihood for almost all the rural population. As a result, accelerated ecosystem degradation and climate change based floods, unpredictable rainfall, crop pests and disease, snowfalls, livestock, and other human diseases, and small farmlands among other factors have direct effects on poor peoples' food security and crop productivity in northern Ethiopia (Teshome, 2017). According to the World Bank (2010) report, Ethiopia's GDP may reduce beyond the baseline scenario of 2015 by 2–6% and 2045 by up to 10% because of climate change. Therefore, mitigation and adaptation mechanisms are useful to cope up with climate change-driven challenges.

Amhara National Regional State is among the most severely affected areas in Ethiopia due to climate change and variability. Climate change and variability have aggravated the vulnerability of the people in the region to climate change impacts and the overall degradation of natural resources. Climate change-induced problems such as drought and land degradation are the vital physical challenges to rain-fed agriculture in the Regional State. The recurrent droughts occurring in the region are one of the indicators of susceptibility to climate change (Bewket, 2009; Lemma, 2016). Moreover, the Central Gondar Zone has faced low rainfall amounts and floods as manifestations of climate extremities over the past few years. Besides, farmers' agricultural production in the zone has been declining from time to time.

Adaptation is globally documented as a crucial component of the policy response to climate change (Smithers and Smit, 1997). Several studies have been documented on area-specific climate change adaptation mechanisms and their adoption factors in Africa and Ethiopia (Bryan et al., 2009; Reidsma et al., 2010; Seo and Mendelsohn, 2008). Several works reported that adaptation mechanisms are experienced by farmers depending on farm size and types, climatic conditions and other settings like ecological, cultural, geographical, political, institutional and socio-economic factors (Deressa et al., 2009; Eriksen et al., 2011; Hisali et al., 2011; Reidsma et al., 2010). Some studies were conducted on the determinants of farmers' adoption of climate change and variability adaptation mechanisms in Ethiopia (Deressa et al., 2009; Saguye, 2016). Nonetheless, area-specific studies focusing on the factors hindering the adoption of climate change adaptation mechanisms are very limited in the northern part of Ethiopia (Tesfahunegn et al., 2016). Therefore, studies of climate change adaptation and determinant of adoption are required in the northern part of Ethiopia (including the study area).

The knowledge of adaptation strategies of climate change could play a significant role in influencing policymakers. Hence, in this study, an investigation involving mixed research methods was conducted to assess the determinants of farmer's adoption of climate change adaptation mechanisms. More specifically, the objectives of this work are (i) to assess the main indicators of climate change (ii) to evaluate the major adaptation strategies being commonly undertaken by farmers in response to the effect of climate change (iii) to determine the major factors that influence farmers' adoption of climate change adaptation strategies.

2. Materials and methods

2.1. Study site

The study area, Gondar Zuria District, is located in Central Gondar Zone, Amhara Regional State, northwest Ethiopia (Figure 1). The District is among the 11 districts of Central Gondar zone and has 41 rural and 3 urban *Kebeles*. The total area of the district is around 48,204 km^2. The District is characterized by a semi-arid climate with a low and erratic bimodal type of rainfall in which, Belg (small rainy) season starts in February and ends in April/May and the summer (main rainy) season extends from June to September with the highest rainfall in July. The monthly average maximum and minimum temperatures are 29.96 ^{O}C

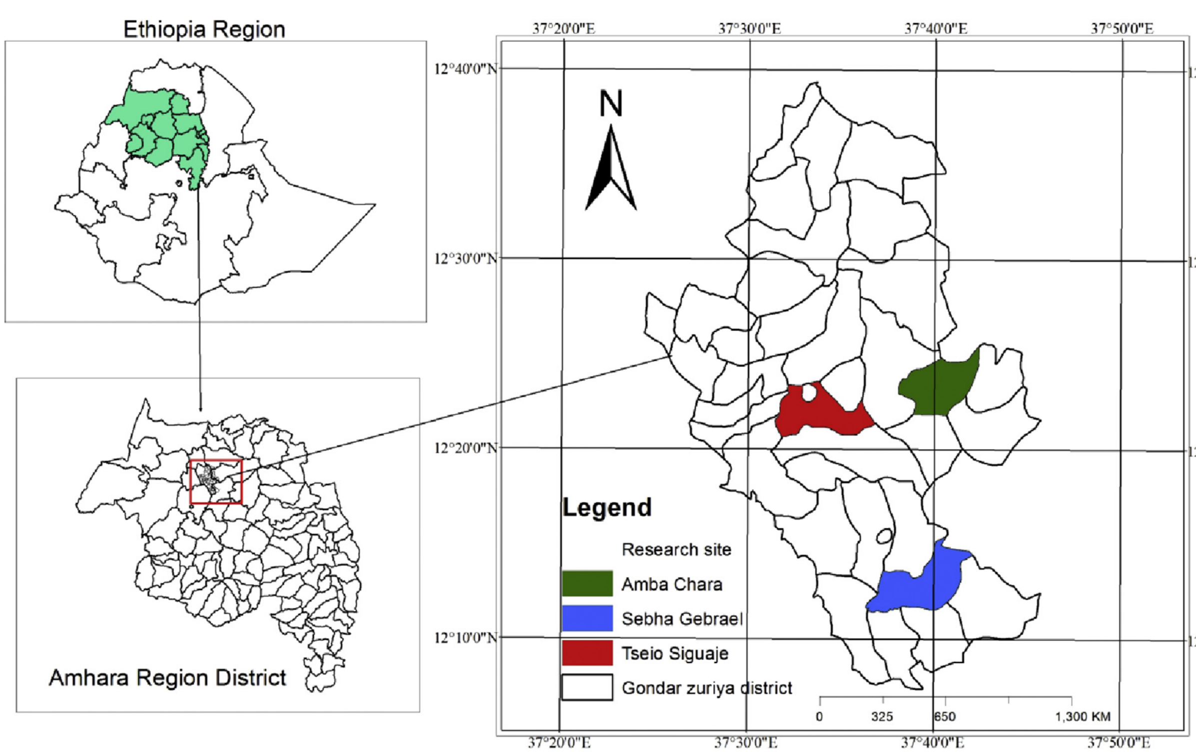

Figure 1. Map of the study area.

and 15.72 ^{O}C, respectively. The altitude ranges from 1500 to 3200 m above seas level (a.s.l). Agro-ecologically, the district falls into two zones: Weyna Dega (72%) and Dega (28 %) (Gondar Zuria District Agriculture Office, 2017). The study area has two types of soils namely; Nitisols and Vertisols. Nitisols occupy areas with sloping topography, and they have better soil depth as compared to vertisols. The vertisols, on the other hand, occupy the lower slope positions especially on the convex slopes (Gondar Zuria District Agriculture Office, 2017). The land use/cover of the area includes cropland (56.5 %), pasture (14.7 %), trees and shrubs (10 %), settlements (5.3 %) and miscellaneous land (13.5 %). The tree vegetation of the study area is part of the evergreen dry Afromontane forests that dominate the high lands of Ethiopia (Gondar Zuria District Agriculture Office, 2017). The district has 38,383 households, of which 30,325 male and 8,058 female-headed households. The population in the district is 230,033, of whom 118,107 were males and 111,926 females. Among the total inhabitants, 201,880 live in rural areas and 28,153 in urban centers. The estimated population density of the area is about 205.9 people per square kilometer and has a high number compared to the zone average of 60.23 (Gondar Zuria District Finance and Economy Office, 2017). Mixed farming is predominant in the District (i.e. crop production and livestock rearing (90%). Major crops that are produced in the area include wheat, sorghum, pea, teff, maize, and others. The livestock population in the district is equivalent to 207,000 tropical livestock units. In terms of irrigation potential, the district has suitable areas, because a relatively small area of the district is adjacent to Lake Tana (Gondar Zuria District Agriculture Office, 2017).

2.2. Analytical framework of the study

The present study focuses on drivers of climate change and identifying factors affecting farmers' adoption of adaptation strategies to climate change. There is a need to examine the relationship of various factors revolving around the farmers' adoption of climate change adaptation strategies. As indicated in Figure 2, farmers' adoption of climate change adaptation strategies is determined by different socio-economic, demographical and institutional factors. It includes socio-economic factors (farm size, farm income, member of a farmer-based organization and farming experience), demographic factors (family size and age) and institutional factors (Access to credit service, access to market, access to training, and climate change information).

2.3. Sampling, data collection and variable definition

The multistage sampling procedure was applied to identify the determinants of farmers' adoption of climate change adaptation mechanisms. Out of 11 rural districts in the Central Zone of Gondar, Gondarzuria district was purposively selected at first, as the district is one of the semi-arid and drought-prone areas. Secondly, study *Kebeles* (the smallest administrative units) were identified and stratified based on their agro-ecology. Accordingly, one *Kebele* (Amba-chara) from highland agroecology (Dega) and two *kebeles* (Sabah-Gebriale and Tseion-Siguaje) from midland (Woina Dega) were selected purposely. Finally, the list of total households of the three selected *Kebeles* were found from the district agricultural office and the sampling frame of all *Kebeles* were organized. Out of this, 121 respondents were randomly drawn using simple random sampling based on probability, proportional to size from the sampling frame (Table 1).

In this study, both primary and secondary data were used. The primary data were collected from the socio-economic, institutional and biophysical situation of the sample respondents using field observation, semi-structured questionnaires, and a key informant interview at the household level from a total of 121 households and 10 key informants. Three data collection instruments were used in order to capture the data from different sources and triangulations were carried out to confirm and clarify the research issues. Field observation was conducted throughout the whole course of the research in order to ensure the validity of the information obtained. It was done with the purpose of getting guidance for the development of the formal question and to be familiar with the values of local people. The key informants' interview was conducted with purposely selected individuals composed of local leaders (three), model farmers (four) and Agriculture and Rural Development experts (three), about the history climate change, kind of adaptation strategies and factors that influence farmers' adoption of adaptation strategies. The semi-structured interview was used because it ensures each key informant has equal opportunities to provide information and were assessed accurately and consistently. In this work, both closed and open-ended questionnaires were applied. The majority of the survey questionnaires were

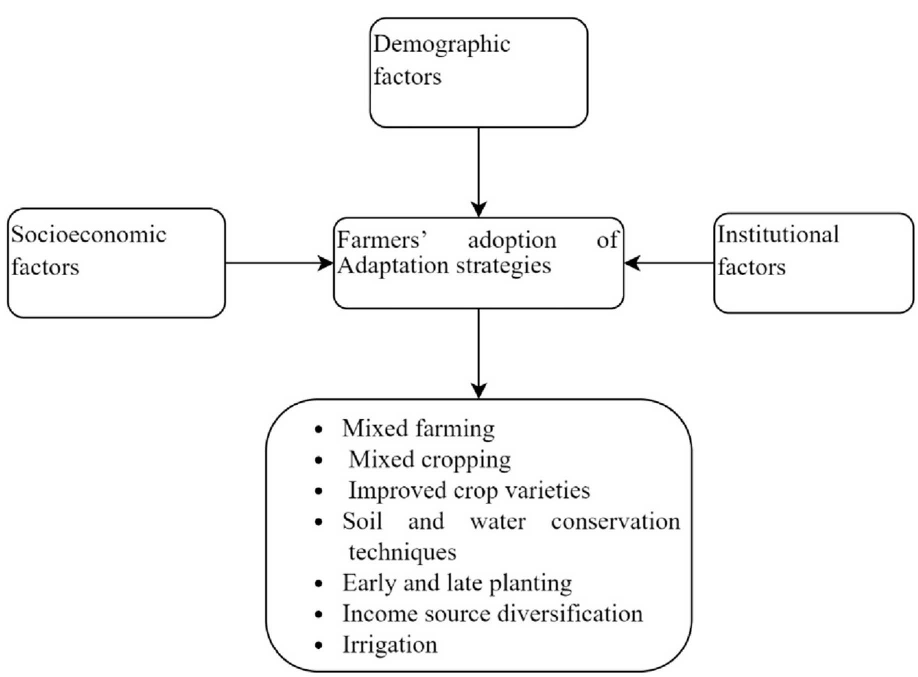

Figure 2. The analytical framework of the study.

Table 1. Sampled kebeles, numbers of households and sample size.

No	Name of Kebeles	Household size	Sample size
1	Tseion Siguaje	1425	52
2	Sabah Gebriale	1097	41
3	Amba chara	768	28
Total		3290	121

closed-ended questions. The remaining small number of questionnaires were open-ended. The survey questionnaire covered a wide range of information which included household characteristics, farming system, farmers' perceptions about climate change, and determinants of their adoption of adaptation strategies from the selected three Kebeles. The questionnaires were administered by trained data collectors who were university graduate students. The researchers played the role of supervisory. A brief orientation and training for four data collectors were given. Prior to implementing the survey, the questionnaire was briefed and tested its clarity for data collectors. The questionnaires that were found not clear to the local people and data collectors during training and testing were modified. Amendments were also incorporated into the questionnaire so as to make the idea easily comprehendible to the interviewees and data collectors. Besides, secondary data were collected from documents such as journal articles, books, annual reports, Intergovernmental Panel on Climate Change (IPCC) report, and other related resources. This study was conducted with full consent of the respondents and ethical approval was obtained from the Ethical clearance committee of the graduate studies of Oda Bultum University.

2.4. Data analysis techniques and model specification

The Statistical Package for Social Sciences (SPSS) (21^{th} edition) was employed to analyze the data. Multinomial and binary logistic regression models were the main analytical techniques used in this study. The multinomial logistic regression model was used to analyze the relationship between the socio-economic characteristics and farmers' choices of adaptation strategies to climate change. In accordance with studies by Saguye (2016) and Debela (2017), the dependent variables (Adoption of adaptation strategies) were binary and their values were 1 for a farmer who used at least one of the listed strategies and 0 for a farmer who used none for this study. This was done to distinguish between farmers who adapted and those who did not in the study area. A farmer was considered to have adapted to climate change if he/she has employed at least one of the adaptation strategies such as mixed farming, irrigation, early and late planting, use of improved drought-resistant crops, soil and water conservation, income source diversification and mixed cropping. The independent variables that are hypothesized to affect the farmers' adoption of adaptation strategies are combined effects of various factors such as demographic, socioeconomic and institutional characteristics in which farmers operate. Based on the review of past studies on adaptation strategies the following explanatory variables were considered in this study and examined for their effect in farmers adopting adaptation strategies to climate change (Table 2).

The hypothesized independent variables were evaluated for some statistical issues like multi-collinearity. The multi-collinearity issue among the continuous explanatory variables was detected by the variance inflation factor (VIF). The correlation matrix method was also used to detect the degree of association between dummy explanatory variables. When the coefficient correlation matrix is greater than 0.4, the variables are said to be collinear. If the correlation coefficient value is very high (greater than 0.4), it shows the presence of multicollinearity (Long and Freese, 2006).

According to Gujarati and Porter (2003), a binary logistic model specification is employed to model climate change adaptation strategies of farmers involving dummy dependent variables with binary choices. The logistic distribution function for the decision on adopting adaptation measures to climate change can be specified as:

$$\text{Logit (P)} = \log\left(\frac{P}{1\text{–}P}\right) \tag{1}$$

$$\text{Let Pi} = \Pr\left(\frac{Y=1}{X=xi}\right)\text{, then the model can be written as} \tag{2}$$

$$\Pr\left(y=\frac{1}{x}\right)=\frac{\exp^{x'b}}{1+e^{x'b}};=\log\left(\frac{Pi}{1\text{–}Pi}\right)=\text{Logit(Pi)}=\beta 0+\beta 1xi \tag{3}$$

where; Pi is a probability of deciding to adopt adaptation strategies (dependent variable), xi's are the independent variables, β0 is the intercept and β1 is the regression coefficient.

We can write the model in terms of odds as;

$$\frac{\boldsymbol{Pi}}{(1-\boldsymbol{Pi})}=\exp(\beta 0+\beta 1xi) \tag{4}$$

3. Results and discussions

3.1. Socioeconomic background of sample households and choice of adaptation strategies

The multinomial logistic regression model was used to estimate the effect of the socio-economic characteristics of sample households on the farmer's decision to choose climate change adaptation strategies (Table 3). The result indicated that marital status had positively impacted the decision to early and late planting of the adaptation strategies and negatively in the case of others. The result also revealed that gender of the households had a positive impact on farmer's decision to choose adaptation options in all cases but it was statistically significant in the

Table 2. Variables hypothesized to affect farmers' adoption decision.

Variable	Description	Value	Expected sign
FAS	Number of family members	Number	+
TLAND	Total landholding in hectare	Hectare	+
FEXPR	Farming experience of HHH (household head)	Years	+
AGE	Age of HHH	Years	+
MARKTACCSS	Market access to HHH	1 = yes, 0 = no	+
TRAINCC	Access to training related to climate change issues	1 = yes, 0 = no	+
CLIMINFO	Access to climate change information	1 = yes, 0 = no	+
CREDIITS	Access to credit services	1 = yes, 0 = no	+
MFBO	Member of farmer-based organization	1 = yes, 0 = no	+
PERCPCC	Perception of HHH on climate change	1 = yes, 0 = no	+
ANFINCOME	Annual income from farming	ETB	+

Table 3. The effect of the socio-economic characteristics on the farmer's decision to choice adaptation strategies.

Explanatory variable	Use of improved crop varieties	Early and late planting	Soil and water conservation	Mixed cropping	Mixed farming	Use of irrigation	Income source diversification
MARSTUS	-0.155 (0.610)	0.060 (0.809)	-0.182 (0.529)	-0.059 (0.820)	-12.502 0.992)	-1.948 (0.202)	-10.046 (0.990)
AGE	0.029 (0.415)	0.061 (0.079)	0.022 (0.523)	0.019 (0.558)	0.009 0.902)	0.049 (0.224)	0.238 (0.024*)
TLAND	0.139 (0.647)	0.152 (0.541)	0.129 (0.638)	0.037 (0.895)	0.616 (0.611)	0.195 (0.535)	0.406 (0.460)
GENDHH	1.708 (0.048) *	0.218 (0.721)	0.153 (0.812)	1.257 (0.066)	16.39 (0.995)	1.747 (0.068)	15.85 (0.992)
FAS	0.154 (0.351)	0.290 (0.063)	0.153 (0.333)	0.065 (0.666)	-0.025 (0.944)	0.130 (0.485)	1.060 (0.024*)
ANFICOM	1.344 (0.506)	0.128 (0.257)	0.215 (0.285)	5.32 (0.728)	0.036 (0.796)	0.023 (0.106)	0.0153 (0.670)
Diagnostics Number of observations = 121 LR chi2(36) = 53.28 Prob > chi2 = 0.0317 Pseudo R2 = 0.1191 Log likelihood = -197.04373							

Notes: * denote significant at 10%. The values indicate coefficient (P-value); MARSTUS is marital status, TLAND is total land size, GENDHH is the gender of household head, FAS is the family size of the households, and ANFICOM is annual farm income of households.

choice of use and growing of improved crop varieties. This implies that male-headed households had better opportunities to practice adaptation measures than female-headed households. It showed that male-headed households could be more likely to have access to technologies and climate change information than female-headed households. As a result, they were in a better position to practice diverse adaptation strategies than female-headed ones. This result was in agreement with the study by Belay et al. (2017). The result indicated that the family size of the household head had a positive impact on farmer's decision to choose adaptation options in all cases but it was negative in the mixed farming climate change adaptation strategy. This implied that the farmer's choice of adaptation strategy to climate change affected by the number of family size.

A large number of active household members had increased adaptation decision mechanisms to reduce the impact of climate change. This result agreed with the finding of Belay et al. (2017) and Deressa et al. (2014). The total land size of the household had a positive effect on farmer's choices of adaptation strategies to the adverse effects of climate change in all cases. This means the amount of farmer's land size was positively affect these farmers who are using an adaptation method to climatic change. This implies that farmers who have an adequate amount of farming land size are more likely to take any adaptation decisions because they have resources to implement new agricultural technology. This result is in agreement with the study by Kide (2014) pointed out households with relatively large farm sizes were more likely to take up new adaptation strategies when compared to farmers with small farm sizes. The result revealed that total farm income had negatively affected these farmers' decisions to choose adaptation methods to climatic change. This implies that farmers who have a small amount of annual total farm income, are more likely not to take any adaptation decisions because they have no adequate income to implement adaptation strategies against the negative effects of climate change. The age of the household head was one of a statistically significant explanatory variables that had a positive coefficient. The positive sign indicates that it has a positive influence on taking an adaptation strategy to climate change. The age of the household head significantly influences farmers' choice of income source diversification adaptation strategies with the p-value of 0.024 (Table 3). This result indicates that as the age of the household head increase the probability of using any adaptation strategy increase.

According to Table 4, the age of the household head was one of the statistically significant explanatory variables that have a negative and a positive coefficient. The positive sign indicates that it has a positive influence on taking an adaptation strategy to climate change. As the age of the household head increase by one year, the probability of household head using improved crop varieties as an adaptation strategy to climate change is increased by 1.3% with the p-value of 0.015, keeping other variables constant. Similarly, as a year increase in the age of the household head, the probability of farmers to use mixed cropping as adaptation strategy increase by 1.9% with the p-value of 0.000, keeping other variables constant. The result indicates that as the age of the household head increases by one year the probability of not using mixed farming adaptation strategy to climate change decrease by 0.5% (Table 4).

The amount of farmer's land size had a positive impact and significantly affects these farmers' choice of adaptation methods to climatic change. As farm size of household head increase by one hectare, the probability of the farmers uses improved crop varieties adaptation option of climate change increased by 1.4% with the p-value of 0.047, keeping other variables constant. In addition, as farm size of the household head increases by one hectare, the probability of farmers to use mixed cropping and mixed farming as adaptation strategy increase by 4.2% with the p-value of 0.015 and 11.6% with the p-value of 0.001 respectively, keeping other variables are constant. This implies that farmers, who have a large amount of farming land size, are more likely taking any adaptation decisions because they have resources to implement new agricultural technology. This result is in agreement with the study by Kide (2014). The findings of the marginal effects showed that the probability of male-headed households used irrigation as an adaptation strategy to climate change increased by 7.4% with the p-value of 0.002 than female-headed households. In this case, male-headed households are often considered less likely to gain information about new technologies and take on risk than female-headed households. This finding is in line with the findings of Gebrehiwot and van der Veen (2013) that reported male-headed households were more likely to apply adaptation strategies to adapt to climate change.

The family size of the household head was a statistically significant explanatory variable in this model, which indicates farmers' adaptation strategy to climate change is also significantly affected by the number of family size. A large number of active household members had increased adaptation decisions mechanism to reduce the impact of climate change. A one-unit increase from the member of the family resulted in a 2% increase in the probability of farmers using improved crop varieties as adaptation strategy with the p-value of 0.003, holding other variables constant. The result indicated that one unit increases from the member of the family resulted in a 3.1% & 1.6% increase in the probability of farmers implement soil and conservation techniques and mixed cropping as adaptation strategy with the p-value of 0.000 & 0.004, respectively. This is in agreement with the study reported by Belay et al. (2017) study. The result of the analysis reveals that the total annual farm income of a household had a positive and significant influence on using irrigation systems and planting trees. One unit (ETB) increase in the farm income of

Table 4. The marginal effect of the explanatory variable of the multinomial Logit model.

Explanatory variable	Use of improved crop varieties	Early and late planting	Soil and water conservation	Mixed cropping	Mixed farming	Use of irrigation	Income source diversification
MARSTUS	0.231 (0.250)	0.051 (0.402)	0.372 (0.739)	0.016 (0.910)	1.502 (0.062)	1.928 (0.402)	2.046 (0.190)
AGE	0.013 (0.015)*	0.002 (0.601)	-0.039 (0.513)	0.019 (0.000)***	-0.005 (0.001)**	-0.069 (0.232)	-0.865 (0.08)
TLAND	0.014 (0.047)	0.132 (0.001)***	0.0229 (0.638)	0.042 (0.015)*	0.116 (0.001)**	1.145 (0.315)	0.220 (0.280)
GENDHH	1.023 (0.081)	0.401 (0.523)	0.346 (0.502)	2.026 (0.081)	1.214 (0.094)	0.074 (0.002)**	1.105 (0.802)
FAS	0.020 (0.003)**	0.024 (0.083)	0.031 (0.000) ***	0.016 (0.004)**	0.036 (0.831)	0.021 (0.081)	1.004 (0.071)
ANFICOM	0.012 (0.000)***	0.0104 (0.062)	0.014 (0.095)	0.089 (0.708)	0.006 (0.696)	0.102 (0.043)*	0.023 (0.510)

Notes: ***, **, * denote significant at 1%, 5% and 10% respectively.

the household is associated with probabilities using improved crop varieties and irrigation management increase by 1.2% and 10.2% with the p-value of 0.000 and 0.043, respectively, and keeping other variables constant. When the main source of income in farming would be increased, farmers incline to participate in productivity smoothing options such as improved crop varieties and using an irrigation system. This result is also in agreement with the studies reported by Deressa et al. (2009) and Mulatu (2011).

3.2. Indicators of climate change

In this study, the sample respondents were requested to identify the intensity of different climate-related problems in the study area. Their response to the intensity of these problems is shown in Table 5. According to this table, 24.8% of the respondents labeled crop failure as the primary indicator of climate change in the study site. Crop failure is followed by severe soil erosion and shortage of water chosen by 18.2% and 14% of the respondents, respectively. Loss of income, poor livestock productivity, and drying of streams and rivers are also another climate change-related problem reported by 12.4%, 9.9% and 9.1% of the respondent respectively. On the other hand, the increase in flood disasters, high-intensity wind, and drying of vegetation were chosen by the respondents as the least three indicators of climate change.

3.3. Climate change adaptation mechanisms implemented by farmers

Based on the data from the farm households survey, this section was briefly summarized farmers' adaptation strategies in response to climate change. In the study site, farmers have used different coping strategies in response to the effect of climate change. These include mixed farming, mixed cropping, growing od drought resistance improved crop varieties, implementing soil and water conservation techniques, early and late planting (changing sowing period), enhancing traditional irrigation schemes (including water harvesting) and income source diversification. Among these adaptation strategies, almost 25% of sample households used mixed farming as the primary adaptation strategy followed by early and late planting (changing sowing period) (18.3%). On the other side, only 4% of the respondents used an income source diversification adaptation strategy (Figure 3).

Table 5. Climate change indicators (N = 121).

Climate change indicators	Number of respondents	Percentage
Drying of streams and rivers	11	9.1%
Shortage of water	17	14.0%
Crop failure	30	24.8%
Severe soil erosion	22	18.2%
Loss of pasture land	6	5.0%
Loss of income	15	12.4%
Poor livestock productivity	12	9.9%
Increase deforestation	3	2.5%
Drying of vegetation	2	1.7%
High-intensity wind	2	1.7%
Increases flood disaster	1	0.8%
Total	121	100%

The results indicated that farmers used mixed farming adaptation strategies (i.e. commonly applied by most of the respondents) to reduce the consequences of climate change in the District (Figure 3). In line with this, previous studies by Collier et al. (2008), Bewket (2010) and Lemma (2016) also demonstrated that mixed farming adaptation practice was the dominant adaptation strategy to reduce climate change-related problems in the drier areas of Ethiopia.

Mixed cropping was one of the strategies for climate change adaptation which is regularly practiced by most of the respondents next to mixed farming and early and late planting (changing sowing period) adaptation strategies. Mixed cropping refers to the cultivation of two or more crops at the same time in one plot of land. Moreover, the sampled households reported that they used to mix the main crop with complementary crops such as barely with Faba bean or tomato, barley with sorghum, chickpea with sunflower and maize with beans and peas in the study areas. In this regard, a study conducted in Ghana by Ndamani and Watanabe (2016) indicated the implementation of mixed cropping to minimize the effects of moisture stress on crop plants. Bikila (2013), Haji and Sani (2014) also stated that mixed cropping is one of the most commonly used adaptation options next to mixed farming change in Ethiopia.

Growing drought-resistant improved crop varieties is one of the adaptation mechanisms widely used in the study district (Figure 3). For example, the farmers in the district tend to recover, multiply and use barley crop varieties having short growth periods. Another practice is the increasing tendency of planting teff (*Eragrostis* teff) and wheat varieties which have short growth periods as an adjustment to erratic or reduced rainfall. Similar studies were reported on Bikila (2013) and Saguye (2016), different drought resistance improved crop varieties and applied short maturing crop variety was the common climate change adaptation strategy of farmers in Southern Ethiopia. Similarly, Bewket (2010) indicated that growing short duration, drought-resistant crop varieties were one of the most widely employed adaptation mechanisms in Choke Mountain, Ethiopia. Mburu et al. (2015) also indicated that growing drought-tolerant crop varieties was one of the most common and vital adaptation strategies in practice on small scale farms in Kenya. Moreover, due to the unreliable and low rainfall amounts in northern Ethiopia, farmers have shifted to planting crop varieties that are more drought-resistant (Meze-Hausken, 2004).

Construction of physical soil and water conservation was perceived by the farmers as one of the most important adaptation strategies in the district. However, the use of physical soil and water conservation measures should be implemented in conjunction with biological measures to obtain better moisture levels and biomass production required for livestock consumption. Studies by Abebe (2014), Kide (2014) and Debela (2017) showed that farmers used physical and biological soil and water conservation management practice as an adaptation strategy to climate change in different parts of Ethiopia.

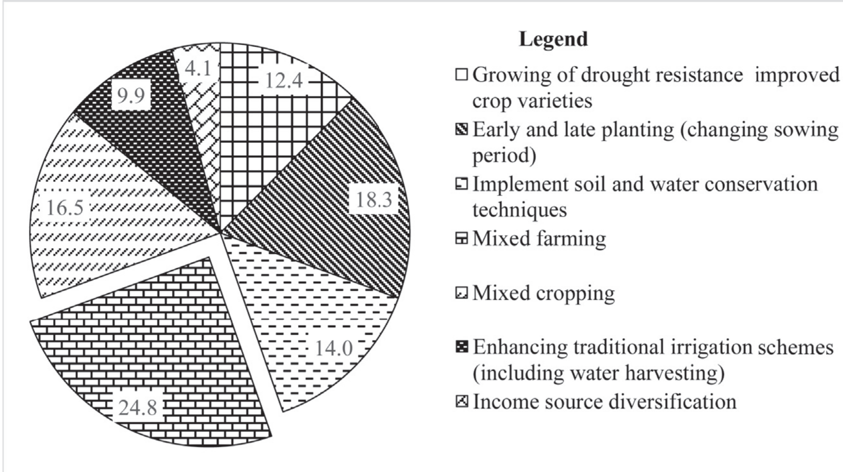

Figure 3. Adaptation strategies implemented by the farmers in the study area.

Expansion of small scale irrigation is one of the priorities of policy-makers of Ethiopia for rural poverty reduction and boosting growth (MoFED, 2010), as well as climate change adaptation options (National Meteorology Agency, 2007). Irrigation development is one way of enhancing food production and carrying capacity of farmland and reducing the dependency of rain-fed agriculture. It also helps farmers to enhance their household incomes, improve their adaptation capability, and decrease climate change-related hazards (Bikila, 2013). In the District, irrigation was used by a small number of farmers (i.e. 10% of the respondents) as an adaptation strategy to overcome the direct and indirect effects of climate change. This adaptation strategy helps protects farmers against losses due to dynamism in temperature and rainfall. However, the availability and accessibility of water for irrigation was a great problem for farmers' in the study area. Bikila (2013) and (Kide, 2014) also suggested irrigation as a common adaptation strategy. Mburu et al. (2015) were also identified irrigation as one type of climate change adaptation strategies employed in Kenya.

3.4. Factors hindering climate change adaptation

In the district, there are various barriers that hinder the farmer's ability to adopt adaptation strategies. These include lack of information about the potential of climate change, lack of knowledge about appropriate adaptation options, lack of credit services and money, lack of own land, lack of adequate irrigation facility and lack of market access. As shown in Figure 4, the highest number (26.4%) of the respondents reported that lack of information about the potential of climate change is one of the main barriers that hinder farmer's ability to embrace climate change adaptation strategies. About 20.7% of the respondents perceived lack of knowledge about appropriate adaptation options as a barrier that affects farmer's adoption of adaptation strategies. However, only 4.1% perceived market access as a barrier to climate change adaptation. This study is in agreement with the results obtained by Abid et al. (2014) and Kide (2014), which concluded that lack of information about potential of climate change, lack of knowledge about appropriate adaptation option, lack of credit services and money were the major constraints to hinder farmers' willingness to adopt adaptation strategies in response to climate change effects.

3.5. Factors influencing farmers' adoption of climate change adaptation strategies

Binary logistic regression was conducted to determine the influence of the 11 variables considered in the model. The probability of the model Wald chi-square ($X^2 = 22.583$, $df = 11$, at p-value 0.020) was found to be significantly associated with observed individual household variables related to implementing adaptation strategy and model prediction. The p-value ($p = 0.020$) implies that a well-fitting model is significant at the 1% level, hence, Hosmer and Lemeshow Test p-value ($p = 0.903$) is in the acceptable value signifying a well-fitting model.

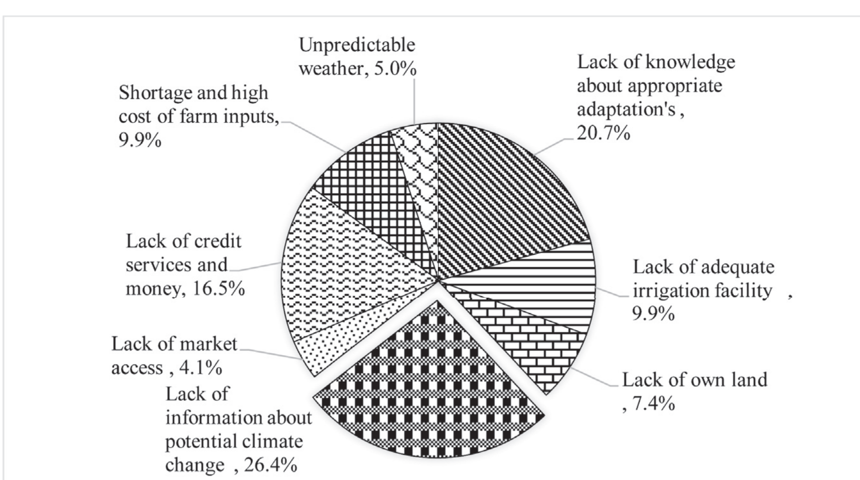

Figure 4. Barriers to climate change adaptation.

Table 6 presents logistic estimates of the determinants of farmers' adoption of an adaptation strategy to climate change. Among the eleven independent variables considered in the binary logistic regression model, three variables were found significant at 5% alpha level that influences farmers' adoption of climate change adaptation strategy. These are annual total farm income, access to information on climate change and market access. Similarly, the majority of interviewed key informants reported that there are several determinant factors that affect farmers' adoption of adaptation strategies. These are access to climate change information, annual farm income and market access, and access to training in climate change-related issues. However, land size of households, household heads' age, perception of climate change, family size, farming experience, number of farmer-based organization, access to credit and access to training on climate-related issues were found statistically insignificant ($p > 0.05$) factors. The logistic regression coefficients showed that a change in the log-odds resulted in a one-unit increase in the predictor variable. Thus, analyses of statistically significant explanatory variables and the finding from this study are consistent with other findings are discussed below.

The results showed that a statistically significant (coefficient = 0.000, $p = 0.032$; odd ratio = 1.000) positive association between annual farm income and farmers' adoption of adaptation strategy. This indicates that a unit (by 1 Ethiopian birr) increase in total annual farm income increased farmers' probability to adopt a climate change adaptation strategy by a factor of one. These results are in agreement with Abid et al. (2014), Iheke and Agodike (2016), and Saguye (2016). In both studies, a positive significant association was obtained between the adoption of climate change adaptation strategies and income level. This indicates that farmers that have better yearly income have more chance to adopt climate change adaptation strategies than farmers with less income.

The results also revealed that access to climate information (coefficient = 1.147; $p = 0.031$; odds ratio = 3.150) had a positive and significant factor. This indicates that farmers having access to climate information were appeared to have a higher probability to adopt adaptation strategy than farmers without access to climate information. This is due to the fact that access to climate information increases farmers' awareness and knowledge of the changing rainfall and temperature patterns as well as the possible climate change response strategies. This result is consistent with the findings of Saguye (2016) who found a positive relationship between access to climate change information and the adoption of adaptation strategies to climate change and variability in Ethiopia. Similar resulted were reported by Ndamani and Watanabe (2016), and Mutunga et al. (2018) in Ghana and Kenya, respectively. This implies that farmers with access to climate change information and related extension services are highly likely to adopt adaptation strategies to climatic change.

The binary logistic regression model revealed that market access had a significant (coefficient = 1.091; $p = 0.032$, odds ratio = 0.336) positive impact on farmers' adoption of adaptation strategy to climate change. In this study, farmers with market access were appeared to have 0.34 times higher probability to adopt adaptation strategy than farmers without access to the market. The results are similar to the conclusions by Maddison (2007) who reported a decrease in the tendency of farmers to adopt climate change strategies as markets get further from their neighborhood because markets are the platforms through which farmers share information and goods in Africa. As stated by Deressa et al. (2011) market access is an important factor that significantly affects farmers' technology adoption by farmers. Hassan and Nhemachena (2008) also indicated that accessibility of markets creates an opportunity for farmers to grow cash crops and thereby enhancing their income and capacity to cop-up climate change variabilities. This also indicates that farmers with easy access to different drought resistance seed varieties and irrigation technologies in the market are highly likely to accept adaptation strategies.

3.6. Policy implications

Farmers' ability to choose effective adaptation strategies is affected by household socioeconomic characteristics, household demography, annual farm income, access to markets, and access to climate information and extension. This suggests the essential of governmental and NGOs support the indigenous adaptation strategies of the smallholder farmers with a wide scope of institutional, policy, and technology support, some of it focused on female-headed family households. Future policy should focus on promoting awareness creation and advancing education on climate change by knowledge and skill sharing platforms such as training, conferences, and seminars. Also, facilitating the availability of credit and market access, especially for adaptive technologies could improve smallholder farmers' ability to spread their adaptation strategies across a range of adaptation portfolios and the level of adaptation measures. Besides, importing adaptive technologies from other countries with similar socioeconomic and environmental settings could enhance the adaptive capacity of farmers in the study site. The rain-fed agriculture in the area is less unlikely due to unpredictable and uncertain rainy season and hence policy-driven actions are crucial to provide both ground and surface water irrigation facilities. Moreover, attention should be given for income diversification, essentially to non-farm income sources that are less sensitive to climate change. Therefore, including these climate change adaptation strategies in the existing formal governmental structure like the Ministry of Agriculture and other lines of ministries will be useful to the smallholder farmers.

Table 6. Logit regression of factors determining the adoption of climate change adaptation strategies.

Variables	Coefficient	Standard error	Wald	*P*-value	Odd ratio
AGE	-0.027	0.030	0.842	0.359	0.973
TLAND	-0.042	0.200	0.044	0.835	0.959
FAS	-0.111	0.109	1.044	0.307	0.895
PERCPCC(1)	-0.753	0.726	1.075	0.300	0.471
FEXPR	0.020	0.030	0.443	0.506	1.020
ANFINCOME	0.000	0.000	4.614	0.032*	1.000
MFBO(1)	-0.690	0.470	2.161	0.142	0.501
CLIMINFO(1)	1.147	0.532	4.655	0.031*	3.150
MARKTACCSS(1)	1.091	0.510	4.581	0.032*	0.336
CREDIITS(1)	-0.286	0.460	0.387	0.534	0.751
TRAINCC(1)	-0.662	0.581	1.297	0.255	0.516
Constant	2.264	1.215	3.474	0.062	9.620

Notes: * significant at $p < 0.05$; Log likelihood = 128.014; Omnibus tests of model coefficients ($chi^2 = 22.583$ and $p = 0.020$); Hosmer and Lemeshow Test ($chi^2 = 3.446$, $df = 8$, $p = 0.903$); Pseudo R^2 (Cox and Snell $R^2 = 0.170$; Nagelkerke $R^2 = 0.239$).

4. Conclusions

This study was conducted in Gondar Zuria district in northwestern Ethiopia with the aim to identify the major factors that influence farmers' decision to adopt climate change adaptation strategies. According to this work, crop failure, severe soil erosion and shortage of water are the most common climate change-related hazards that occurred in the study area. To respond to these challenges, farmers were used different adaptation strategies such as mixed farming, mixed cropping, growing of drought resistance improved crop varieties, implement soil and water conservation techniques, early and late planting, enhancing traditional irrigation schemes (e.g. water harvesting) and income source diversification. The key informants were also reported that lack of effective access to information on climate change, lack of market access and lack of credit services are major constraints that hinder farmer's decision to adopt climate change adaptation measures in the study area. Thus, there is a need for effective and reliable access to information on changing climate to farmers. In addition, improving market access and credit facilities is crucial in enhancing farmers' adaptation decision making and planning. The multinomial logistic regression model used to analyze the relationship between the socioeconomic characteristics and farmers' choices of adaptation strategies to climate change indicate that age, gender, family size, farm income, and farm size had a significant influence on farmers' choice of climate change adaptation strategies. In the binary logistic model, access to climate information, total annual farm income, and market access variables were found the significant adoption determinants of climate change adaptation strategies by farmers.

Declarations

Author contribution statement

Mequannt Marie: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Fikadu Yirga, Mebrahtu Haile, Filmon Tquabo: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the Ministry of Science and Higher Education, Ethiopia.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The two anonymous reviewers are highly acknowledged for their constructive comments on an earlier version of this paper.

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