



Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia

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Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia

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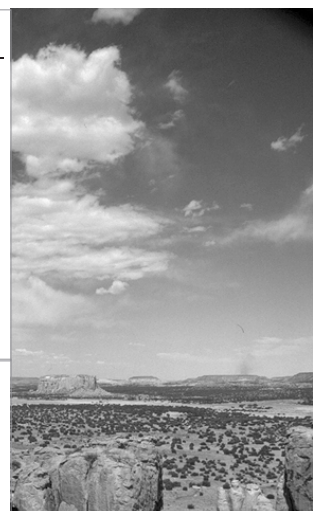


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Abstract

The study examined the perception of farmers towards climate change; assessed local impacts of climate change on the agriculture sector; identified local innovations for climate change adaptation; and assessed the barriers and determinants of climate change adaptation options at the farm level. The study was conducted in three dominant agro-ecological zones, Highland, Midland, and Lowland, of the upper catchment of Blue Nile based on farm-level data collected from 384 households for 2010/2011 cropping season. According to the survey results, the majority of the respondents, up to 85% were of the view that there has been a rise in temperature. Approximately 61% of the respondents observed a decrease in rainfall volume, whilst about 90% perceived a change in the timing of rains. The perception of most farmers' on temperature rise was in harmony with the trend analysis of temperature records. However, there was a clear contradiction between the perception of majority of farmers' on rainfall volume and the trend analysis of the rainfall records. Most of the farmers' who perceived changes in climate employed local adaptation options in response to climate signals. The most common adaptation options include: implementation of soil conservation practices, cropping calendar adjustment, tree planting, change of crops, crop diversification and adjustment to crop and livestock management. However, lack of knowledge and information, lack of inputs, inappropriate policy, land scarcity, shortage of labor, lack of market, water scarcity, poverty and lack of extension services were identified as barriers to adaptation. The multinomial logit model result highlighted the frequent extension visit, resource endowment, access to climate information, large size of productive labor and increased farming experience as positive influences on farmers' adaptation to climate change. On the other hand, farmers' perception of possessing fertile land was a disincentive to undertake adaptation measures. The Government could also contribute to counteract the impact of climate change on agriculture by investing in research, soil conservation measures, technology, animal health centers, and irrigation and water harvesting development, expanding fertilizer use, market, and education, establishing crop insurance institutes, reforming land policy, establishing local meteorology stations, monitoring and publishing climate data, and creating job opportunities by expanding non-agriculture sectors.

1. Introduction

There is a growing understanding that climate variability and change poses serious challenges to development in Ethiopia. The reason for this is that the mainstay of the Ethiopian economy is rain-fed agriculture, which is heavily sensitive to climate change and variability. Seventy percent of Ethiopia is arid, semi-arid, or categorized as dry sub-humid; areas that are prone to desertification and drought (National Meteorology Agency, 2007). In addition, the Ethiopian highlands are fragile because of over cultivation, overgrazing, erosion, and deforestation. The country is expected to experience changing patterns of rainfall, increased temperatures leading to elevated evaporation rates, and flooding; these will in turn lead to greater levels of land degradation, transmission of infectious disease, and loss of surface and ground water potential.

The poor subsistence farmers, who on average account for 98% of the total area under crops and for more than 90% of the total agriculture output (Belshaw, 1997), are first line victims to the impacts of the changes in climate. For instance, the farming community of the upper Blue Nile catchment reported losses in their agricultural production due to erratic rain, increased temperature, perils of flood and drought, and scarcity of water. According to farmers, climate related hazards, namely, flood, drought, erratic rainfall, pest and disease, hailstorms, and land slide were not new phenomena to them, but their socio-economic and biophysical effects had increased in intensity and coverage across decades. Even though they are exposed to those hazards and have a low adaptive capacity, they have survived and coped by making tactical responses to these changes. Adaptation had been practiced in Ethiopia before the concept of “climate change” became more prominent (McKee, 2008). However, these local adaptations have not been valued and documented so far, and hence, recognizing and documenting the local adaptation strategies is an important entry point to strengthen the resilience of local people to climate change. Analyzing local adaptation is, therefore, important to inform policy for future successful adaptation of the agricultural sector to the impact of climate change.

The overall aim of this study is to provide research evidence based policy findings that would contribute to enhancing farmers’ capacity to adapt to the impact of climate change in Ethiopia. To this end, the specific objectives are to:

- Assess the perception of farmers and development stakeholders (NGOs, local authorities, experts in the field of agriculture and natural resource management) towards climate change and variability; perception is a precondition for adaptation;
- Assess climate hazards in the area;
- Identify and document local innovation options for climate change adaptation of the different agro-ecologies;
- Assess the barriers and determinants of climate change adaptation options at the farm levels.

2. Literature Review

2.1 Empirical Studies

There are a few studies conducted on Ethiopian farmers' climate change adaptation strategies. In the following subsection relevant studies conducted in Ethiopia are briefly presented.

Mahmud et al., (2008) studied impact of climate change on food production in a typical low-income developing country. Their analysis relies on primary data from 1,000 farms producing cereal crops in the Nile Basin of Ethiopia. They found that climate change adaptations, namely, changing crop varieties, adopting soil and water conservation measures, water harvesting, tree planting, and changing planting and harvesting periods have significant impact on farm productivity. Extension services, both formal (extension officer-farmer), and farmer-farmer, as well as access to credit and information on future climate changes, affect adaptation positively and significantly. Farm households with larger access to social capital are more likely to adopt yield-related adaptation strategies. On the other hand, lack of information and shortages of labor, land, and money were identified as major reasons for not adapting.

There are also studies conducted on farmers' adaptation strategies in other parts of Ethiopia. These studies identified the use of different crops or crop varieties, tree planting, soil conservation, changing planting dates, and irrigation as common adaptation strategies; and level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agro-ecological settings, and temperature all influence farmers' choices; lack of information on adaptation methods, financial constraints, and lack of access to land as main barriers to adapt (Bryan et al., 2010; and Temesgen et al., 2008). According to Temesgen et al., (2008), age of the household head, wealth, information on climate change, social capital, and agro-ecological settings have significant effects on farmers' perceptions of climate change.

The limitation with the above studies is that they are too aggregated to exactly indicate local climate change and variability impacts, adaptation strategies, farmers' perception on climate change, barriers, and determinants of adaptation strategies at specific location. The authors have acknowledged the need of further studies at local levels, particularly at district and villages, one of the gaps this study is aimed at filling. However, the previous studies were very relevant in providing good information for performing this local specific study.

2.2 Concepts of Climate Change Adaptation

This subsection deals with definitions of terms which are important to understanding climate change adaptation issues. Accordingly, "climate change" refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007a). It refers to any change in climate over time, whether due to natural variability or as a result of human activity. "Climate variability" is variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forcing (external variability) (IPCC, 2001a). Turner et al., (2003) defined "resilience" as the degree to which an impacted system rebounds or recovers from a perturbation. Adaptive capacity is the ability or potential of a system to respond to climate variability and change in a manner that reduces vulnerability (Brook, and Adger, 2005). "Climate hazard" is a potential climate treat to the welfare of systems (Downing et al., 2001). Climate change impacts necessitate responses and adjustments to the biophysical and social

conditions which together determine exposure to climate hazards. These responses may occur in form of autonomous action or through public as well as private planned, individual and institutional mechanisms.

Climate change adaptation is a very broad concept, and different authors defined adaptation differently. For instance, Burton (1992) defined climate change adaptation as the process through which people reduce the adverse effect of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides. According to Stakhiv (1993), adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means of ameliorating the anticipated adverse consequences associated with climate change. On the other hand, the IPCC (2001b) defines adaptation as adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. This term refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change. Adaptation hence involves adjustments to decrease the vulnerability of communities, regions, and nations to climate variability and change and in promoting sustainable development (ibid).

Depending on its timing, goal and motive of its implementation, adaptation can either be reactive or anticipatory, private or public, planned or autonomous (Klein et al.,1999). Adaptations can also be short or long term, localized or widespread (IPCC, 2001b).

3. Methodology

Study Area

The study area of this research is situated in the upper Blue Nile catchment of Ethiopia. It is located approximately between coordinate 10033'06" to 10050'24" North latitude and 37042'36" to 37058'24" East longitude. It covers a total estimated area of 58122.94 hectares and with the total population of about 132069. Topographically, the area lies in the altitudes range of 878m to 4000m.a.s.l (Figure 1).

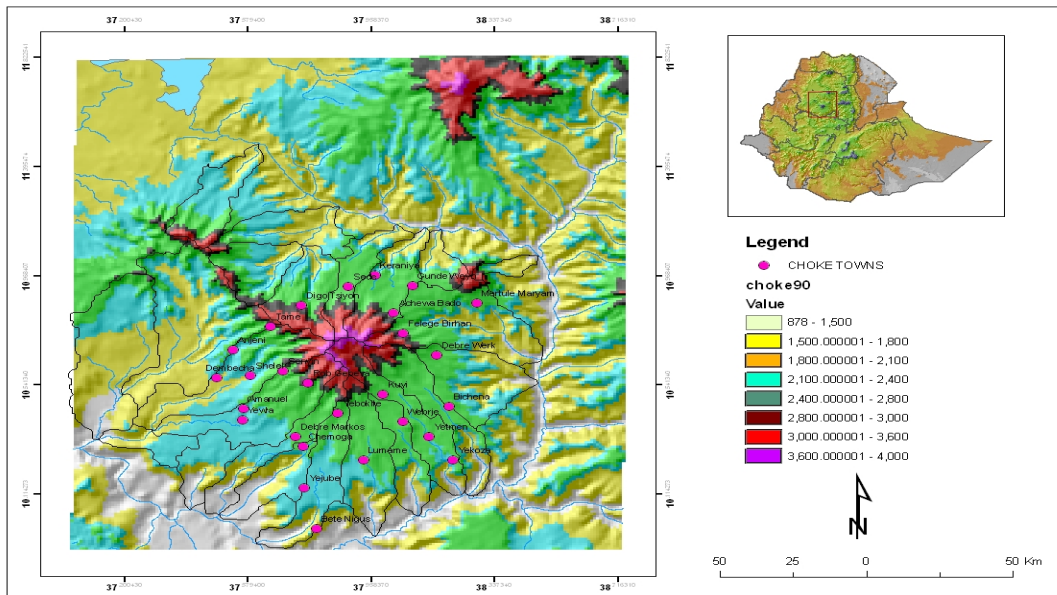


Figure 1: Location of the study area (Source: Choke Mountain Initiative project document, 2010)

As a result of this the area is characterized by three distinct agro-ecological zones- Dega, Weynadega, and Kola. According to the traditional classification system, which mainly relies on altitude and temperature for classification, Ethiopia has five climatic zones (Table 1). The information which is obtained in Weredas' Agricultural Offices revealed that the rainfall amount and temperature of the area ranges from 385 -1300mm, and 10- 26oC respectively. The area gets monomodal type of rain fall (that is Kirmt rain fall regime). The soil types were identified based on their colors (red, brown, black and grey); on the average percentage, about 60 %, 39 %, 36% and 2.5% are brown, red, black and grey soil respectively. The cultivated land covers a total area of 34161.93 ha of the area. The major annual crops cultivated in the catchment are barley, Avena species (Ingedo), wheat, beans, peas, potato, maize, and sorghum. The common domestic animals in the area are cattle, sheep, goats, horses, mules, donkeys, and poultry.

Table 1: Traditional climatic zones and their physical characteristics

Zone	Altitude(meters)	Rainfall(mm/year)	Average temperature(Co)
Wurch(upper high-land)	3200 plus	900- 2,200	>11.5
Dega(highlands)	2,300- 3,200	900- 1,200	17.1/16.0- 11.5
Weynadega(midlands)	1,500- 2,300	800- 1, 200	20.0- 17.5/16.0
Kola(lowlands)	500- 1,500	200- 800	27.5- 20.0
Berha(desert)	Under 500	Under 200	>27.5

Source: Ministry of Agriculture (MOA, 2000)

Data Collection and Method

A household survey was conducted among 384 household heads during the 2010/2011 production year in the upper catchment of Blue Nile. Three sample districts, namely, Sinan, Goziamn and Dejen were purposely selected to represent Dega, Weynadega, and Kolla agro-ecological zones respectively. The purpose of analysis in relation to agro-ecological differentiation is to investigate how farmers living in different agro-ecologies perceive, and adapt climate change and how different agro-ecologies are affected by climate change and variability. In the survey, farmers were asked to evaluate the temperature and precipitation trends of the area over the last three decades. The primary qualitative data on farmers' perception of temperature and rainfall changes was triangulated with trend analysis of 38 years (1970- 2008) climate records obtained from Debre Markos meteorological station. Descriptive statistics (count, percentage, and mean) and Multinomial Logit Model (MNL) were used to analyze the data collected. To assess farmers' perception, adaptation options, local climate impacts and the barriers they faced to adapt, descriptive statistics based on summary counts of the questionnaire structure were used. MNL model was used to identify the major factors determining adoption of adaptation options to climate change and variability. MNL model is preferred because it is most widely used in adoption decision studies involving multiple choices, and computationally easier and more convenient.

Multinomial Logit Model (MNL) Specification

Let A_i be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as (Greene, 2003):

$$Prob(A_i = j) = \frac{e^{\beta_j x_i}}{\sum_{k=0}^j e^{\beta_k x_i}}, j = 0, 1, \dots, J \tag{1}$$

Where β_i is a vector of coefficients on each of the independent variables X. Equation (1) can be normalized to remove indeterminacy in the model by assuming that $\beta_0 = 0$ and the probabilities can be estimated as:

$$prob(A_j = j/x_i) = \frac{e^{\beta_j x_i}}{1 + \sum_{k=1}^J e^{\beta_k x_i}}, i = 0, 2, \dots, J, \beta_0 = 0 \tag{2}$$

Estimating equation (2) yields the J log-odds ratios

$$\ln\left(\frac{p_{ij}}{p_{ik}}\right) = x_i'(\beta_j - \beta_k) = x_i'\beta_j, \text{ if } k = 0 \quad \dots\dots\dots(3)$$

The dependent variable is therefore the log of one alternative relative to the base alternative.

The MNL coefficients are difficult to interpret, and associating with the jth outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as (Greene, 2003):

$$\delta_j = \frac{\partial p_j}{\partial x_i} = p_j[\beta_j - \sum_{k=0}^J p_k \beta_k] = p_j(\beta_j - \bar{\beta}) \quad \dots\dots\dots(4)$$

The marginal effects measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable (Greene, 2003). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

In the adoption of various adaptations measure by farm household the MNL model is used to estimate the effects of explanatory variables on the dependent variables.

Based on the above theoretical justification, we specify the multinomial logit model for farm households' adaptation option strategies (AOS) like Portfolio diversification, water-additions and management, enhancing livelihoods productivity, economizing land, change use of inputs, diversifying income, and changing agricultural calendar that safe guard the farm household from climate change hazard and increase their agricultural productivity as follows:

$$AOS_i = X_i'\beta_j + U_i \quad \dots\dots\dots(5)$$

Where AOS_i is reported adaptation option strategies used by the surveyed farm households, is regression parameters, is vector of the explanatory variable and is the error term. This model is estimated by using the standard econometric software, STATA.

Definition of Variables

The major variables expected to have influence on the adoption of adaptation measures are explained below:

The dependent variable of the model : In the study the following 25 common adaptation strategies, which are all explained by similar explanatory variables, were identified: change crop variety, plant a different crop, diversify crops, shift planting dates, move to a different site, change quantity of land under cultivation, build a water-harvesting scheme, implement soil conservation techniques, buy insurance, put trees for shading, irrigate more or using irrigation, change from crop to livestock, adjust to livestock management, reduce number of livestock, change from livestock to crops, adjust to crop management, migrate to urban area, find off-farm job, diversify from farming to non farming activities, lease your land, change use of capital and labor, use of weather derivatives, pray more or increase your ritual offerings to traditional rainmakers, change use of chemicals or fertilizers, and decreased use of irrigation/ ground water/watering.

The explanatory/ independent variables: The independent variables that are hypothesized to affect the farmers' adoption decision of an adaptation measure are combined effects of various factors, such as: household characteristics, socioeconomic characteristics and

institutional characteristics in which farmers operate. Based on the review of adoption and adaptation literatures, and past research findings, 17 potential explanatory variables were considered in this study and examined for their effect on a farmer's adoption decision of an adaptation option to climate change and variability (see Appendix: Table 11).

Variable Adjustments for MNL Analysis

Econometric analysis with cross-sectional data is usually associated with problems of multicollinearity, and heteroscedasticity. Thus, prior to running the logit model the presence or absence of multicollinearity was checked using ¹Variance Inflation Factor (VIF) for testing association among the continuous explanatory variables and Contingency Coefficients (CC) for the dummy variables. Based on the test results, all the screened variables except credit service usage, perception, and gender included in the model for analysis. To avoid heteroscedasticity the logit analysis was run with robust.

To avoid multicollinearity effects in the dependent variables and to make the analysis simple and suitable, the model was restructured by grouping closely related choices together in the same category. Using different crop variety, changing crops, and crop and animal diversification were grouped in the same category, labeled "portfolio diversification." These three choices are closely related because they are considered for the same purpose of risk-spreading. Similarly, digging water wells, using irrigation, and reducing the frequency use of irrigation were grouped in the same category, labeled "water-additions and management." They are related to the use of water for the purpose of increasing productivity and withstanding rainwater shortages. Adjustment to crop production, adjustment to livestock production, changing from livestock to crop, changing from crop to livestock, reducing the number of livestock and planting trees were grouped in the same category, labeled "enhancing livelihoods productivity". The management aspects including reducing number of livestock and planting trees for shade, and the swapping of livelihoods are done to have better productive livelihoods. Change of the quantity of land under cultivation, implementing soil conservation, leasing land, moving to different farming site were merged to the "economizing land" category, as they all are using land as a base to enhance their income in terms of crop production or capital. Changing use of capital and labor, changing use of chemicals or fertilizers were grouped to the same category, labeled "change use of inputs." They are grouped on the same category because capital, labor and agro-chemicals are important inputs for the agriculture sector. Migrating to urban areas, finding off-farm jobs, and diversifying from farming to non farming activities were pooled together as "diversifying income." These are related in that they are the means to earning additional incomes other than their own farm income. Change of planting date, and use of weather derivatives were grouped on the same category, labeled "changing agricultural calendar". Changing planting dates could be one of the practical applications of weather derivatives, which may also include other applications like changing harvesting dates, managing pest and disease prevalence, managing floods and droughts, and others. Ritual offering and insurance were removed from analysis. This is because there is no a single respondent who offered rituals to traditional rainmakers, and there is also no crop insurance institute around the study areas. Accordingly, the choice set in the restructured multinomial logit model included the following adaptation options: 1) Portfolio diversification, 2) water-additions and management, 3) enhancing livelihoods productivity, 4) economizing land, 5) change use of inputs, 6) diversifying income and 7) changing agricultural calendar.

1. Decision rule: statistically strong correlation if $VIF > 10$ (Gujarati, 2003) ,and $CC > 0.75$ (Paulos ,2002). The tools of analysis were STATA and SPSS.

4. Results and Discussion

4.1 Farmers' Perception of Long-term Changes in Temperature and Precipitation

4.1.1 Perception of Temperature Changes

84.4% of the interviewed household heads perceived an “increase” in temperature volume, 2.3% of respondents perceived a “decrease” in temperature volume, 8.1% of respondents perceived “no change” in temperature volume, 3.6% respondents did not have any idea about the trend of the temperature volume, and 1.6% of the respondents refused to give their opinion on the issue. On the other hand, 85.2% of the respondents felt an increase in heat intensity; 1% of the respondents perceived a decrease in heat intensity; 9.9% of the respondents claimed no change in heat intensity; 2.3% of the respondents did not give enough attention about the heat intensity trend; and 1.6% of the respondents failed to respond. As indicated in Figure 2 below, the trend analysis of both annual mean minimum and maximum temperatures follow increasing trends. This was in accordance with the perception of most farmers towards temperature.

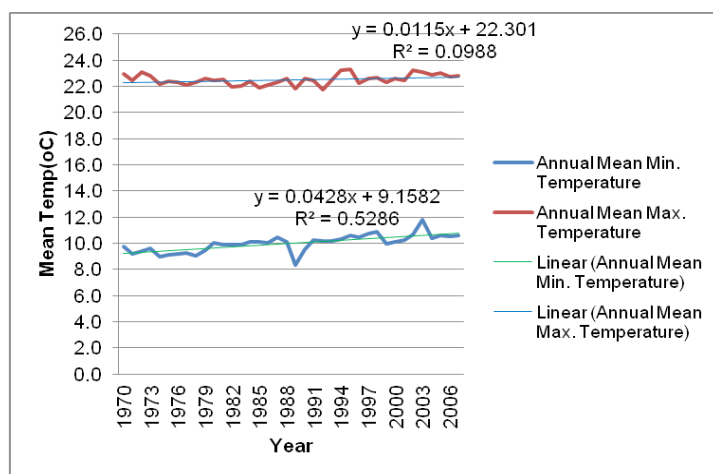


Figure 2: Annual mean minimum and maximum temperature trends of upper Blue Nile catchment.

There was no statistically significant variation in perception of temperature across the agro-ecological zones (Appendix: Table 12). This implies that the change in temperature occurred in all agro-ecologies and it was felt more or less equal by every farming community. The analysis of variance for perception of temperature change shows significant variation among the different educational levels (Table 2).

Table 2: Farmers perception on temperature across educational levels

Perception on temperature (%)						χ^2
Heat intensity per day						
Educational level	Increased	No change	Decreased	I do not know	No answer	
Illiterate	78.9	18	0	1.5	1.5	
Read and write	89.2	5.9	0	3	2	
Complete first cycle	83.3	7.1	7.1	2.4	0	
Complete second cycle	90.9	0	9.1	0	0	41.4*(df=12)
Number of hot days per year						
Illiterate	75.8	15.6	2.3	3.9	2.3	
Read and Write	90.1	3.9	0.5	3.9	1.5	
Complete first cycle	81	7.1	9.5	2.4	0	
Complete second cycle	90.9	0	9.1	0	0	32.6*(df=12)

* Significant at 1% level; Source: Own survey, 2011

Highest proportion of respondents in all educational levels perceived the increase in heat intensity and volume. However, there was not a single respondent who had not noticed or felt no change in temperature from those who completed second cycle education. The implication is that educated peoples are keener in noting changes in temperature more than less or uneducated people; educated people become very conscious about their environment and sense the changes in climate better. Same tests indicated a significant difference between the views of experienced and inexperienced farmers existed in temperature change perception (Table 3). Most farmers with short farming experience (< 10 years) observed no change in heat intensity where as farmers with more experience (> 10 years) perceived an increase in heat intensity. On the other hand, highest number of respondents in all experience groups perceived an increase in temperature volume on time scale of three decades and more. However, farmers with more experience who perceived the increase in temperature volume are more than twice of the respondents of short experience. Besides, the percentage of respondents with short farming experience who felt no change in temperature volume are more than six times to that of farmers with medium and long experience. Moreover, a considerable number of short experience farmers did not give enough attention about the temperature trend of the area they are living (Table 3). This implies that experienced farmers tend to perceive an increase in temperature more than less experienced farmers.

Table 3: Perception of changes in temperature by farmer experience

Perception on temperature (%)						X
Heat intensity per day						
Farming experience	Increased	No change	Decreased	I do not know	No answer	
Short(<10 yrs)	42.9	48.6	2.9	5.7	0	
Medium(10-30yrs)	86.9	8	2.2	0.7	2.2	
Long(>30yrs)	91	5.6	0	3.4	0	94.6*(df=16)
Number of hot days per year						
Short(<10yrs)	40	37.1	5.7	17.2	0	
Medium(10-30yrs)	86.9	6.6	2.2	1.5	2.9	
Long(>30 yrs)	89.3	5.1	2.2	3.4	0	83.4*(df=16)

* Significant at 1% level; Source: Own survey, 2011

All other stakeholders interviewed believe that temperature has increased in the area over the last three decades.

4.1.2 Recognition in Changes of Precipitation

Most of the interviewed farmers perceived precipitation changes, quantity of rainfall and/or distribution, in the study area over the last 30 years. Substantial percentage of respondents (88.3%) perceived the change in the amount of rainfall. Out of 88.3% respondent who perceived the change in rainfall amount, 60.7% of the respondents felt a decrease in the amount of rainfall, and the remaining 27.6 % respondents oppositely felt an increase in the amount of rainfall; on the contrary, 7.8% of the respondents noticed no change in the amount of rainfall; 2.6% of the respondents did not give enough attention about the trend of the rainfall volume; and 1% of the respondents refused to respond. The result also indicated that the majority of the respondents (89.6 %) noticed a change in the timing of rains, specifically, 73.9 % observed shorter rainy seasons, and 15.7 % observed extended rainy seasons; 5.7% of the respondents observed no change in the rainy season; 2.9% of the respondents had no opinion about the rainfall pattern; and 1.6% of the respondents did not give a response. According to the recorded data on rainfall from 1970 to 2008, the annual and the seasonal rainfall volume follow increasing trends over the period (Figure 3). There was a clear contrast between the majority of the farmers' perception towards amount of rainfall and rainfall trend over the past 30 years. The divergence in farmers' perception and the actual rainfall data could be seen from two different perspectives.

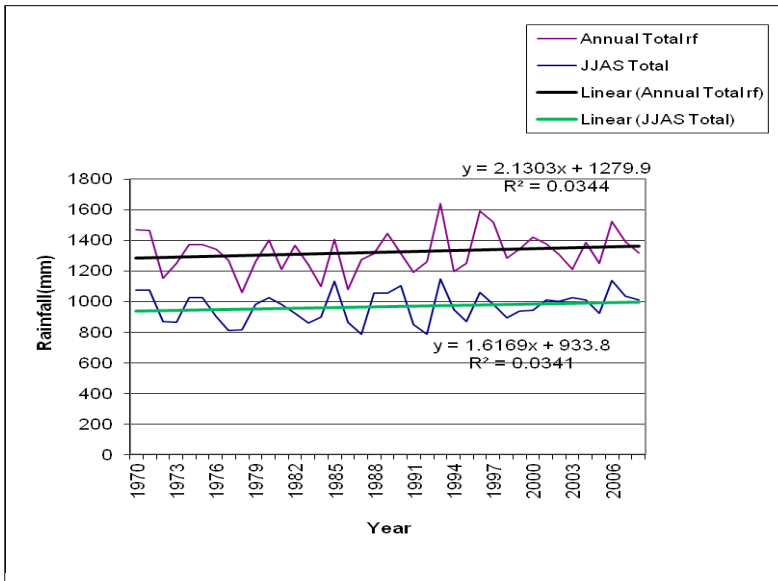


Figure 3: Rainfall trend of upper Blue Nile catchment (1970-2008)

On one hand, there could be an increasing demand for water and food in the study areas due to recorded population growth (CSA, 2008). The increasing population could have put a lot of pressure on existing water bodies for crop production, livestock production, and household consumption. Moreover, the demand for stable crops to feed the increased population might fail because of low agricultural productivity which could not be necessarily resulted from climate change and variability. Farmers, however, might perceive the decrease in water availability due to these factors, and the deficit in crop production to feed the increased population as decrease in rainfall amount, despite it remained stable or increased throughout the years. On the other hand, the recorded monthly meteorological rainfall data might hide the actual rainy days within a month or the amount of rain in a single shower. From experience most farmers know specific days or weeks with in a critical crop growth period when a crop demand for water is highest; if it does not fall enough in those actual time of the critical crop growth period, farmers might perceive it as decrease in rainfall amount.

Unlike temperature, perception in precipitation shows significant variation across the different agro-ecological zones (Table 4 and Table 5). The lowland community is the one with the highest proportion of respondents who felt a decrease in rainfall amount and the least to perceive an increase in amount. This is probably because in the lowland zone water is already very scarce, and a little change in the amount of rainfall could be felt highly, for existing livelihoods are already on climatically stressed conditions.

Table 4: Perception of rainfall amount change by agro-ecology

Agro-ecology	Perception on rainfall amount per day (%)					χ^2
	Increased	No change	Decreased	I do not know	No answer	
Highland	30	0.8	67.5	1.7	0	
Midland	30.7	14.1	48.5	4.9	1.8	
Lowland	19.8	5.9	72.3	0	2	36.28*(df=10)

* Significant at 1% level; Source: Own survey, 2011

Table 5: Perception of rainfall pattern change by agro-ecology

Agro-ecology	Perception on rainfall pattern (%)					χ^2
	Not changed	Changed	No Answer	I do not know	No answer	
Highland	0	100	0		0	
Midland	11	82.8	6.2		2.2	
Lowland	4.9	91.1	4	24.3*(df=6)	0	94.6*(df=16)

* Significant at 1% level; Source: Own survey, 2011

The statistical analysis of variance for perception of precipitation change shows significant variation among the different educational levels (Table 6). Except those who completed second cycle education all others perceived the change in more or less similar manner.

Table 6: Farmers perception on precipitation by educational levels

Educational level	Perception on Precipitation (%)					χ^2	
	Rainfall amount per day						
	Increased	No change	Decreased	I do not know	No answer		
Illiterate	31.3	6.3	58.6	1.6	2.3		
Read and write	28	7.4	63.1	0.5	1		
Complete first cycle	11.9	4.8	66.7	16.7	0		
Complete second cycle	36.4	45.5	18.1	0	0	68.5*(df=12)	
Educational level	Number of rainy days per year					χ^2	
	Illiterate	19.5	5.5	70.3	1.6		3.1
	Read and Write	16.7	3.9	76.8	1		1
	Complete first cycle	2.4	4.8	73.8	16.7		2.4
	Complete second cycle	0	45.5	54.5	0		0

*, **, *** Significant at 1%, 5%, and 10% respectively; NS= not significant at 10% level Source: Own survey, 2011

The same tests indicated a significant difference between the views of experienced and inexperienced farmers existed in rainfall change perceptions. The number of persons who felt a decrease and no change in rainfall volume and pattern seems to decrease as farming experience increased. On contrast, the number of people who felt an increase in rainfall volume and pattern seemed to increase as farming experience increased (Table 7).

Table 7: Perception of changes in precipitation by farmer experience (% of respondent)

Perception on Precipitation (%)						χ^2
Rainfall amount per day						
Farming experience	Increased	No change	Decreased	I do not know	No answer	
Short(<10 yrs)	11.4	11.4	74.3	0	2.9	
Medium(10-30yrs)	23.4	9.5	63.5	2.2	1.5	
Long(>30yrs)	36	5.6	54.5	3.9	0	65.8*(df=20)
Number of rainy days per year						
Short(<10yrs)	8.6	8.6	77.1	2.9	0	
Medium(10-30yrs)	13.9	6.6	75.9	2.2	1.4	
Long(>30 yrs)	20.2	5	69.7	3.9	0.5	50.1*(df=20)

* Significant at 1% level; Source: Own survey, 2011

There was also statistically significant variation of perception in precipitation by gender (Table 8). Highest proportion of respondents in both sexes believed a decrease in rainfall volume and a shrink in rainy season. However, substantial proportion of female respondents i.e., 31.6% confirmed no change in rainfall volume or pattern.

Table 8: Perception of changes in precipitation by gender

Perception on Precipitation (%)						χ^2
Rainfall amount per day						
Gender	Increased	No change	Decreased	I do not know	No answer	
Female	18.4	31.6	50	0	0	
Male	28.6	5.2	61.8	2.9	1.2	34.2*(df=5)
Number of rainy days per year						
Female	13.2	31.6	55.3	0	0	
Male	15.9	2.9	75.7	3.2	1.7	53.2*(df=5)

70% of the interviewees from other stakeholders felt an increase in rainfall amount, 25% of the respondents believed a decrease in rainfall amount, and the rest 5% believed no change in amount. On the other hand, 93% of the respondent observed a change in the pattern of rainfall; out of the 93% who observed the change in rainfall, 82 % of them observed late coming and early cessation, and 11% of the respondents noticed late coming and late cessation; and on the contrary, 4 % of the respondents felt no change on the rainfall pattern.

4.2 Local Impacts of Climate Change and Variability

In the household survey, farmers were provided with a list of production problems and asked to prioritize in order of importance. As seen in table 9, farmers' prioritized erratic rainfall, soil erosion, decline of soil fertility, land shortage and drought as major production constraints. Except land shortage all others are climate related factors.

Table 9: Farmers' perceived production constraints and their priority ranking

Constraint	Highland (n=120)					Midland (n=163)					Lowland (n=101)					Chi-square
	1st	2nd	3rd	4th	Mean Rank	1st	2nd	3rd	4th	Mean-Rank	1st	2nd	3rd	4th	Mean	
Land shortage	25	10	1	6	162	35	14	8	33	201	43	9	8	3	215	18.6*
Labor shortage	2	5	2	0	187	4	6	5	7	199	1	1	5	1	188	3.5NS
Oxen shortage	1	9	6	6	203	2	7	8	4	192	2	3	2	0	181	6.3**
Declining soil fertility	8	20	33	31	206	7	28	30	38	181	21	20	15	15	195	5.6***
Drought	21	8	21	29	213	14	16	54	4	190	2	13	10	21	173	9.6*
Pest and diseases	8	4	5	7	202	6	2	7	2	184	2	6	4	5	196	5.2***
Soil erosion	15	37	28	16	191	30	58	18	21	179	4	6	9	33	217	12*
Erratic rainfall	35	20	16	15	154	49	13	21	24	218	20	31	25	10	198	36.3*
Planting mat.	1	3	3	6	209	16	19	12	25	205	1	7	18	8	154	27.4*
No answer	4	4	4	4	-	0	0	0	5	-	5	5	5	5	-	-

* , ** , *** Significant at 1%, 5%, 10% level respectively, NS-Not Significant at 10% level; Source: Own survey, 2011

Flood frequency and its associated impacts were worst in the highland before 2002, and this was mainly attributed to the sloppy nature of the farmlands. There was statistically significant difference in the flood impacts across agro-ecology. But after 2002 all agro-ecologies affected by flood more or less equally and there is no statistically significant difference in flood occurrence. This could be attributed by the compounding effect of the ever degrading vegetation cover and unstable rainfall pattern in all agro-ecological zones.

Drought was most common in the lowland than in the highland or midland a decade ago (before 2002). With highest level of impact on the lowland, there was a significant impact difference across the agro-ecologies. The number of respondents who were once affected by drought in the production period between 1990 and 2001 was 6.7%, 17.8 %, and 98% in the highland, midland, and lowland zones respectively. However, the number of farmers who claimed to be affected by drought at least once in the 2002- 2011 production period was 100% in the highland, 96.9% in the midland, and 97% in the lowland. The survey result also indicated that in the 2002-2011 production period drought brought a very serious damage (> 50% possession loss) in the highland and midland than in the lowland, and the difference in the level of damage was statistically significant This lowest level of drought damage record in the lowland despite its' increased severity could be resulted from the relatively longest experience of the lowlanders with drought which helped them to manage it well.

Erratic rainfall was not a very common event to the farmers before 1990. Rainfall pattern was relatively stable, and most farmers responded "no damage on livelihoods" due to erratic rainfall between 1978 and 2001 production seasons. However, the rainfall was very unstable between 2002 and 2011 production seasons, and caused heavy crop losses and increased flood frequency. Besides, its damage was not skewed to any agro-ecology and there is no

significant impact difference across the agro-ecologies. This indicates that rainfall variability is not a localized problem; it affects the farming communities of the different agro-ecological zones in more or less balanced manner.

Pest and diseases, and ice fall were other production constraints that brought the highest damage in production periods that lie between 2002 and 2011. Highest level of pest and disease damage was observed in the lowland and the level of damage show statistically significant difference across the agro-ecologies. Ice fall incidence was highest in the highland and there was also significant difference in occurrence across agro-ecologies. Frost and land slid were not serious problems in the study area.

4.3 Farmers' adaptation to Climate Change and Variability

4.3.1 Coping Mechanisms

To escape climatically bad years the farming community has been using a wide range of inbuilt coping mechanisms. All climate hazards end up either in eroding the asset of the farmers, or the natural base on which their livelihood depends. Hence, coping strategies adopted are not specific to the climate hazard type. Farmers in the upper catchment of Blue Nile have used a wide range of strategies to cope with the natural hazards. Reduced socialization for saving(37.5%), inter household transfers and loans(29.7%), reducing household consumption(22.5%), store grains(16.4%), sale forest products(8.5%), rent tools/ animals(7.3%), Wage laborer (5.8%), government assistance(4.5%), sale of household assets(4.3%), petty trading(4.3%), appeal for food aid(4.3%), land Mortgage(3.2%), migrate in search of employment(2.6%), community service (food for Work) (2.2%), Handicraft(1.6%), credit from merchants or money lenders(1.5%), making of local drinks(0.7%), and Begging(0.16%) were the main coping mechanisms experienced by the farming community. Recurrent impacts of climate change on crops and livestock, and its considerations- farm sector and yield vulnerabilities -forced the rural community to focus on adaptive strategies that reduce impact and vulnerability. The following sub- sections focus on the various adjustments that farmers in the survey area made in their farming activities in response to climate change and variability.

4.3.2 Changes in Agricultural Calendar

In the household survey, farmers were asked to evaluate the current cropping calendar against the cropping calendar that was 10 or 20 years ago. A considerable number of respondents shifted the sowing and harvesting dates of their crops as an adjustment to the changing climate especially rainfall variability. For instance, in the 2010/2011 production season 287 household heads out of 384 reported to sow crops lately; from the 287 household heads 250 of them confirmed to harvest the lately sown crops earlier This production period was preferred, for it was the most recent in terms of chronology, and had the least missed data. This result implies that crops were harvested before completing their life cycle or reaching maturity period due to rain fall pattern change. This in turn result low grain filling period, and thereby low yield. Farmers shorten the growing length of the crops knowing the side effect because they preferred low yield to 100% production loss. The benefit of this strategy is highly minimized unless drought resistance or early maturing varieties are used. Group discussion and key informant interviews report indicated that the present agricultural calendar of most crops is shorter than it was before 1990 (Figure 4).

The result implicitly showed a tendency towards shorter growing season, indicating that most crops are planted today during mid- to end of June, and are often harvested some weeks earlier as well. For instance, the growing period of wheat and barley has shortened by one month now compared to the period before 1990s. Presently, potatoes are planted 2-3 weeks

later and harvested 1 week earlier than they were before the 1990s. The reduction in the growing period of crops is more likely resulted from the long dry spell, warming, and erratic rainfall.

Agricultural calendar before 1990

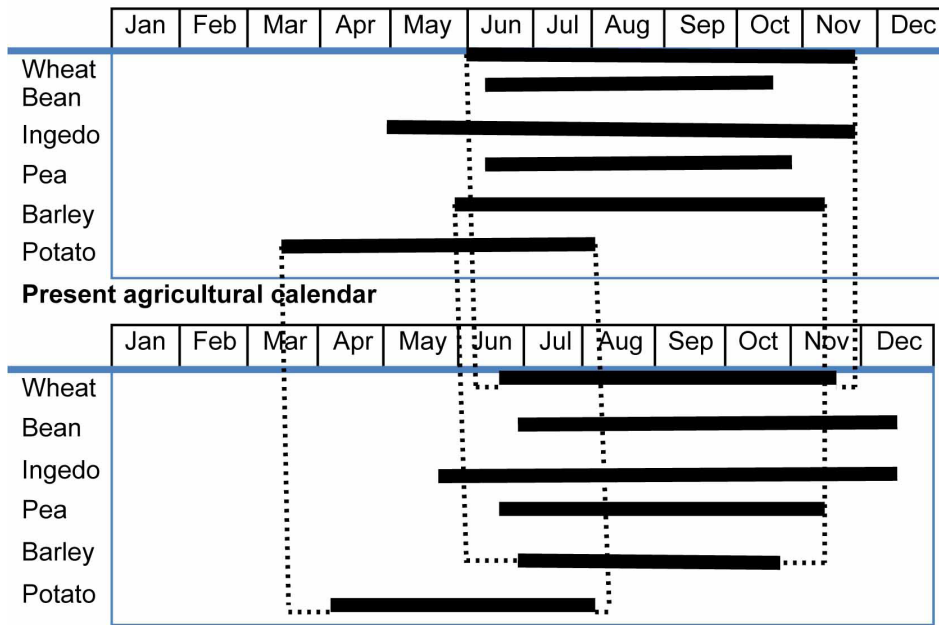


Figure 4: Comparison between the agricultural calendar before 1990 and the present

4.3.3 Farm Level Adaptation Strategies

A diversity of adaptation options was employed by the farming community to counteract the impacts of temperature and rainfall pattern changes. The strategies used by the different farming communities to minimize the impacts of the perceived changes of climate were more or less similar, but the extent of implementation varied.

Farmers' Response to Perceived Change to Temperature

Out of 86.7% of respondents who perceived the change in temperature, 84.4% employed at least one adaptation measure to counteract the impact of the change in temperature. About 39% respondent implemented soil conservation measures, 36 % respondent planted trees for shade, 28% respondent changed crop, 27.1% respondent adjusted crop management, 22.1% respondent changed planting dates, 21.1 % respondent adjusted to livestock management, 14.1% respondent reduced number of livestock, 10.7 % respondent sow different crop varieties, 8.1% respondent engaged in off-farm activities, 8.1% respondent diversified from farming to non farming, 6.5% respondent build water harvesting schemes, 4.2% respondent changed use of chemicals or fertilizers, 3.1% respondent changed use of capital and labor, 2.6% respondent Irrigated more or used irrigation, 1.8% respondent changed from crop to livestock, 0.5% respondent diversified their crop and animal, 0.3% respondent moved to a different site, and 0.3 % respondent changed quantity of land under cultivation. 86.5% of the interviewed household heads believed that under the existing constrained environment the adaptation measures they employed were best and suitable for the current and future changes of temperature.

Farmers' Response to Perceived Change to Precipitation

Change in precipitation pattern caused far more serious problems in crop production than temperature change in the study area. This could be evidenced by two of the tree dominant climate hazards in the study area, namely, flood and erratic rainfall, are resulted from change in precipitation, not in temperature. Even the remaining high level impact climate hazard in the study area, drought, is partly resulted from the change in precipitation. Hence, larger number of respondents (97.4%) took adaptation measures in response to changing rainfall patterns than apprehended temperature change. Among those who made adjustment to perceived precipitation change, 82.3% implemented soil conservation practices, 55.2% changed planting dates, 40.6% planted trees for shade, 34.4% switched to other crop, 33.3% planted different crop varieties, 25.3% adjusted crop management, 10.9% extended Irrigation coverage, 8.6% adjusted livestock management, 8.1% changed use of capital and labor, 8.1% changed use of chemicals or fertilizers 6% changed quantity of land under cultivation, 4.7% moved to a different site, 3.6% engaged in off-farm activities, 2.1% used crop & animal diversification, 2.1% diversified from farming to non farming, 1.8 % build water harvesting schemes, 0.5% decreased use of water, and 0.3% reduced number of livestock. 81.5% of the respondents believed that under the current constrained environment the adaptation measures employed were best and suitable for the current and future changes of precipitation. This indicates that the farming community will continue to use the existing adaptation strategies despite increasing effects of climate change in the future unless local specific adaptation interventions are done.

4.4 Barriers to Adaptation in the Upper Blue Nile Basin

The adaptation section of this paper explicitly indicated that the farming community had tried to counteract the impact of climate change and variability by employing local adaptation strategies. However, farmers' perceived adaptation measures were not the same with the adaptation measures they actually employed, for lack of access to information, knowledge, productive resources, institutional arrangements, infrastructure, and other factors which are described below.

4.4.1 Farmers Perceived Barriers to Adaptation

Results on barriers to taking up adaptation options indicated that lack of knowledge (99.2%), lack of information (99.2%), not feasible and/or lack of belief(99%), lack of agricultural technologies and inputs (97.7%), presence or absence of agricultural policy (97.2%) land scarcity (91.7%), shortage of labor(85.5%), market problem (78.5%), water scarcity (76.9%), poverty or lack of credit or saving services(59.8%), lack of extension service (30.8%), and lack of health service (7.8%) to be major constraints of adaptation for most farmers.

4.5 Determinants of Farmers' Adaptation

Farmers' adaptation behavior, especially in low-income countries, is influenced by a complex set of socio-economic, demographic, technical, institutional and biophysical factors (Feder et.al., 1985). Hence, modeling farmers' response to agricultural adaptations has become important in identifying major determinants of adoption of the various adaptation measures. Statistically influential determinants are factors on which efforts should be exerted to enhance farm-level agricultural adaptations to climate change and variability in the study area.

Out of the thirteen explanatory variables hypothesized to affect farmers' adaptation education level, size of productive labor, wealth, farm size, farming experience, perception of soil fertility status, frequency of extension visits, access to media information, and agro-ecology were flagged as being statistically significant at 5% level and above (Table 10). The results of the multinomial logit model highlighted that, frequent extension visit encourages the adoption of enhancing livelihood productivity strategy; resource endowment promotes

portfolio diversification, water addition and management, economizing land, and enhancing livelihood productivity strategies; access to climate information increases the use of portfolio diversification and economizing land strategies; large size of productive labor encourages the use of economizing land and diversifying income; and farming experience positively influences farmers to use water addition and management, economizing land, changing agricultural calendar. However, perception of having a fertile soil discourages the use of enhancing livelihood productivity, and increased market distance decreases the use of different agricultural inputs; on the other hand, having large farm size encourages the adoption of water addition and management to produce more than once and discourages enhancing livelihood productivity, and diversifying income (Table 10). Findings from Bryan et al., (2010), Mahmud et al., (2008) and Temesgen et al., (2008) identified wealth, access to extension, credit, and climate information as factors influencing farmers' adaptation in Ethiopia, which are in agreement with this study.

Table 10: Results of marginal effects of the multinomial logit model for rainfall variability

Variables	Portfolio diversification	Water addition & Management	Economizing land	Enhancing livelihood productivity	Changing use of inputs	Diversifying income	Changing agriculture calendar
Educational Level	0.3565169**	0.1504134	0.3718583	0.2816848	0.1805782	-0.0457751	0.0848938
Productive Labor	0.0697929	-0.0238653	0.8099018*	-0.2005943**	0.1720983	0.6570776*	-0.0851975
Wealth Status	0.4815438**	1.281404*	0.6556129**	1.027497*	-0.1164325	0.1145385	-0.3000091
Farming Experience	-0.0023619	0.0540775*	0.0268566*	0.0095987***	-0.0129019	-0.0007229	0.0144243*
Farm Size	0.0629484	0.1995393*	0.3648458	-0.2608765*	-0.0458638	-0.4964536**	0.1298603***
Soil Fertility	0.0094905	-0.0006027	0.0011932	-0.0220486*	0.0032055	0.0084933	-0.0572679***
Extension Visit	0.0233558***	-0.0458624	0.0439862	0.0430084*	-0.0477418	-0.2925768	0.1707737
Access to climate information	0.0237762**	-0.7110336	0.0575824*	0.0270215*	0.0276453*	0.0178055**	-0.0080937
Credit Usage	0.0067909	0.0050855	0.0056881	-0.0033672	-0.0035179	-0.4111038	0.0203514***
Market Distance	0.1109852**	0.2201145***	-0.0895975	-0.0230277	-0.2295205*	-0.0773399	0.0993896***
Non/off-farm activities	-0.6818418***	-0.419601	-0.1482988	1.25544*	0.1294997	0.5263476	-0.2263743
Tenure Security	0.0869807	-0.006451	0.2450501	-1.624273*	0.0076348	-0.0402502**	0.1697459
Highland	-0.6447678	3.857046*	-2.148138*	-1.336209*	0.7764744	-0.6918312	-1.801694*
Midland	-1.925736*	0.9979419	-0.3957069	0.962623*	2.492288*	2.50576*	-2.261947*
No. of observation	353						
Wald $\chi^2(90)$	1176.70						
Prob > χ^2	0.0000						
Log pseudo likelihood	2760.3716						
Pseudo R^2	0.1492						

*Significant at 10% **significant at 5% ***significant at 1%; Illiterate, resource poor, non-fertile soil, and no visit by extension agent are dropped base categories; Source: Own computation, 2011.

5. Conclusion and Recommendations

Farmers living in the Upper Catchment of Blue Nile perceive changes in temperature and rainfall. They are able to recognize that temperature, and rainfall volume have increased, and rainfall pattern has become unpredictable. They feel a major shift in agro-ecological conditions i.e., the area is becoming hotter and drier. However, the way farmers perceived the changes in climate significantly varies across agro-ecologies, farming experience, gender, and educational level. The majority of farmers' perception towards temperature change is in line with the temperature records, but a clear contradiction was observed between rainfall volume records and most farmers' perception towards rainfall volume.

The community identified erratic rainfall, flood, and drought as dominant natural calamities in the study area. According to farmers these climate hazards are not new phenomena, but the frequency of occurrence of these events, and their associated impacts are increasing in due course of time. Erratic rainfall, soil fertility decline, soil erosion, and drought were prioritized as major production constraints.

Evidence for farmers' perceived changes in climate is reflected in the adjustment of agricultural calendar and adoption of different adaptation strategies. Survey results confirmed that farmers have shortened the cropping calendar, and the majority of the respondents have adjusted their farming practices to counteract the impacts of changes in temperature and rainfall patterns. The common adaptation strategies of farmers were: implementing soil conservation practices, changing planting dates, plant trees for shade, switch to other crop, plant different crop varieties, adjust crop management, extend Irrigation coverage, adjust livestock management, change use of capital and labor, change use of chemicals or fertilizers, change quantity of land under cultivation, move to a different site, engage in off-farm activities, use crop and animal diversification, diversify from farming to non farming, build water harvesting schemes, decrease use of water, and reduce number of livestock. These options are reactive ones, born out of necessity by the farmers themselves. Farmers in the area can be considered as good adopters against climate change impacts. However, their actual adaptations were not the same as their perceived adaptations due to various barriers.

The study identified lack of knowledge, inappropriate agricultural policy, shortage of labor, water scarcity, land scarcity, poverty or lack of credit or saving services, market problems, lack of information, forage and feed scarcity, lack of agricultural technologies and inputs, lack of health service, and others such as lack of institution, ineffectiveness of an option, strong family ties, lack of job opportunities, etc., as major barriers of adaptation. The results of the multinomial logit model highlighted that frequent extension visit encourages the adoption of 'enhancing livelihood productivity' strategy; resource endowment promotes 'portfolio diversification', 'water addition and management', 'economizing land', and 'enhancing livelihood productivity' strategies; access to climate information increases the use of 'portfolio diversification' and 'economizing land' strategies; large size of productive labor encourages the use of 'economizing land' and 'diversifying income'; and farming experience positively influences farmers to use 'water addition and management', 'economizing land', and 'changing agricultural calendar'.

However, perception of having a fertile soil discourages the use of 'enhancing livelihood productivity', and increased market distance decreases the use of 'different agricultural inputs';

on the other hand, having large farm size encourages the adoption of 'water addition and management' and discourages 'enhancing livelihood productivity', and 'diversifying income. The implications of these findings are that adaptation measures significantly increase for households with more educational level, frequency of extension visits, farming experience, resources (assets), and climate information. Hence, designing policies with the aim of improving these factors will improve farm-level adaptations.

The Government could contribute to counteract climate change impacts on agriculture by investing in research (drought and disease resistance varieties, early maturing varieties), soil conservation measures, technology (farming machineries like improved plough design which could penetrate the hard soil pan to enhance water percolation and minimize flood impacts; Introduce mud bricks house), health centers, irrigation and water harvesting development, expanding fertilizer use, markets, and education (farmers training centers, formal education), establishing crop insurance institutes, reforming land policies, establishing local meteorology stations, monitoring and publishing climate data, developing climate forecasts, and formulating planned and anticipatory adaptation strategies, and creating job opportunities by expanding non-agricultural sectors. For instance, early warning system prepares farmers to use agricultural technologies, soil conservation structures, and complementary or alternative livelihoods in the face of climate change. Institutions such as local meteorological station which provides climate information, crop insurance which insures crop losses due to climate change, market which provides access to agricultural technologies and Teaching and Vocational Educational Training (TVET) Center which provides skills and knowledge to farmers to engage in other livelihoods are also important in expanding the coping ranges of farmers to climate change. Current land use policy of Ethiopia which promotes land fragmentation and hence, discourages soil conservation measures need to be reviewed in the merit of the farmers.

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