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Food Security and Adaptation Strategies to Climate Change in Eastern Ethiopia

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Abstract: Agricultural sector remains the main source of food and income for most rural communities in Ethiopia. Being dependent mainly on rainfall, this sector has been affected by climate change. Hence, employing adaptation strategies within the agricultural sector to climate change is vital to ensure food security and care for the livelihoods of farmers. Food security and adaptation are among the options to abate the negative impact of climate changes. This study has analyzed factors influencing the impact of climate change on food security and adaptation choices by farm households in eastern Ethiopia. The study used data obtained from 330 household heads randomly and proportionately sampled from two agroecologies in East Hararghe Zone of Oromiya Region and Dire Dawa Administration, Ethiopia. The study used a univariate profit model and multinomial logistic regression model to identify factors affecting food security and the choice of adaptation strategies to climate change. As food security indicator, calorie intake per adult equivalent per day was considered for adaptation strategies; changing planting date, irrigation water use, soil and water conservation, and crop variety selection were considered. The result indicated that farmers in the study area are vulnerable to climate change and the factors determining the choice of climate adaptation options were determined by sex of household head, family size, education status of household head, Agroecology, distance to market, cultivated land, credit access, decreasing precipitation and change of temperature. Policy thrust should focus on linking farmers to fertilizer usage, credit access and social participation as well as in creating awareness of climate change.

Keywords: Food security; Climate change; Adaptation strategies; Univariate probit; Multinomial logit.

1. Introduction

The links between food security and climate change are complex, because food security involves food and its production, trade and nutrition as well as how people and nations maintain access to food over time in the face of multiple stresses including climate change. The impact of climate change is a global issue because it affects all countries and sectors.

Climate is an important factor for agricultural productivity. Its change affects all dimensions of food security (*i.e.* food availability, food accessibility, food utilization and food systems stability). It has an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Climate change effects are already being felt in global food markets, and are likely to be particularly significant in specific rural locations where crops fail and yields decline. Its impact is felt in both rural and urban locations where supply chains are disrupted, market prices increase, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope (FAO, 2007).

People who are already vulnerable and food insecure are likely to be the first affected in climate change and those agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds, planting material and loss of livestock (IPCC, 2007; Schipper and Pelling, 2006).

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Higher temperature and changing precipitation levels caused by climate change depress crop yields. This is particularly true in low-income countries, where adaptive capacities are perceived to be low. Hence, many African countries which have economies largely based on weather-sensitive agriculture are vulnerable to climate change. Ethiopia with its rain-fed dependant agriculture together with low level of socioeconomic development is highly affected and vulnerable to climate change.

Ethiopia's economy is based on agriculture, which accounts for 46% of GDP and 85% of total employment. Coffee has been a major export crop. The agricultural sector suffers from poor cultivation practices and frequent drought, but recent joint efforts by the Government of Ethiopia and donors have strengthened Ethiopia's agricultural resilience, contributing to a reduction in the number of Ethiopians threatened with starvation (MoFED, 2012).

Adaptation to climate change includes adjustments in socioeconomic systems to reduce their vulnerability both to long-term shifts in average climate and to change in the frequency and magnitude of climatic extremes. These extremes are hazardous now, and often exceed the capacity of a country or community to cope.

Development of strategies for supporting adaptation and responding to the consequences of climate change will require collaboration at local, regional and global level, across disciplinary boundaries and between different sectors of the economy. Enhancing the ability of communities to adapt to climate change or manage climate change risks requires addressing pertinent locally identified vulnerabilities, to involve stakeholders and to ensure that adaptation initiatives are compatible with existing decision processes (Brooks and Kelly, 2005).

This study focused on two *Woredas*, found in the highland of Eastern Hararghe Zone and the lowland of Dire Dawa Administration (DDA) which are included under the productive safety net program (PSNP), to look into the impact of climate change on smallholder farmers and its interaction with food security situation. Therefore, this study is undertaken with the objective of identifying the food security status and the widely practiced climate change adaptation strategies at farm level.

2. Research Methodology

2.1. The Study Area

East Hararghe Zone and Dire Dawa Administration (DDA) of Ethiopia were selected for this study mainly because these are among the areas highly affected by climate change. The specific study areas are Meta Woreda from the highland of East Hararghe Zone and Dire Dawa Administration from the lowland. Both of these study areas are under the productive safety net program. East Hararghe and Dire Dawa are situated in the eastern part of Ethiopia, at 520 and 515 kilometers, respectively, east of Addis Ababa, the capital city of the country (CSA, 2011).

The land use pattern of Meta Woreda consists 48% arable and 13% pasture and forest, and the rest 39% regarded as degraded (CSA, 2007). Sorghum, maize, barley and wheat are the major crops in the Woreda and *Khat* and coffee are the major cash crops. DDA is characterized by relatively high temperature throughout the year with minor seasonal variations. The farming system of the Administration consists of crop production (4.1%), livestock production (7.9%) and holders that are engaged in mixed crop and livestock production (88.0%). The DDA rural Woredas have more or less homogenous characteristics in terms of agroecology and hence have similar agricultural production pattern.

2.2. Sampling Technique

In this study, a multi-stage sampling method was used to select respondents. In the first stage eastern Ethiopia was stratified into two major agroecologies that are highland and lowland areas. Then East Hararghe Zone and DDA were selected to represent the highlands and lowlands, respectively. In the second stage, after listing all the Woredas in each study agroecologies, one Woreda from each was selected using a simple random sampling technique. In the third stage, eight sample Kebeles were selected using lottery method. Finally sample households were selected from each Kebels by preparing a comprehensive list of households and systematic randomly sampling method was applied. The sampling units at each stage of sampling were drawn using the probability proportional to size (PPS) sampling method.

2.3. Analytical Methods

2.3.1. Measurement of Food Security

The food insecurity was captured by measuring the head count and food insecurity gap which enable to capture successively more detailed aspects of food insecurity at household level, using the Foster-Greer-Thorbecke (FGT) decomposable indices (Foster *et al.*, 1984) for computing incidence, depth and severity of food insecurity.

The FGT measure is given as:

$$FGT(\alpha)=\left(\frac{1}{n}\right)\sum_{i+1}^{q}\left[\frac{(Z-y_i)}{Z}\right]^{\alpha} \quad (1)$$

where: FGT is the index; *n* is the number of sample households; y_i is the measure of per adult equivalent food calorie intake of the i^{th} household; Z represents the cutoff point between food security and food insecurity households (expressed here in terms of caloric requirements of 2200kcal); *q* is the number of food-insecure households; and α is the weight attached to the severity of food insecurity. In FGT index, $y_i \geq Z$ that the specified household is food secure.

Within this FGT index, we compute the three most commonly employed indices: head count ratio, food insecurity gap and squared food insecurity gap (Hoddinott, 2001). Head count ratio describes the percentage of sampled households whose consumption is below the predetermined subsistence level of energy (2200kcal), means FGT (α=0) = q/n. The food insecurity gap, FGT (α=1), measure how far the food insecure of households, on average, are below subsistence level of energy. Here, it means that, giving equal weight to severity of food insecurity among all the food insecure households will be equivalent to assuming that α = 1. This index characterizes the amount of resources that will be required to bring all the food insecure households to this subsistence level. To put it differently, it will provide the possibility to estimate resources required to eliminate food insecurity through proper targeting. Finally, squared food insecurity gap, FGT (α=2), is a measure closely related to severity of food insecurity gap but giving those further away from the subsistence level a higher weight in aggregation than those closer to the subsistence level.

2.3.2. Determinants of Food Security

Household and socioeconomic determinants of the household food security status and their likely effects were estimated by a univariate probit representation. The latent variable was specified by the structural equation (Cameron and Trivedi, 2009; Greene, 2012; Long, 1997; Maddalla, 1983).

$$Y^* = X'\beta + \varepsilon_i \quad (2)$$

where *Y** is binary latent variable for food security status (observed if *Y*>0*, 0 otherwise); X' is a vector of household specific and other socioeconomic factors determining food security status; **β** is a vector of parameters of interest, and ε_i is random error.

These equations are identical to those for the linear regression model with the important difference that the dependent variable is unobserved. The link between the observed binary *Y* and the latent Y* is made with a simple measurement equation:

$$Y_i = \begin{cases} 1 \text{ if } & Y_i^* = X'\beta + \varepsilon_i > 0 \\ 0 \text{ if } & Y_i^* \leq 0 \end{cases} \quad (3)$$

Assuming the distribution of ε_i to be with mean 0 and variance 1 leads to the binary probit model,

2.3.3. Adaptation Strategies

The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the multinomial logit (MNL) (Kurukulasuriya and Mendelsohn, 2006). The MNL is important for analyzing farmer adoption decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Hausman and Wise, 1978; Wu and Babcock, 1998).

Considering the multiple adaptation options available to the households, the MNL model was used to analyze the determinants of household adaptation decisions. This model was similarly applied to analyze crop choices selection (Kurukulasuriya and Mendelsohn, 2006; Temesgen *et al.*, 2008b) and livestock choices (Seo and Mendelsohn, 2008) as a method to analyzing the decision to adapt to the negative impacts of climate change. The advantage of the MNL model is that it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories (Maddalla, 1983; Wooldridge, 2002). The usefulness of this model in terms of ease in interpreting estimates is likewise recognized (Greene, 2012).

This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman and McFadden, 1984).

Let Yi be a random variable representing the adaptation measure chosen by any farm 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 Y*i* and the set of explanatory variables X (Greene, 2012).

$$\Pr(Yi = j) = \frac{e^{\beta'_j X_i}}{\sum_{k=0}^{j} e^{\beta'_k X_i}} = 0,1.....j \quad (4)$$

where β_j 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:

The MNL coefficients are difficult to interpret, and associating the β_j with the *jth* outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived (Greene, 2012):

$$\frac{\partial P_j}{\partial X_i} = P_j\left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j\left(\beta_j - \bar{\beta}\right) \quad (5)$$

Where P is the probability, X is socioeconomic characteristics and other factors and β is a vector of coefficients. 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, 2012; Long, 1997). 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.

Finally, the model was run and tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions by using both Hausman test for IIA and the seemingly unrelated post estimation preside (SUEST).

3. Results and Discussion

In this part the results have been interpreted based on the descriptive analyses and econometric estimation. The results from analyses of climate change impacts and food security measures, and adaptation strategies are presented and discussed.

3.1. The Socioeconomic and Institutional Characteristic of Households

The rural households in the two agroecologies of the study area basically differed in their major institutional and socioeconomic characteristics (Table 1). Households in the highland areas were significantly better off in their food security status, calorie intake and distance to the nearest market and town. On the other hand, the lowland households were significantly better off in credit access, adapt crop variety selection, soil and water conservation, and distance to office of agricultural extension agents.

The mean differences of highland and lowland for crop variety selection and soil and water conservation were 0.04 and 0.52, respectively. The application of this technology is used to protect soil erosion and increase of productivity of the land and to increase the economic performance and livelihood as well. Terracing or tree planting is common practice in the study area. In an attempt to improve soil fertility, organic fertilizer is used in addition to inorganic fertilizer, but the fertility level of the farm is decreasing from year to year. The rate of such investment varied from household to household depending on social engagement and wealth statues.

Table 1 also indicated that the results of respondents' calorie intake per adult equivalent per day. Households in the highlands and lowlands had on average 2229.02 and 2168.26 kilocalories food intake, respectively. This indicates that households in the study areas were not better off in calorie intake as compared to the required average kilocalorie intake for a healthy adult. However, this result cannot tell us the problem of food insecurity. Farmers in highland were able to practice mixing crop production and generate off-farm income and also adopt high yielding crop varieties, which might have resulted in better asset formation.

3.2. Farmers' Perception of Climate Change

Extensive literature reviews have revealed that a number of different socio-economic and natural factors have contributed to the increasing perception level of farmers about climate change variables like temperature, precipitation, etc. However, there were a significant proportion of the respondents who did not recognize the effect of climate change.

Climate change is expected to influence crop and livestock production and other components of agricultural systems. In this study, farmers were asked if they had noticed any significant climate changes from the past ten to twenty years. Results shown in Table 2 indicate that almost more than 50% of the sample farmers had noticed significant changes in both agroecologies and they ascribed reduction in farm production. About 71% of the sample households have perceived changes of precipitation, 55% understood increasing temperature and 63% recognized the occurring of untimely rain. In addition, farmers perceived that climate change affected direct crop production and livestock health, and resulted in land degradation and hence had negative impact on livelihoods.

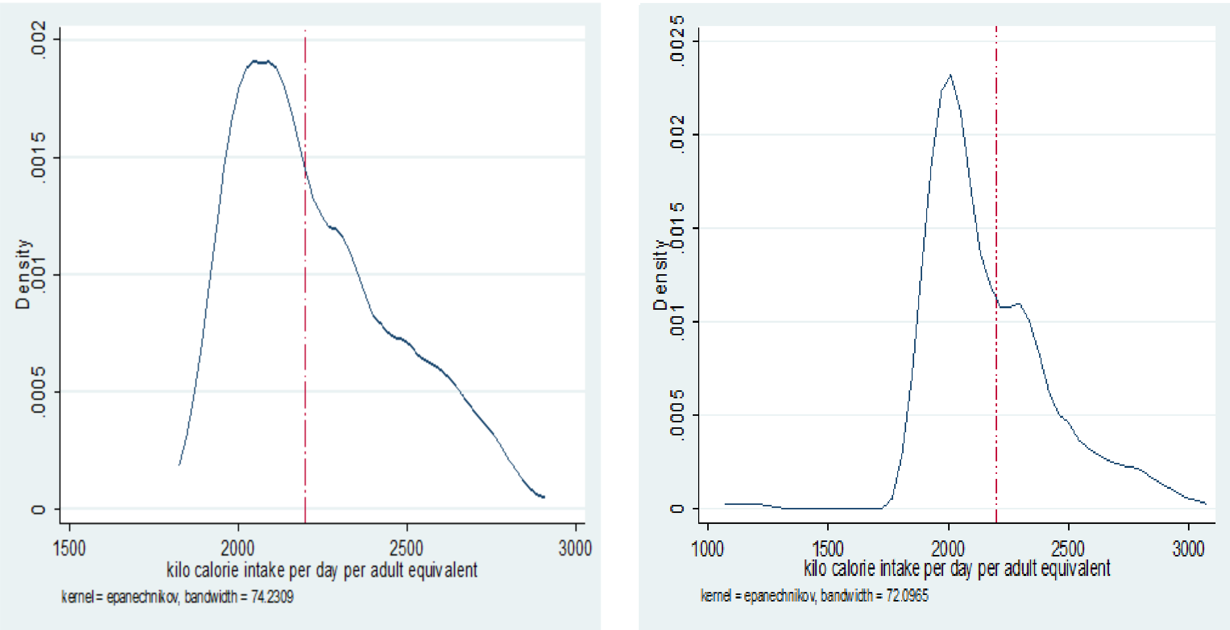
Farmers noticed that over the last ten to twenty years, rainfall variability has been increasing substantially, as rains fail to come more frequently or come suddenly at abnormal times of the year. All farmers have also noticed more frequent droughts in the last ten years as compared to twenty years ago.

Flooding had a significant impact on the long-term productivity of their land as well. Much of the fertile topsoil was washed away and only hard-panned soil remains. The degraded land has hardly been supplying sufficient soil nutrient which improves farm productivity and requires more time for recovery.

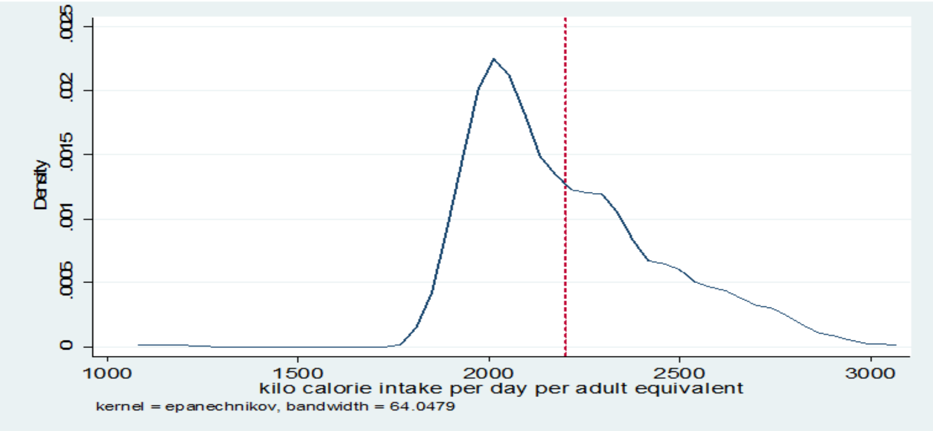
From the farmers perception and supported by the literature, it is the climate-related hazards that significantly increased household vulnerability to climate change through reduced farm productivity and household food security. Although farmers have been able to deal with past drought and floods, the increasing frequency and intensity of climate-related hazards is forcing farmers to engage more frequently in emergency coping strategies such as consuming seeds reserved for planting and selling farm implements to smooth their consumption.

Figure-1. Kernel density estimation of daily calorie intake per adult equivalent of the sample households by agroecology.

A. Highland agroecology B. Lowland agroecology



C. Combined highland and lowland agroecologies



Source: Author's computation

3.3. Food Security Status and its Determinants

Food security at a household level is analyzed and best measured by direct survey of income, expenditure, and consumption and comparing it with the minimum subsistence requirement (Von Braun *et al.*, 1992). This study used daily calorie availability per adult equivalent (kilocalorie) as a measurement for food security. Accordingly, food security status was measured by comparing the level of the daily calorie availability per adult equivalent with the minimum acceptable weighted average food requirement per person per day for Ethiopia which has been set at 2200 kcal (Kifle and Yosef, 1999). In the highland and lowland areas, the estimated calorie intakes are indicated in Figures 1A and 1B. Figure 1B which is more right-skewed from the mean of the lowland indicates that there is more number of food insecure households.

The combined highland and lowland calorie availability graph as indicated in Figure 1C also shows the distribution of the estimated daily calorie availability per adult equivalent for all households which is right-skewed indicating higher number of food insecure households falling below the mean value of 2200 kcal

The daily calorie availability per adult equivalent was low in the lowland than in the highland. The two agroecologies had a significant difference in terms of the deviation from the food security threshold. The mean of households in highland were relatively better-off to escape from the food security threshold by 250 kcal whereas the lowland rural households had 145 kcal deficits from the minimum daily calorie requirement of 2200kcal (Table 3).

Agricultural production is the source of rural households' income in Ethiopia and is mainly generated from crop production. In this regard, it was found that 63% and 37% of the households in the highland and lowland, respectively, have income inequality from agricultural production, which is higher than the national rural income inequality estimated at about 30% percent in the year 2010/2011(FDRE, 2012).

As the head count index measures the incidence of food insecurity, the mean food insecurity gap and the squared food insecurity gap measure the depth and severity of food insecurity, respectively. The incidence of the food insecurity in highland was 34.12% compared to the incidence in lowland (43.13%). Intensity of mean food insecurity gap or calorie measured by calorie adequacy also follows the same scenario. Also the severity of food insecurity (squared food insecurity gap) was 15% and 19% in highland and lowland, respectively.

Table 4 indicates that by randomly taking the significant explanatory variables, the predicted probability of the sample households of being food secure was about 0.374. The predicted probability of the households in highland agroecology to be food secure was about 0.609 which was higher as compared to that of predicted probability of the lowland agroecology which was about 0.409. The likelihood of food security in different parts of rural Ethiopia is different; because the food insecurity prevalence is different. It is difficult to obtain comparable and representative empirical evidences because there is significant difference in measurement and estimation biases in food security indicators.

The probability of households to be food secure with social participation was 0.58 which is greater than that without participation (0.45). The predicted probability of households to be food secure with irrigation water use was negative and significant (33.7%) compared with the without irrigation situations (60.8%). Irrigation is generally considered an effective way of increasing agricultural production. It can supply the water needed for crop growth when rainfall is limited or, in more humid climates, it can bridge dry spells and reduce agricultural risks. However, the negative sign shows that the mass production of irrigation products such as perishable vegetables ignoring the infrastructural facilities such as distance to the nearest market, road, transport, processing industries and information access leads to reduced profitability of the sector even though there are sufficient resources such as water, labor and land.

Credit is an important factor for food security status. The probability that households are food secure with credit access in the study area was 63.1% and it was 41.5% for those who do not have access to credit. Access to credit enables to increase per capita incomes and food security status of households. The probability of univariate probit estimation output of the food security status is 45% for food secure household and 55% for food insecure household in the study areas.

3.4. Adaptation Strategies

The adaptation strategies adopted and practiced by farmers in the study area more than ten in number. From these strategies, the most frequently applicable include choice of crop variety selection, changing the planting and harvesting dates of different crops, using irrigation, and increasing the use of soil and water conservation techniques. Table 5 shows these adaptation options and other strategies that serve as important mechanisms to cope with drought and temperature stress.

As shown in Table 5, 8.1% and 12% of the farmers in the highland and lowland agroecologies used crop variety selection strategy, and about 10.5% and 7.4% of the farmers in the highland and lowland areas used changing planting date, respectively. Proportion of households participating in soil and water conservation in the highland and lowland areas were 12.4% and 13.9%. Irrigation was used by 11% and 7.4% of the sample households of highland and lowland, respectively. The lowlanders were relatively better off on adoption of crop variety and soil and water conservation, but the highlanders were better in changing planting date and irrigation water use. However, the adoption of climate change adaptation strategies in both agroecologies was generally very low (less than 50%). The great majority of households were not yet using these very common agricultural technologies which have been introduced to the rural Ethiopian farmers since many years.

Adaptation measures help farmers guard against losses due to increasing temperatures, decreasing precipitation, and frequently happening drought and flood. Therefore, the dependent variable in the empirical model for this study is the choice of an adaptation option from the set of adaptation measures. In the study area, more than ten different adaptation strategies to climate change were identified. Such adaptation strategies were categorized and identified by the works of Bradshaw and Smit (2004), Maddison (2006), and Nhemachena and Hassan (2007). From different categories of adaptation strategies, this study focused on those strategies indicated by farmers as most important such as selection of crop variety, changing crop calendar, adoption of soil and water conservation, irrigation water usage, and no adaptation.

Farmers have considered the main adaptation choices to mitigate the exposure to climate change. However, this study has taken those who do not adopt any adaptation strategy as the base category. More than 17% of respondents did not adopt any adaptation strategies.

The empirical study on factors affecting adaptation strategies to climate change was done using MNL model. The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable. Thus, the marginal effects measure the expected change in probability of a particular choice being made with respect to unit change in an explanatory variable (Greene, 2012; Long, 1997).

Table 6 presents results of the estimates of the marginal effects for each outcome in the MNL model. This analysis used the no adaptation strategy as the base category and evaluated the other choices as alternative options. The general interpretation of a marginal effect of a given estimate shows how the probability of the outcome changes when the corresponding variable changes by one unit from its mean while the rest of the variables are held constant at their means.

The result suggested that agroecology promotes switching of crop variety selection and changing of planting date. The lowland agroecology was related with strongest adaptation measure which results in a 33.8% increase in the probability of crop variety selection and 18.9% decrease in the probability of changing planting date to adapt to climate change. This means, the highland farmers practiced change of planting dates as an adaptation strategy more than their lowland counterparts.

Distance to market center is important factor affecting adoption of agricultural technologies (Feder *et al.*, 1985). Input markets allow farmers to acquire the inputs they need such as improved seed varieties, fertilizers and irrigation technologies. On the other hand, access to output markets provides farmers with positive incentives to produce and adopt alternative strategies. The longer the distance to the market, the lower will be the probability that farmers adopt improved technologies. In this study, distance to markets positively affected the use of irrigation and negatively and significantly affected soil and water conservation and crop variety selection. That is, one kilometer increase in distance to market center would reduce the probability of adoption of soil and water conservation and crop variety selection strategies by 1.3% and 1.9%, respectively; but increase use of irrigation by 1.6%. Therefore, proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Maddison, 2006).

Family size as a proxy to labor availability may influence the adaptation of new technology positively as its availability reduces the labor constraints (Legesse *et al.*, 2006). However, in this study it was found that household's family size is negatively and significantly related to the probability of crop variety selection as an adaptation strategy. This could be because households with large families may be forced to divert part of the labor force to off farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family rather than adopting crop variety selection. On the other hand, it was inferred from the result that more educated households were more likely to implement soil and water conservation adaptation strategies than the less educated households.

Cultivated land had significant effect on some of the farmer's choice of adaptation strategies. The marginal probability of the multinomial logit model indicates that increasing cultivated land by 1 unit decreases the probability of adopting soil and water conservation by 48%, but the probability of crop variety selection as adaptation to climate change increases by 36.3%.

Access to credit service had a strong positive influence on the probability of adopting all adaptation strategies. Access to affordable credit increases financial resource of farmers and their ability to meet transaction cost associated with various adaptation options they might want to take Hassan and Nhemachena (2008). This result implies that access to credit is critical in helping farmers to adapt to climate change.

Social participation (a proxy of economic independence and organizational membership and participation in collective action) was found to significantly influence some of the households' adaptation decisions. Social participation increases the probability of farmers' adoption of crop variety selection strategy by 13.5% while it decreases the probability of irrigation water use by 0.9 percent. Thus, social participation and social network are increasing awareness and forecasting use of climate change adaptation options.

In this study a unit increase in precipitation decrease the probability of using crop variety selection by 30.5% while a unit increases in temperature increases the probability of using crop variety selection by 24.7%. This exerts more pressure on the livelihood activities to sustain households' life.

The predicted probabilities of adaptation strategies suggested that the likelihood of the sample households to adopt the strategies of changing planting date, irrigation water use, soil and water conservation and crop variety selection in reference to the base category of no adaptation strategy were 0.9%, 28.4%, 38% and 18.5%, respectively.

4. Conclusions and Recommendation

This study has analyzed factors affecting food security and adaptation strategy to climate change based on a cross-sectional data collected from 330 farm households in Eastern Ethiopia during the 2011/2012 agricultural production year.

The food security and adaptation strategy options which are believed to mitigate climate change impacts on agricultural production and implemented by farmers are considered in this study. A Univariate probit model and MNL model were used to analyze the determinants of farmers' household food security and choice of adaption strategies. Results from the model showed that there are different socio-economic and environmental factors that affect farmers' food security and adaptation strategies to climate extreme events. These include the educational status of household head, credit access, social participation, size of cultivated land, use of chemical fertilizer, access to nearest market, agroecology and awareness of change in temperature and precipitation.

Farmers in the study area have adopted four types of strategies among from different adaptive strategy alternatives, namely changing of planting date, use of irrigation, soil and water conservation, and crop variety selection. The current food insecurity status is 55% and food security is 45% and adopted changing planting date, irrigation water use, soil and water conservation and crop variety selection were in 0.9%, 28.4%, 38% and 18.5%, respectively, indicating a decrease in negative impact of climate change as a result of the likelihood of food insecurity and adopting the strategies.

The issue of climate change has gone beyond effort alone. Government policy and investment strategies should also work to support the provision of access to education, access to credit, and awareness creation on climate change and adaptation mechanisms. In addition, policy interventions that encourage social network participation which can promote group and community discussions and enhance better information flows, ultimately enhances the ability to adapt to climate change. Future policy could also focus on creating awareness of climate change and facilitating the development and adoption of adaptation strategies. The intensive awareness on climate change will be best achieved in the study area through extension agents, agricultural show, symposium and the likes.

Tables

Table-1. Socioeconomic and institutional characteristics of the sample households by agroecology

Variable	Highland	Lowland	Mean difference	Mean difference test (t-value)
Kilocalorie intake(Kcal)	2229.02	2168.26	60.76	2.27**
Food secured (proportion)	0.49	0.40	0.09	1.72*
Adapt crop variety selection (proportion)	0.33	0.37	-0.04	0.75*
Adapt soil and water conservation (proportion)	0.19	0.61	-0.52	11.75***
Distance to the nearest market(Km)	5.9	12.59	-6.69	11.36***
Distance to the nearest town(Km)	7.33	15.34	-8.01	-13.37***
Distance to the extension service (Km)	3.96	3.16	0.80	4.35***
Credit (proportion)	0.71	0.84	-0.13	-2.90***

Note: ***, **, and *, signify significance levels of 1%, 5% and 10%, respectively.
Source: Author's computation

Table-2. Farmers' perception of changes in climate indicators and its effects

Variables	Frequency	Percentage
Reduction in precipitation	234	71
Increase in temperature	182	55
Untimely rain	209	63
Frequent drought	141	43
Flood	151	46
Livestock disease	265	80
Land degradation	144	44
Decreasing crop production	212	64

Source: Author's computation

Table-3. The households' food security status and climate change

Variables	Highland	Lowland	All sample
Food insecure households (%)	58	69	64
Head count index (%)	34.12	43.13	37.625
Mean Food insecurity gap (kcal)	+250	-145	385
Squared food insecurity gap (%)	0.15	0.19	0.34
Daily calorie availability (kcal)	2229.02	2163.59	2197.297
Gross income inequality (Gini coefficient) (%)	0.63	0.37	0.50

Source: Author's computation

Table-4. Univariate probit estimation of determinants of household food security status

Variables	Coefficient	Robust Std. Err.	Marginal
Education	0.526*	0.295	0.207*
Social participation	0.329*	0.138	0.131*
Flood incidence	-2.792***	0.331	-0.836***
Family size	-0.249***	0.06	-0.099***
Credit access	0.205*	0.18	0.082
Sex of household head	0.986**	0.501	0.352**
Irrigation water use	-0.693**	0.289	-0.27**
Farming experience	0.174***	0.025	0.07***
			Continue
Tropical livestock unit(tlu)	0.116	0.088	0.046
Fertilizer usage	0.04**	0.017	0.016
Off-farm income	-0.137	0.299	-0.055

Agroecologies	-0.507*	0.122	-0.2
_cons	-2.351***	0.2711	
Predicted probability			0.374
Pr(highland agroecology)			0.609
Pr(lowland Agroecology)			0.409
Pr(with Social participation)			0.583
Pr(without Social participation)			0.453
Log pseudo likelihood			-54.078
Wald χ^2 (12)		124.79	
Pseudo R^2		0.762	
goodness-of-fit test, Pr > χ^2 (318)		0.983	

Note: ***, **, and *, signify significance levels at 1%, 5% and 10%, respectively.
Source: Author's computation

Table-5. Adaptation strategies used by farmers (mean)

Strategies	**Highland**	**Lowland**	**Total**
Selection of crop variety (%)	0.162	0.240	0.201
Changing planting date (%)	0.220	0.148	0.180
Irrigation water use (%)	0.220	0.148	0.184
Soil and water conservation (%)	0.248	0.280	0.263
Combined more than one adaptation strategies (%)	0.006	0.000	0.003
No adaptation strategy (%)	0.160	0.184	0.170
All sample	100.000	100.000	100.000

Source: Author's computation

Table-6. The marginal effects of explanatory variables from multinomial logit model

Variables	**Changing planting date**	**Irrigation water use**	**Soil and water conservation**	**Crop variety selection**
Agroecology	-0.189***	0.103	-0.113	0.338***
Awareness of climate change	4.870	0.006	0.016	-0.008
Distance to market	-1.440	.016**	-0.013**	-0.019**
Fertilizer usage	-0.006	-0.037	-0.343***	0.288***
Sex of household head	2.120	0.150	-0.142	0.011
Family size	-6.860	-0.023	-0.006	-0.032**
Education of household head	0.007	-0.056	0.187**	-0.066
Cultivated land	-0.005	0.994	-0.480**	0.363***
Off-farm income	5.260	-0.054	0.944	-0.015
Credit access	0.008*	0.47*	0.038**	0.028***
Social participation	0.009	-0.009*	0.077	0.135***
Farming experience	-8.540	-0.002	-0.009	0.009
Untimely rain	-5.530	-0.378	-0.039	0.080
Precipitation	0.009	0.002	0.137	-0.305**
Temperature change	-0.004	-0.035	-0.126	0.247***
Pr(predicted)	0.009	0.284	0.383	0.185

Note: ***, **, and *, signify significance levels of 1%, 5% and 10%, respectively.
Source: Author's computation

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