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Climate change adaptations of smallholder farmers in South Eastern Ethiopia

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The negative impact from the climate change has been striking the agriculture sector in Africa. For countries like Ethiopia, whose livelihood occupation of the nation is mainly based on subsistence agriculture that highly rely on rainfall, making an adjustment to adapt to the changing situation is crucial. Therefore, designing context specific adaptation strategies are essential to moderate the negative effect of climate change. This study was intended to answer how farmers perceive climate change, what adaptation measures are farmers practicing in their area and factors influencing adaptation to climate change. Four stage sampling procedure was followed in selecting the study Woreda, villages and representative respondents. Accordingly, 3 villages and 160 household heads were selected using simple random sampling and systematic sampling, respectively. In addition to the secondary data, structured interview schedule was developed, pre-tested and used for collecting quantitative data. The model result depicted the strong and positive association relation between the combined measures of agronomic practices and use of agricultural inputs with education, access to weather information, access to credit and farm income. Similarly, sex of the household head and access to weather information were found to significantly affect the choice decision of adoption of inputs and agronomic practices like use of drought tolerant crop species and crop diversification measures. Therefore, government policies on climate change adaptation program should be given due emphasis to in enhancing the adaptive capacity of the farming society through improving the provision of credit, promoting adult education, and enhancing means of income generation in the rural areas.

Key words: Climate change, adaptation measures, adaptation strategies, smallholders.

INTRODUCTION

Climate change describes changes overtime in parameters such as temperature, precipitation, wind speed and direction, and humidity (Erikssen et al., 2008; Hellmuth et al., 2007). Changes can occur in extreme events, average values, as well as in spatial and temporal variability. According to Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment Report, global average temperature would rise between

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1.4 and 5.8°C by 2100 with the doubling of the CO_2 concentration in the atmosphere. Change in precipitation pattern (up to ±20%), and change in other local climate conditions are expected to occur as a consequence of rising global temperature (Cubash et al., 2001).

Climate change poses serious threats and challenges to Africa. It exacerbates existing risks such as water stress, the spread of infectious diseases, and food insecurity (Eriksen et al., 2008). It is anticipated that African countries in particular will endure some of the worst effects of climate change. Many parts of Africa already experience high variability in rainfall, which threatens the livelihoods of the many people who depend on rain-fed agriculture (Kinyangi et al., 2009). African people have developed coping strategies to deal with this variability, but the ability of African institutions and people to adapt to the magnitude and rate of anticipated climate change impacts over the next 20 to 30 years is limited and considered to be among the most vulnerable regions to climate variability and change due to social, technical, and environmental factors including widespread poverty, fragile ecosystems, weak institutions, and ineffective governance (Eriksen etal., 2008; Kinyangi et al., 2009).

In the Nile region, most scenarios of water availability estimate a decrease in river flow up to more than 75% by the year 2100, with negative implications for agriculture and conflict. Poor water quality, projected to intensify under climate change, would increase water related diseases, reduce agricultural production, and limit economic development options. This projected future water stress and scarcity will have serious impacts on the socio-economic development of the countries affected and will likely adversely affect their food production levels and development plans (Anthony, 2005). Anthony (2005), also stated projected losses in cereal production potentials in sub-Saharan Africa up to about 33% by 2060. Climate change could have also a negative impact on pastoral livelihoods through a reduction in water availability and biomass.

Around 80% of Ethiopia's population is dependent on agriculture, which is almost entirely rain fed and small-scale. Both farmers and pastoralists are highly dependent on the climate for their livelihoods; this is reflected in the remarkable way that gross domestic product (GDP) fluctuations follow rainfall (Hellmuth et al., 2007). In recent years, environment has become a key issue in Ethiopia. The main environmental problems in the country include land degradation, soil erosion, deforestation, loss of biodiversity, desertification, recurrent drought, flood and water, and air pollution. Ethiopia is highly vulnerable to drought. Drought is the single most important climate related natural hazard impacting the country from time to time. Drought occurs anywhere in the world but its damage is not as severe as in Africa in general and in Ethiopia in particular. Recurrent drought events in the past have resulted in huge loss of life and property as well as migration of people (NMS, 2007). Causes for vulnerability of Ethiopia to climate variability and change include very high dependence on rain fed agriculture which is very sensitive to climate variability and change, under-development of water resources, low health service coverage, high population growth rate, low economic development level, low adaptive capacity, inadequate road infrastructure in drought prone areas, weak institutions and lack of awareness (NMS, 2007). The east and north of the country are the most vulnerable to drought and have the highest food insecurity. Ethiopia's characteristically variable climate presents a significant challenge to its people. Poverty compounded by other factors including high population density, environmental degradation, and conflict, increases people's vulnerability to drought, leading to food insecurity (Hellmuth et al., 2007).

Hence, assessing vulnerability to climate change and preparing adaptation options as part of the entire national adaptation program is very crucial for the country (Admassie et al., 2008).

Adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them (Maddison, 2006). Climate change is a global issue, while adaptation will happen locally. Hence, any strategy for adaptation must consider the local context (Eriksen and Otto, 2003). In particular, policymakers should be sure to draw on knowledge and experience from local communities. By overlooking local knowledge, policies can constrain rather than enhance the adaptive capacity of communities (Admassie et al., 2008). The efforts made by the farmers to adapt with the changing climate at local level are mostly unorganized and influenced by a set of factors. It needs well integrated and holistic approach to the entire system of the agriculture sector to make less sensitive to climate change impact. For this, assessing the existing condition at local level is worthwhile to design appropriate adaptation programme in place.

For this reason, the farming communities in the district have been experiencing repeated food security problem and receiving grain assistance on a yearly basis according to the report from Dello Mena district food security, DPP office. Therefore, the issue necessitated conducting local level empirical study to make use of the knowledge and experience of farmers on climate change and adaptation measures that would be used as an input in designing feasible adaptation programme based on the context of the area.

Objectives of the study

Specific objectives

1) To explore the adaptation strategies of farmers to climate change impacts in the study area.

2) To identify factors determining adaptation measures by farmers to climate change and variability in the study area.

LITERATURE REVIEW

Causes of climate change

Climate change may be due to internal processes and/or external forces. Some internal influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the natural variability of the climate system. Other external changes, such as the change in the composition of the atmosphere that began with the industrial revolution, are the result of human activity. Over the past 10 years, scientific study of greenhouse gas (GHG) emissions and global warming has gradually moved towards the conclusion that human activities are having an inexorable effect on the world's climate system (Stuart and Moura-Costa, 1998).

In 2007, Working Group I of the Fourth Assessment Report (AR4) of the IPCC concluded that 'warming of the climate system is unequivocal' and that most of this recent warming is 'very likely' due to human emissions of GHGs into the atmosphere (Hulme et al., 2009).

Climate change impacts

Erikssen et al. (2008) stated that climate change impact as the effects of climate change, from the first order (direct effects of increased CO_2 concentrations in the atmosphere as well as changes in climate parameters on plants, animals and human beings), to downstream effects of such changes on ecosystems and societies. Croplands, pastures and forests that occupy 60% of the earth's surface are progressively being exposed to threats from increased climatic variability. Abnormal changes in air temperature and rainfall, and resulting increases in frequency and intensity of drought and flood events have long-term implications for the viability of these ecosystems (FAO, 2007).

Climate change adaptation and vulnerability

Adaptation is the term used to describe all activities aimed at preparing for or dealing with the impacts of climate change, be it at the level of individual households, communities and firms, or of entire economic sectors, watersheds and countries. Adaptation thus serves to reduce the damage resulting from the unavoidable impacts of climate change, as well as to protect people's lives and livelihoods (Hulme et al., 2009).

According to Ericson et al. (2008), adaptation is adjustments in practices, processes, or structures to take into account changing climate conditions, to moderate potential damages, or to benefit from opportunities associated with climate change. Hulme et al. (2009) explained adaptation as it is not just attaining a physical outcome, but a dynamic process relying on institutional mechanisms to enable the implementation of selected measures and the building of local capacity. Involving stakeholders in adaptation and risk management processes is a key component of building adaptive capacity.

Adaptation and mitigation are sometimes regarded as alternative strategies, but they are certainly not mutually exclusive. Effective climate policy involves a portfolio of both adaptation and mitigation activities. Even with high levels of mitigation - limiting global-mean temperature increase to no more than 2°C above pre-industrial levels - climate change impacts will require considerable adaptation efforts (Hulme et al., 2009). Adaptation does not replace mitigation of GHG emissions. On the contrary, both adaptation and mitigation need to be pursued in parallel during the same period of time, thus complementing each other, and they need to be implemented through sufficient financing and appropriate technology (UNFCCC, 2009).

Coping capacity refers to the ability to prepare for an anticipated event, respond to that event once it takes place, and recover from its effects, such as through accessing alternative sources of food and income when agriculture fails. Coping can be distinguished from adaptation in that it refers to the immediate actions in the face of an event or changes and ability to maintain welfare, whereas adaptation refers to long-term adjustments to the framework within which coping takes place. Significantly, improving adaptation to current climate and strengthening coping can lead to measures that both address current vulnerability and contribute to adaptation to climate change (Eriksen and Otto, 2003)

Nhemachena and Hassan (2008), assess smallholder farmers' adaptation to climate change in Southern Africa. In their study, they have seen farmers' perception of climate change, the determinants of farm-level adaptation strategies and recommend issues of policies that could help stabilize national and regional food production given the anticipated adverse effects of climate change. From the cross-sectional survey data for South Africa, Zambia and Zimbabwe, the study found that most farmers detect a rise in temperature over the past 20 years, drier conditions, and pronounced changes in the timing of rains and frequency of droughts. In response to these perceived changes in climate, 67% of survey respondents are adopting some form of adaptation. In assessing farmers' perception of barriers to using various adaptation measures, the authors found that lack of credit, lack of information on climate, and insufficient access to inputs are key obstacles to adaptation.

In Ethiopia, for example, rescue and analysis of historical data recently confirmed the relationship between El Niño and reduced rainfall in the June to September rainy season. In a combined effort by the Ethiopian meteorological service and IRI, data were obtained from 200 of the country's weather stations. Of these, 78 had mostly complete records for 1960 to 2005 for the June to September rainy season, and 55 of these had data of high enough quality from 1971 to 2005 to be used in the analysis. A general pattern of below-normal summer rainfall across Ethiopia's highlands was found to be clearly associated with El Niño conditions, while above-normal rainfall was associated with La Niña conditions (Hellmuth et al., 2007).

Nhemachena and Hassan (2008) used an econometric model to identify the factors that affect farmers' use of adaptation strategies. Modeling results confirm that awareness of climate change is an important determinant of farm-level adaptation. Access to credit, markets, and free extension services also significantly increase the likelihood of farmers adopting adaptation measures. In addition, households with access to electricity and technology such as tractors, heavy machines, and animal power are more likely to adapt to changes in climatic conditions. The type of farming system also determines farmers' use of adaptation strategies: those engaged in mixed crop and livestock farming, as well as those engaged in subsistence farming are more likely to adapt to changes in climatic conditions than farmers engaged in specialized farming systems.

From her study, Slegers (2008) concluded that the resilience level of socio-ecological systems depends on the local bio-physical, economic and socio-cultural contexts. Actions have to be area-specific and focused on local practices and the constraints that farmers have to deal with a better understanding of the local dimensions of vulnerability is therefore essential to develop appropriate adaptation measures that will mitigate these adverse consequences.

The farming community was identified as the most vulnerable because of its dependence on agricultural production for its livelihood (Admassie et al., 2008). According to Admassie et al. (2008), within the farming community, small-scale, rain fed subsistence farmers as well as pastoralists were identified as more vulnerable to changing climatic conditions than others.

METHODOLOGY

Description of the study area

Geographically, the study district is situated between 60° 40'' and 7°10'' N latitude, and 39° 30'' and E40° 00'' E longitude in the south eastern parts of the Ethiopia. The district has two rainy seasons, Short rainy season starts from mid of March up to end of May, and the main rain season extends from mid-September to end of October. The mean annual rainfall is 861.5 mm with lowest and highest rainfall amount of 628 and 1112 mm, respectively. The mean annual temperature is 23.5°C with 14°C lowest and 33°C highest in the range. The month January, February and beginning of March are months that exhibit very high temperature (ORBoFP, 2008). Regarding the livelihood strategy out of the total population of 93,655 about 12% of the population depend on crop production, while 75% follow crop and livestock mixed production, the remaining 8% involved in livestock production only and the other 5% are engaged in trade and others (PDO, 2010). The farming system is highly dependent on rainfall with less than 5% share of irrigation from the total land under cultivation. The major crops grown in the district include maize, teff, sorghum, pulses and oil seeds (sesame). And, in addition to these forest coffee, banana, mango, avocado, chat and vegetables are grown widely in the district (PDO, 2010).

The agro-climatic division of the district is based on the topography, rain fall and soil type and hence, three agro-climatic zones has been recognized vis., Kola/low land (63.6%), Woina dega/semi highland (21%) and Dega/highland (15.4%) (ORBoFP, 2008).

Sources and method of data collection

Both qualitative and quantitative data were used in this study. The data used in this study was primarily obtained from the survey conducted at 3 villages using structured interview schedule and from focus group discussion conducted at the same villages in the study district.

Sampling technique

Four-stage sampling procedures were followed in designing the survey. At the first stage the study district was selected purposively based on its drought history. According to the regional government the district has long history of drought and known for its venerability to the food insecurity. At the second stage, the whole district consisting of 23 villages were grouped into three strata based on their agro-ecological characteristics including the rainfall, soil and topography. The number of household in each village is given in Table 1. One village from each strata was selected randomly using simple random sampling technique. Then 160 sample respondents were selected from the 3 villages using systematic sampling technique on the basis of probability proportional to size (PPS). The list of the household was taken from the village administration which was used as the sampling frame. Households for focus group discussion were also drawn from the three identified villages and the composition of the group was from both sexes and different social groups having 12, 11 and 9 members. The group members were identified with the help of village leaders and development agents working in the selected villages.

Characteristics of sampled households

The composition of the households surveyed represented different age categories, both sexes, different levels of education, households with different income status and varied size of land holdings (Table 2).

Data collection

An interview schedule was developed to administer formal survey and the survey was conducted on 160 randomly selected household heads. Pre-testing of the interview schedule was made on non-sampled farmers before the actual data collection. Likewise, secondary data were obtained from national meteorological agency and district food security office was collected to supplement the study. Qualitative data were used to determine adaptation

Table 1. Distribution of sampled household heads by village.

Village/Kebele	Total number of household heads*	Percentage of each Kebele to total	Number of household heads in the sample
Chirri	2200	50	80
Gomgoma	825	18.75	30
Erba	1375	31.25	50
Total	4400	100	160

Table 2. Summary of descriptive analysis for continuous variables.

Variable	Unit	Mean	SD	Minimum	Maximum
Age	Years	37.3	11.35	19	75
Education status (EDUS)	Year	2.975	2.72	0	10
Size of total HH member	AE	6.40	2.878	1	16
Farm experience (FARMEX)	Years	17.51	9.9	3	50
Farm land holding (FLNDH)	Hactar	2.26	1.467	0.4	8.5
Livestock holding in (NTLU)	TLU	3.89	2.83	0	23.9

'SD' - Standard deviation; Source: Survey result, 2011; 1 USD_= 18 ETB.

measures that have been taken by farmers to moderate the potential effect of climate change and variability. Furthermore, the interpretation result from focus group discussion and key informant interview were used for triangulating the study results.

Method of data analysis

Descriptive statistics

To determine farmers' perception to climate change and variability, descriptive statistics such as frequency and percentage were used. Mean and standard deviation were used to analyze annual and seasonal records of temperature and rainfall. In the literature, several studies have applied the same type of analysis (Maddison, 2006; Gbetibouo, 2009). In order to see the relationship between hypothesized explanatory variables and the dependent variable, mean, frequency of occurrence, standard deviation, percentage, t-test and Chi-square test were employed. T-test was used to check the mean difference of the variables under consideration (continuous) between adapted farmers and non-adapted farmers. Also, Chi-square test was employed to see the association of independent variables (discrete) with the dependent variable.

The econometric model

This study used the multinomial logit model (MNL) to analyze factors that affect the choice of adaptation methods.

The logit model can be used to estimate a utility maximization problem where the farmer is assumed to have preferences defined over a set of adaptation strategies:

$$U_j = \beta_j \chi_i + \ell_j \quad (1)$$

Where U_i is the utility of adaptation strategies j, x_i a vector of attributes of the factors, β_j a parameter to be estimated and ℓ_j the disturbance term. The disturbance terms are assumed to be independently and identically distributed. If the farmer's choice is alternative j, we assume that the utility from alternative j is greater than the utility from other alternatives, that is,

$$u_{ij} > u_{ik}, \forall k \neq j \quad (2)$$

Where u_{ij} is the utility to the i^{th} farmer of adaptation strategy j, and u_{ik} the utility to the i^{th} farmer of adaptation strategy k. When each adaptation strategies of climate change impact thought as a possible choice decision by a farmer, the farmer will be expected to choose the adaptation strategy that has higher expected utility among the alternatives strategies. The i^{th} individual's decision may, therefore, be modeled as maximizing the expected utility by choosing the j^{th} adaptation strategy from among J discrete adaptation strategies of climate change impact, that is,,

$$\max_j E(u_{ij}) = f_j(x_i) + \varepsilon_{ij}, j = 0,..., J \quad (3)$$

Where $E(u_{ij})$ is the expected utility of alternative j to the i^{th} farmer, and f_i is a function of $X_i = (X_i 1 ... X_i n), a(1xn)$ vector of factors that potentially affect the desirability of adaptation strategies of climate change impact. The probability of choosing alternative j from among J alternative choices is equal to the probability that the expected utility from alternative j is greater than the expected utility from any other alternative, that is,

$$\Pr(choice = j) = P\lfloor E(u_j) - E(u_k) > 0 \ \rfloor, \forall_k \neq j \quad (4)$$

Following Greene (2000), the MNL form for a multiple-choice problem is:

$$\Pr(y = j) = \frac{\ell^{\beta_j x_i}}{\ell^{\beta_o x_i} + \ell^{\beta_j xi} + ... + \ell^{\beta_j xi}}$$

Table 3. Definition of explanatory variables.

Variable	Description	Value	Expected sign
Age	Age of the household head	Years	±
Sex	Gender of the respondent	1 for male and 0 otherwise	+
EDUS	Education status of the household head	Formal school attained in years	+
THHM	Total number of HH size	Number	±
FARMEX	Farm experience of the household head	Years	+
ACWINF	Access to weather information	1 = Yes, 0 = No	+
EXTNS	Access to extension service	1 = Yes, 0 = No	+
CREDA	Access of credit/ whether the HH received credit or not	1 = Yes, 0 = No	+
NFINSM	Membership in the informal institutions	1 = Yes, 0 = No	+
FLNDH	Farm land holding	In hectare	+
NTLU	Number of livestock in tropical livestock unit	Number	+
TFINC	Total farm income of the HH	ETH BIRR	+
INCNFA	Income from non-farm activities	ETH BIRR	+
LANDSC	Land security/tenure arrangement	1 = if the farmer feel secured and 0 otherwise	+
LNFERT	Fertility of the land as perceived by the farmer	1 = fertile; 0 = not fertile	+

or

$$\Pr ob(y = j) = \frac{\ell^{\sum_{k=1}^{k} \beta_{jk} x_k}}{1 + \sum_{j=1}^{J-1} \ell^{\sum_{k=1}^{k} \beta_{jk} x_k}} \quad (5)$$

Gives $\Pr ob(y = 1)$ where j = 1, 2, J-1.

Parameter β has two subscripts in the model, k for distinguishing x variables, and j for distinguishing response categories.

The subscript j indicates that now there are J-1 sets of β estimates. In other words, the total numbers of parameter estimates are (J-1) k. This implies that the sample size should be larger than (J-1) k.

The reference category against which other response categories are compared in this study is the ‘no adaptation’ which represented by ‘0’ (Table 3).

RESULTS AND DISCUSSION

Adaptation strategies

In response of the risks on agricultural productivity from the increasing temperature and unpredicted rainfall, farmers in the study area adopted various adaptation strategies. As revealed by the focus group discussion, the major actions that have been taken by farmers in response to negative impact of climate change were: increasing use of irrigation, increasing use of agricultural inputs mainly chemical fertilizers, making an adjustment on planting time, using drought tolerant crop species, growing of multiple crops on the same unit of land, increasing size of land under cultivation, planting fodder trees and grasses for livestock feed and temporary migration into the high forest. It was disclosed that in the study district, there was only four small-scale irrigation schemes established by government. At earlier stage of the establishment of the schemes, farmers did not utilize the irrigation land efficiently. However, from some years afterward because of unreliable and erratic pattern of rainfall and repeated drought, farmers showed the tendency of intensively using irrigation in their farming system. Traditionally diverted streams, pond construction and use of water pump are found as means of irrigation in the area.

Previously, the major crops grown in the area were maize (*Zea mays*) and teff (*Eragrostis tef*). But currently, farmers are switching into sesame (*Sesamum indicum*) and sorghum because of their comparative tolerance of dry condition (drought). To minimize the risk from total loss of crop production, farmers are exercising diversification of crops on the same plot of land. Fodder trees like *Sesbania sesban*, *Leaucenea equistiflora* and elephant grass were grown by farmers to provide feed for their livestock. Likewise, during dry season farmers move with their cattle into the high forest by leaving their residence temporarily in search of feed and water for their cattle, and to escape the harsh weather condition occurring in the low land areas during dry time. In this study, non-adapted farmers are defined as farmers that did not apply any adjustment or change in their farming system in response to the prevailing climate change impact. These farmers remained with business as usual farming system due to various reasons.

As observed in Table 4, majority of the farmers who implemented adaptation measure have a propensity of implementing multiple adaptation strategies in combination. Therefore, in this study the identified adaptation strategies are combined into 8 categories

Table 4. Farmers implemented different adaptation measures

Adaptation strategy	Number of respondents	Percent
Intensification of irrigation	46	28.75
Increase use of agricultural inputs	88	55
Use of drought tolerant crop species	86	53.75
Adjustment in planting time	93	58.13
Crop diversification	85	53.13
Increasing size of land	41	25.63
Fodder tree planting	34	21.25
Temporary migration to the high forest	20	12.5
No adaptation (business as usual)	63	39.38

including the "No Adaptation" category for the convenience of model analysis. Similar procedure was followed by Nhemachena (2009). He grouped 21 perceived farm-level adaptation strategies into 10 categories of adaptation although he excluded some of the perceived adaptation measures taken by farmers from the categories. In this study, because of their close relation, adjustment of planting time, use of drought tolerant crop species, crop diversification and increasing size of land have merged together and categorized as an agronomic practices. Farmers who adapted to climate measure have actually employed a combination of two or more measures of adaptation to climate change. Accordingly, the following adaptation categories are included in the MNL model as outcomes of the dependent variable.

As shown in Table 5, 16.8% of the sampled respondents adopted agricultural inputs and improved agronomic practices in combination. Whereas, farmers who adapted by using agricultural inputs and agronomic practices and planted fodder trees are only 5%. From the total respondents, 39.4% of them are non-adapted and 59.6% of the respondents have adapted by taking different adaptation measures.

Determinants of decision on choice of adaptation measure

Although most of the sampled respondents recognized the existence of change and variability in climate and the majority have taken an adaptation measures, the possibility and choice of taking various actions in response to climate change impact is affected by several socio-economic factors.

Age, household (HH) size and education level of sampled households

Age of the household head: Age of the household is assumed to have close association with farm experience. In this study, the age distribution of sampled households ranges from 19 to 75 years with average of 37.3 and 11.351 years of standard deviation. An independent sample t-test was conducted to assess if the mean difference in age between farmers adapted to climate change using different adaptation measures and non-adapted farmers has statistical significance. Accordingly, it has been determined that there was no significant mean difference with regard to age between adapted farmers and non-adapted farmers.

Size of HH: The total number of household members was expected to affect adaptation measures either positively or negatively. According to the survey results, the average number of family members is 6.4 (in adult equivalent). From the t-test result, there was statistically significant mean difference between non-adapted farmers and farmers adapted by using irrigation, input and agronomic practices in combination ($p < 0.01$) with t-value 3.359.

Education status

Many studies on adaptation to climate change showed that education status is positively affected by the decision to take climate change adaptation measures. From the total sampled households, 50 (31.25%) of the respondents did not attend any formal education. From the survey result, it has also been determined that there is significant mean difference between non-adapted farmers and farmers adapted different adaptation measures at less than 1% significance level with 6 categories of adaptation and at less than 5% with use of irrigation and agricultural inputs category.

Farm land size, farm income and farm land holding

Farm land holding: Land accounts for the largest share of agricultural resources in the study area since the livelihood of the peoples is dependent on land. The mean

Table 5. Categorized adaptation measures employed by farmers (combinations of multiple adaptation measures).

S/N	Adaptation Category	Number of respondents	Percentage
1	Irrigation, Ag. inputs, Agronomic practices and fodder trees planting in combination (IRINAGPT)	23	14.4
2	Irrigation, inputs and agronomic practices (IRINAGP)	14	8.8
3	Irrigation and inputs (IRIN)	8	5
4	Irrigation and agronomic practices (IRAGP)	8	5
5	Inputs, agronomic practices and fodder trees (INAGPT)	8	5
6	Inputs and agronomic practices (INAGP)	27	16.8
7	Agronomic practices (AGP)	9	5.6
8	No Adaptation (NOADAP)	63	39.4
	Total	160	100

Source: Survey result (2011).

difference with regard to size of farm land was found statistically significant among non-adapted farmers and farmers adapted by employing irrigation with input, agronomic practices and fodder tree planting ($p < 0.01$) with t-value 3.44.

Livestock holding: The mean livestock holding of the respondents after converted in tropical livestock unit is 3.89 TLU. The test statistic showed a significance difference between the mean of non-adapted farmers and farmers adapted by involving on irrigation, agricultural inputs, agronomic practices and fodder tree planting adaptation category ($p < 0.01$, $t = 2.796$).

Farm income: The t-test analysis was conducted to measure whether there are significant mean differences or not in the farm income of non-adapted farmers and who adapted by taking different measures. The result showed that there was a statistically significant difference in total farm income among non-adapted farmers and farmers adapted different adaptation measure to climate change impact at less than 1% level of significance. Average farm income of non-adapted farmers differ significantly from those who adopted intensification of irrigation and applied agronomic practices in combination ($t = 4.16$; $p < 0.01$). This implies that adaptation measure is affected significantly by farm income and farmers with higher farm income have better chance to adapt.

χ^2 -Test result

To test whether there is significance difference in the percentage of farmers adapted to climate change and farmers who did not adapt to any measure with respect to various hypothesized discrete variables, Chi-square analysis were conducted. The Chi-square analysis shows the existence of significant difference between non-adapted farmers and farmers who adapted various adaptation measures at less than 1% and χ^2 result 54.4, 19.8, 32.6 and 20.24 for access to weather information, access to extension service, credit access and membership of local institutions, respectively (Table 6).

In this study, male household heads take the highest proportion than female household heads. This is due to the very rare possibility of getting households headed by females in the rural areas of the district. Substantiating this, from the total sampled households only 8 female household heads were selected although the selection of respondents were based on probability sampling. None of the sampled female household heads adapted to climate change impact. This result confirm the prior expectation that male headed households have more access to improved technology, information on climate, credit and extension services than female headed household which in turn help them to adapt to climate change impacts. The Chi-square test revealed the existence of significant difference between adapted and non-adapted farmers ($p < 0.1$) with χ^2 results of 12.9 with respect to sex.

On the other hand, the Chi-square analysis did not show statistically significant differences in percentage between farmers who adapted different adaptation measures and farmers remain not adapted with respect to security of land and perceived fertility of their farm.

Explanatory variable selection for model estimation parameters

Potentially significant variables to be incorporated in the model estimate were sort out based on their significance level. Accordingly, tenure arrangement and land fertility were dropped as they are less significant for this study ($P = 0.879$ and $\chi^2 = 11.36$). In addition to this, to detect the existence of collinearity among the potential explanatory variables multicollinearity test were conducted.

Econometric model results

Hausman specification test were used to check the

Table 6. Summary of chi-square test result for discrete explanatory variables.

Variable	Description	Frequency (N)		Percent (%)		χ^2	P-level
		Adapted	Not adapted	adapted	Not adapted		
sex	Male	97	55	60.63	34.37	12.96	0.073*
	Female	0	8	0	5		
Access to weather information (ACWINF)	Yes	92	28	57.5	17.5	54.49	0.000***
	No	5	35	3.13	21.87		
Extension service (EXTNS)	Yes	94	47	58.75	29.375	19.88	0.006***
	No	3	16	1.875	10		
Credit access (CREDA)	Yes	44	5	27.5	3.13	32.6	0.000***
	No	53	58	33.125	36.25		
Non-formal institution membership (NFINSM)	Yes	91	44	56.875	27.5	20.24	0.005***
	No	6	19	3.75	11.875		
Land fertility (LNFERT)	Yes	74	34	46.25	21.25	24.8	0.256
	No	23	29	14.375	18.125		
Land security (LANDSC)	Yes	94	62	58.75	38.75	11.36	0.879
	No	3	1	1.875	0.625		

Source: Own survey (2011). **N,** Number of sampled households; *****, **, and *,** significant at 1, 5 and 10% level respectively.

validity of the independence of the irrelevant alternatives (IIA) assumptions before running the actual model estimate. The test result fails to reject the null hypothesis of independence of the adaptation measures under consideration. This implies that the application of the MNL specification is appropriate to model the determinants of adaptation measures. The parameter estimates of the MNL model do not represent the actual magnitude of change rather it provides only the direction of the effect of explanatory variables on the dependent variables (Table 7). Therefore, in determining the magnitude of change the marginal effect from MNL will be seen and discussed (Table 8). From the analysis of the model it has been determined that most of the explanatory variables results were found as expected. The statistical package used to analyze factors affecting adaptation to climate change and variability impact by employing multinomial regression model was STATA version 10.

Gender of the household, education status of the head, size of the household, access to weather information, access to credit, livestock holding and total farm income appeared to have significant effect on adaptation of multiple strategies grouped under different categories.

Age of the HH head

Although statistically not significant, age of the household head seems to have negative association with the integrated adaptation measures of use of irrigation, adoption of inputs, fodder tree planting and the portfolio agronomic practices. In contrary with this, Deressa et al. (2008) pointed out the positive association of age with adaptation to climate change. Based on their report, a unit increase in age of the household results in a 9% in changing of crop varieties and a 10% increase in tree planting. This shows that adaptation to climate change vary in context across different locations.

Sex of the HH head (SEX)

As expected, male household heads had better opportunity to take an adaptation measure than female household heads. From the result, it was found that being male household head increase the likelihood of use of irrigation and agricultural inputs in combination ($p < 0.01$). Male headed households have also better opportunity of adapting to climate change ($p < 0.05$) by involving on agronomic practices (such as crop diversification and use of drought tolerant crop species) and by adopting agricultural inputs to their farm. This result is in consistence with the findings of Deressa et al. (2008) on the study conducted in the Nile Basin of Ethiopia to analyze farmers' choice of adaptation methods of climate change. On the other hand, Nhemachena and Hassan (2008) found that female headed households are more likely to take up climate change adaptation methods than male in assessing determinants of African farmers' strategies for adapting to climate change. The argument by Asfaw and Admassie (2004) in favor of our finding,

Table 7. Parameter estimates of the multinomial logit adaptation model.

Variable	IRINAGPT	IRINAGP	IRIN	IRAGP	INAGPT	INAGP	AGP
Age	-0.0566	.0052	0.0604	-0.0018	0.0186	-0.0132	-0.1343
Sex	-6.6	-4.74	8.361***	8.684	0.6595	1.696**	2.22
Education status	3.577***	3.13***	1.690**	1.846*	4.087***	1.909**	1.023
Household size	0.5426***	0.6351***	0.00714	0.235	0.2145	0.4194**	0.4733*
Access to weather info	7.7	6.12	2.009	7.08	1.886	4.174**	6.75
Extension service	7.96	7.98	0.6461	1.73	1.089	8.634	3.620
Credit access	3.693***	3.275***	1.067	2.074	2.827**	2.78***	4.664***
Informal ins. membership	1.75	0.217671	-0.8990	0.5493	2.41	0.0110	1.79
Farm land size	-0.5574	-0.36125	-0.3880	-0.2818	-0.5324	-0.1826	0.5894
No. of livestock in TLU	-0.0540	-0.23821	-0.4030	-0.2529	-0.1523	-0.3175*	-0.4180
Farm income	0.0016***	0.001585***	0.00048	0.0009***	0.0009***	0.0010***	0.0012***
Non-farm income	0.0013	0.001668	0.00120	0.0009	0.1867	0.00145	0.0013
Constant	-7.247	-8.88	-4.0365	-6.3560	-5.1597	-7.31006	-5.611
Base category	No adaptation						
Number of observation	160						
LR Chi-square	264						
Log likelihood	-151.27						
Pseudo R-square	0.466						

*****, **, and *,** Significant at 1, 5 and 10% probability level, respectively. Source: Own survey. **NOADAP,** Not adapted; **IRINAGPT,** irrigation, input, agronomic practice and fodder tree planting in combination; **IRINAGP**, irrigation, input and agronomic practices; **IRIN**- irrigation and input**; IRAGP**, irrigation and agronomic practices; **INAGPT**, input, agronomic practices and fodder tree; **INAGP,** input and agronomic practices; **AGP**, agronomic practices alone.

Table 8. Marginal effects of explanatory variables from the multinomial logit adaptation model.

Variable	IRINAGPT	IRINAGP	IRIN	IRAGP	INAGPT	INAGP	AGP
Age	-0.0026211	0.0009547	0.005096	-0.00532	0.0039	-0.003341	-0.0018492
Sex	-0.136837	-0.4264019	0.1592012***	0.2690	0.1341	0.3357123**	0.0748091
Education status	0.22142***	.2501945***	0.1001034**	0.1490*	0.439***	0.2875685**	0.0246404
Household size	0.0174319***	0.0418618***	0.0072634	0.0443	0.0481	0.0699786**	0.0067968*
Access to weather info	0.2299063	0.2851482	0.0267712	2501	0.545	-0.0126539**	0.0443796
Extension service	0.2284496	0.3994498	0.0021165	0.3636	0.8024	0.4265475	0.0133125
Credit access	0.2693084***	0.2790375***	0.0040955	0.34	0.4113**	0.5182552***	0.0107823***
Informal ins. membership	0.034571	0.0373029	-0.139449	0.0231	0.0344	0.0743027	0.0743602
Farm land size	-0.022095	-0.0576777	-0.0277515	-0.1145	-0.128	0.0232832	0.0219589
No of livestock in TLU	-0.006897	-0.0406485	-0.0264383	-0.0195	-0.0375	-0.0455514*	-0.0171679
Farm income	0.000986***	0.0001723***	0.000194	0.00012***	0.000283***	0.0001663***	0.00215***
Non-farm income:	0.000673	0.0001716	0.0000693	0.000051	0.0001	0.0002216	0.000347

***, ** and *, Significant at 1, 5 and 10% probability level, respectively. Source: Own survey. **NOADAP,** Not adapted; **IRINAGPT**, irrigation, input, agronomic practice and fodder tree planting in combination; **IRINAGP**, irrigation, input and agronomic practices; **IRIN**, irrigation and input**; IRAGP**, irrigation and agronomic practices; **INAGPT**, input, agronomic practices and fodder tree; **INAGP,** input and agronomic practices; **AGP**, agronomic practices.

male-headed households are often considered to be more likely to get information about new technologies and take on risk than female-headed households.

Education status of the HH head

As hypothesized, education status of head of the household has a significant and positive correlation with almost all of the adaptation measures. Education increases the likelihood of use of irrigation combined with agronomic practices, inputs and fodder tree planting by 22.1% ($p < 0.01$) with a unit increase. Likewise, education status of the household head significantly affect the use of agricultural inputs in combination with planting fodder trees and practicing of agronomic adaptation measures at less than 1% probability level. A unit increase by the level of household education rise up the probability of adapting the above combination of measures by 43.9%. The model result were also revealed the strong association between education status of the household head and the probability of adopting multiple adaptation measures in combination like irrigation with agricultural inputs, agronomic practices with agricultural inputs and irrigation with collection of agronomic practices at less than 5% probability level. These result support the findings of Deressa et al. (2008).

Household size

It appeared that household member size has positive and significant effect on adapting to climate change impact. Larger number of economically active household members increase the probability ($p < 0.01$) of implementing irrigation in combination with use of drought tolerant crop species, diversification of crops and increasing size of land under cultivation (collectively named as agronomic practices), planting of fodder trees and use of agricultural inputs in response of climate change impact. Based on the result of the marginal effect, unit increase in the number of economically active household increases the likelihood of adopting the above adaptation category by 1.7%. The probability of adapting by practicing collection of agronomic measures positively and significantly ($p < 0.1$) affected by the size of the household. The statistical result revealed the positive link between labour and labour demanding farm activities. Larger families are able to practice multiple cropping (Nhemachena, 2009). Gbetibouo (2009) indicated that a large household are more willing to choose labour-intensive adaptation measures. According to his findings, HH size positively and significantly leads to an increase in the likelihood of adapting to climate change. The fact that increasing household size increases the likelihood of adaptation is probably because large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks especially during peak seasons (Croppenstedt et al., 2003 cited in: Deressa et al., 2010). Hence, based on the result from our study and others supporting findings, the size of household has positive and strong association with adaptation to climate change.

Access to weather information

As hypothesized, better access to weather information appear to have positive influence on the decision of performing adaptation measures in response of climate change problem. Farmers with better access to information of the changing climate have more probability of using agricultural inputs and agronomic practices such as drought tolerant crop species and adjustment of planting time ($p < 0.05$). In the same way, other studies also support this finding. Access to information increases the likelihood of adapting to climate change (Maddison, 2006; Nhemachena and Hassan, 2007). Information on temperature and rainfall has a significant and positive impact on the likelihood of using different crop varieties: it increases the likelihood of using different crop varieties by 17.6% (Deressa et al., 2008). Alike to this, access to weather information positively and significantly affects the decision to take up climate change adaptation measures. It increases the probability of using different crop varieties; borrowing lost local crops from community members, use of external fertilizer, use of soil and water conservation and planting more trees at plot level (ACCCA, 2010).

Extension service

Although statistically was not found significant, extension service have positive relation with all categories of adaptation measures. This is probably because most of the respondents have the access of the service. As the survey data shows, from the total 160 respondents, 141 of them have got extension service; this implies that it is other factors that determine more and brought the difference among respondents in adapting various measures of adaptation to climate change. Indeed, Senait (2002) reported that, contact with extension agents did not significantly influence adoption of fertilizer. Unlike to these, based on data from a comprehensive survey of agricultural households across 11 African countries, Nemachena (2009) revealed that better access to extension have strong and positive influence on adaptation to climate change. Having access to extension increases the probability of choosing portfolio diversification by 4% (Gbetibouo, 2009).

Credit access

As hypothesized, access to credit has a positive and significant effect on intensification of irrigation, use of agricultural inputs, use of drought tolerant crop species and adjustment of planting time (agronomic practices) and planting of fodder trees at $p < 0.01$. The advantage of credit provision in solving the financial constraints of farmers to invest on agricultural technologies was clearly expressed from this result. Farmers having better access to credit will have the probability of using irrigation, agricultural inputs and to grow multiple crops in response to adapting to climate change impact by 27.9%. Other studies (Deressa et al., 2008; Gbetibouo, 2009; Nemachena, 2009) reported similar results with regard to the effect of credit access on adaptation decision.

Gbetibouo (2009) reported that access to credit increases the likelihood that farmers will take up portfolio diversification and buy feed supplements for their livestock. Having access to credit indeed increased the likelihood of choosing portfolio diversification by 3%. In opposite to these, credit were found to be significantly and negatively relate to the use of different crop varieties and borrowing lost local seeds form community (ACCCA, 2010). The argument by 'ACCCA' were: credit is expected to relax the financial constraint and this would be expected to have a positive influence on farm-level climate risk adaptation. However, this is only as far as the profitability of the technology supersedes other investment alternatives available to the farmer.

Size of farm land holding

The model result showed that size of farm land has a negative but not statistically significant association with intensification of irrigation and use of agricultural inputs adaptation category. Whereas, farmers with larger size of farm land has better probability of increasing land under cultivation and planting of fodder trees as an adaptation measure in reducing the negative impact of climate change although the result is not statistically significant. Gbetibouo (2009) showed that as farm size positively and significantly leads to an increase in the likelihood of adapting to climate change. As opposed to our findings, the coefficient on farm size is significant and positively correlated with the probability of choosing irrigation as an adaptation measure as revealed by Gbetibouo (2009).

However, Deressa et al. (2010) showed the negative association between farm size and adaptation. According to their argument, the probable reason for the negative relationship between adaptation and farm size could be due to the fact that adaptation is plot-specific. This means that it is not the size of the farm, but the specific characteristics of the farm that dictates the need for a specific adaptation method to climate change.

Number of livestock holding in TLU (NTLU)

In contrary to our expectation, number of livestock found negatively and significantly ($p < 0.1$) associated with adoption of agricultural inputs and implementation of agronomic practices such as use of drought tolerant crop species, adjustment in planting time and diversification of crops in combination. In opposite to this, Tesfaye (2004) reported that number of livestock owned had a significant and positive influence on the adoption of fertilizer. On the other hand, Deressa et al. (2008) found varied effect of livestock ownership in different adaptation measures. The ownership of livestock is, positively related to the adoption of adaptation methods such as conserving soil, planting trees, and changing planting dates, even though the marginal impacts are not significant. And, livestock ownership is negatively related to the use of different crop varieties and irrigation, although not significantly.

Farm income

The sign from the result for this variable is consistent to our prior expectation and it was positive and statistically significant to influence adoption of agricultural inputs, intensification of irrigation, use of drought tolerant crop species, adjustment of planting time, planting of fodder trees and crop diversification at $p < 0.01$ significance level. As depicted in the model result, farm income was found to have positive and strong association with all categories of adaptation measures. The likelihood of adopting multiple adaptation measures together with intensification of irrigation and use of agricultural inputs will increase by 0.09% in a unit increase of households' farm income. Deressa et al. (2008) also reported the positive relationship between farm income and adoption of soil conservation practices, use of different crop varieties and adjustment in planting date.

Non-farm income

The model result showed that non-farm income did not significantly affects the adoption of either of adaptation strategies, in spite of the coefficient in all categories of adaptation measures found positive. This implies that the income from non-farm activities increases the financial base of the household which in turn contribute positively for adaptation at farm level.

Conclusion

Based on the descriptive statistics analysis, it was found that most of the farmers have noticed long-term change in temperature and rainfall, and they were also aware of variability in the starting time, ceasing time and in the distribution of rainfall. The perceptions of farmers with regard to climate change were found in line with the recorded weather data at the station of national meteorological agency in Dello Mena Woreda. The mean comparison test results showed the existence of significant mean difference in farm income between not adapted sampled households and households who adapted by increasing use of irrigation and agricultural inputs in combination. Fifteen explanatory variables were hypothesized to affect farmers' choice decision of adaptation strategies. It was found that education, access to credit, total farm income and household size are positively and significantly affecting the likelihood of adapting by implementing combination of multiple adaptation measures. However, negative relation was noticed with the adoption of agricultural inputs and implementation of agronomic practices in contrary to the expectation. Male household heads have better opportunity to practice crop diversification, use drought tolerant crop species, increasing size of land under cultivation and adjustment of planting time measures (agronomic practices of adaptation) than women headed households. In addition to this, male headed households are more likely to adopt agricultural inputs and to use irrigation than female heads. Better access to climate information was found to increase the probability of adopting agricultural inputs and practicing agronomic measures in response to the brunt from climate change. Moreover, education status of the household head, income from farm activities and access to credit was appeared strong determinants of adaptation to climate change.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

ACCCA, (2010). Farm-level climate change perception and adaptation in drought prone areas of Tigray, Northern Ethiopia. The socio-economic team. Advancing Capacity to support Climate Change Adaptation (ACCCA): Project 093:3. Mekelle, Ethiopia.

Admassie A, Birhanu A, Abebe T (2008). Stakeholders' Perceptions of Climate Change and Adaptation Strategies in Ethiopia. pp..1-4. EEA Research Report (Addis Ababa: Ethiopian Economic Association). Available at: http://www.eeaecon.org/Research%20Materials.htm, (Accessed 11/08/2010).

Anthony N (2005). Cited in Davidson et al., 2003 Key Vulnerabilities to Climate Change in Africa; Global Warming. Joss University; Jos. Looking Beyond Kyoto Yale Centre for the Study of Globalization.

Asfaw A, Assefa A (2004). The role of education on the adoption of chemical fertilizer under different socio-economic environments in Ethiopia. Agric. Econ. 30(3):215–228. http://dx.doi.org/10.1111/j.1574-862.2004.tb00190.x

Croppenstedt A, Demeke M, Meschi MM (2003) Cited in Deressa (2010). Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics 7(1):58–70.

Cubash U, Meehl GA, Boer GJ (2001). Projections of future climate change. The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Deressa T, Hassan R, Ringler C (2010). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J. Agric. Sci.149:23-31.

Deressa TR, Hassan C, Ringler TA, Yusuf M (2008). Analysis of the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI: Washington DC.

Eriksen S, O'Brein K, Rosetrater L (2008). Climate Change in Eastern and Southern Africa; Impacts, Vulnerability and Adaptation. Global Environmental Change and Human Security report 2008. 2. University of Oslo: Oslo

Eriksen S, Ottoo N (2003). Pro-Poor Climate Adaptation. Norwegian development cooperation and climate change adaptation: An assessment of issues, strategies and potential entry points. NORAD: Oslo.

FAO (Food and Agricultural Organization) (2007). Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities. FAO: Rome.

Gbetibouo G (2009). Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa. IFPRI: Washington DC.

Gujarati DN (1995). Basic Econometrics. Third Edition. Mc Graw- Hill, Inc, New York. P. 534.

Hulme M, Neufeldt H, Colyer H (2009). Adaptation and Mitigation Strategies. University of East Anglia: Norwich.

Hellmuth ME, Moorhead A, Thomson MC, Williams J (2007). Climate Risk Management in Africa: Columbia University: Buffalo (Eds.).

Kinyangi J, Herrero M, Omolo A, van de Steeg J, Thornton P (2009). Scoping Study on Vulnerability to Climate Change and Climate Variability in the Greater Horn of Africa: Mapping impacts and adaptive capacity. ILIRI: Nairobi PMid:19544739

Maddison D (2006). The perception of adaptation to climate change in Africa. University of Pretoria: Johannesburg. PMCid:PMC1698947

Nhemachena C (2009). Agriculture and future climate dynamics in Africa: impacts and adaptation options. Ph.D. Thesis presented to Department of Agricultural Economics, Extension, and Rural Development, University of Pretoria. P. 150.

Nhemachena C, Hassan R (2008). Determinants of African farmers' strategies for adapting to climate change. Multinomial choice analysis. Afr. J. Agric. Resour. Econ. 2(1):83-104.

ORBoFP (Oromia Regional Bureau of Finance and Planning (2008). Woreda socio-economic profile 2008. ORBoFP: Robe.

PDO (Pastoralist Development Office) (2011). Annual Activity Progress Report. PDO: Robe. Unpublished document.

Senait R (2002). The economics of managing land resources towards sustainability in the highlands of Ethiopia. PhD Dissertation presented to the University of Hohenheim.

Stuart MD, Moura-Costa P (1998). Climate change mitigation by forestry; a review of international initiatives, policy that works for forests and people series. IIED: London.

Tesfaye Z (2004). Adoption of inorganic fertilizer on maize in Amhara, Oromia and southern regions. EARO. Addis Ababa, Ethiopia.

UNFCCC (United Nations Framework Convention on Climate Change), (2009). The need for adaptation. UNFCCC: New York.

Van B, Jan A, Savenije H, Wit M (2009). Forests and Climate Change. Adaptation and mitigation. Tropenbos International: Wageningen (Eds.).