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Adaptation to Climate Change and Variability in eastern Ethiopia

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Abstract

Agricultural production in Ethiopia is vulnerable to climate change. Adaptation is one of the options to abate the negative impact of climate changes. This study has analyzed factors influencing different climate change adaptation choices by farm households in eastern Ethiopia. The study were analyzed by using the data obtained from 330 household heads randomly and proportionately sampled from two agroecologies in Eastern Hararghe zone of Oromiya Region and Dire Dawa Administration, Ethiopia. The study used a multinomial logistic regression model to identify factors affecting the choice of adaptation strategies to climate change where changing planting date, irrigation water use, soil and water conservation, and crop variety selection. The result indicated that factors determining choice of climate adaptation options were 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 creates awareness to climate change.

Keywords: climate change, adaptation strategies, multinomial logit model

1. Introduction

Climate change is a global issue because it affects all countries in the world. It is one of the biggest environmental challenges. There are already increasing concerns globally regarding changes in climate that are threatening to transform the livelihoods of the vulnerable population segments (Watson, 2010). Climate change and variability is posing the greatest challenge to mankind at global as well as local levels (Slingo *et al*., 2005).

Climate change affects mainly the agricultural sector and agriculture in turn affects climate change through farm practices. Agriculture affects climate change through the emission of greenhouses gas (GHG) from different farming practices (Edwards-Jones *et al*., 2009; Marasent *et al*., 2009). Climate change in the form of higher temperature, reduced rainfall and increased rainfall variability reduces crop yield and threatens food security in low-income and agriculture-based economies. Adverse climate change impacts are considered to be particularly strong in countries located in tropical Africa that depend on agriculture as their main source of livelihood (Dixon *et al*., 2001; IPCC, 2001; IAC, 2004).

Agriculture is the main sector of the Ethiopian economy. It is the livelihood of about 85% of the population living in the rural areas and serves as the major sector for sustainable development and poverty reduction in Ethiopia. Nevertheless, the sector suffers from various factors such as soil degradation caused by overgrazing and deforestation, poor complementary services such as extension, credit, marketing, infrastructure and climatic factors such as drought and flood (Belay, 2003; Yirga, 2007). Often times, climate changes have adverse effect due to drought and unstable rainfall conditions, although there seems to be a recent time claim that climate change also have some positive elements on Ethiopian agriculture. Recognizing the consequences of climate change, the Government of Ethiopia has formulated various strategies. The Green Economy strategy has been prepared in order to meet the green growth agenda. The objective is to identify green economy opportunities that could help Ethiopia reach its ambitious growth targets while keeping greenhouse gas emissions low. Agriculture is the main sartorial focus in this strategy.

Eastern Ethiopia, small-scale agriculture constitutes the backbone lives of rural household. Rainfall variability and associated extreme events like droughts, flood, untimely rain, livestock disease, etc have triggered serious problems. Evidences suggest that even though rainfall variability and the associated shocks like drought and flooding are not new phenomena and the public perception is also improving, there is no sufficient evidence as to whether or not climate change is perceived as a major problem or reality among smallholder farmers, particularly by the poor and most vulnerable farmers in the rural areas (Woldeamlak and Dawit, 2011). As far as published materials covering climate change perception and adaptation are concerned, only few studies (Mahmud *et al*., 2008; Akililu, 2009; and Temasgen *et al*., 2008a) have attempted to address level of perception to decrease in rainfall and increase in temperature.

The adverse effects of climate change on Ethiopia's agricultural sector are a major concern, particularly given the country's dependence on agricultural production (Assefa *et al*., 2011). According to the assessment by National Adaptation Program of Action (NAPA) of Ethiopia, the major adverse impacts of climate variability on the agricultural sector include food insecurity and land degradation (NAPA, 2007). Agricultural producers have been trying to adapt themselves to climate changes since earlier times. Recently, there are some attempts by various stakeholders to design short-run and long-run climate change adaptation strategies so as to enable sustainability of agricultural operations in Ethiopia, for instance through irrigation, soil and water conservation, and the likes.

Although, there are different coping and adaptation strategies designed and applied, the adverse effect of climate on agriculture and in related sectors has been continuing. Looking into impact of climate change, in the past and the expected change in the future, it is imperative to understand how farmers perceive climate change and adapt in order to guide strategies for adaptation in the future. The development of strategies for supporting adaptation and responding to the consequences and adverse effect of climate change will require collaboration at local, regional and global level, across disciplinary boundaries and between different sectors of the economy.

The concept of adaptation to climate is not a new phenomenon. Throughout human history, societies have adapted to natural climate variability by altering settlement and agricultural patterns and other facets of their economies and lifestyles. The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Smit *et al*., 2000). It is the degree to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate. It was further indicated that adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of change in conditions.

Adaptation to climate change includes adjustments in socioeconomic systems to reduce their vulnerability both to long-term shifts in average climate and to changes in the frequency and magnitude of climatic extremes (Adger, 2003). These extremes are hazardous now, and often exceed the capacity of a country or community to cope. The vulnerability of a community to climate change is related to the exposure of the community to hazardous climatic conditions and to the adaptive capacity of the community to deal with those conditions. Enhancing the ability of communities to adapt to climate change or manage climate change risks requires addressing pertinent locally identified vulnerabilities, involving stakeholders, and ensuring that adaptation initiatives are compatible with existing decision processes (Brooks *et al*., 2005). Therefore, planning adaptation as well as adapting to climate change requires an understanding of current conditions. It requires an understanding of the adaptive capacities, resilience and livelihood strategies of the local population who are directly affected by the impacts of climate change and who must cope with the realities of multiple pressures. It also requires an understanding of how the various levels of governance enable or hinder local actors to improve their wellbeing (Maddison, 2006; Hassan and Nhemachena, 2008)

Adaptation to climate change refers to the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects to moderate harm or exploit beneficial opportunities (IPCC, 2001). Even though mitigation targets uprooting the major causes of climate change and offers long-run solutions, adaptation is much more important for the group of developing countries. Fussel (2007) argued that emphasis should focus on adaptation because human activities have already affected climate, climate change continues given past trends, and the effect of emission reductions will take several decades before showing results, and adaptation can be undertaken at the local or national level as it depends less on the actions of others.

This study was focused of the objective to identify the widely practiced climate change adaptation strategies at farm level and factors affecting the choice of these strategies.

2. Research Methodology

2.1. The study area

Eastern Hararghe zone and Dire Dawa Administration (DDA) of Ethiopia was selected for this study mainly because these are among the areas highly affected by climate change like in drought, flood, untimely rain, etc. The specific study areas are Meta Woreda from the highland of East Hararghe Zone and Dire Dawa Administration the lowland. Both of these study areas are under the productive safety net production. Eastern 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 the Meta Woreda consists 48% as 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 and located in lowland agroecology. 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 of agroecology with 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 Eastern 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 from each Woreda was selected using a simple random sampling technique. In the third stage, eight sample Kebels were selected using lottery method. Finally sample households were selected from each Kebele by preparing a comprehensive list of households and apply systematic randomly sampling method. The sampling units at each stage sampling were drawn using the probability proportional to size (PPS) sampling method.

2.3. Analytical Methods

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; Temsgen *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 (Madalla, 1983; Wooldridge, 2002). The usefulness of this model in terms of ease in interpreting estimates is likewise recognized (Green, 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).

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

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:

$$\Pr\left(Yi = {}^{j}\!/_{Xi} \right) = \frac{e^{\beta'_j Xi}}{1 + \sum_{k=1}^{J} e^{\beta'_k X_i}}, \quad j = 0,1,2........,J, \quad \beta_0 = 0 \qquad (2)$$

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

$$\ln\left({}^{P_{ij}}\!/_{P_{ik}} \right) = X'_i \left(\beta_j - \beta_k \right) = X'_i \, \beta_j \, , if \;\; K = 0$$

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):

$$\frac{\partial P_j}{\partial X_i} = P_j\left[\beta_j - \sum_{k=0}^{J} P_k\beta_k\right] = P_j\left(\beta_j - \overline{\beta}\right) \quad (3)$$

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 (Long, 1997; Greene, 2012). 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

2.1. 3.1. Descriptive Results

2.2. The extensive literature review has 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 climate change.

Climate change is expected to influence crop and livestock production and other components of agricultural systems. Therefore, 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 sampled farmers had noticed significant changes in both agroecologies and they ascribed reduction in farm production.

Close to 71% of the sample households have perceived changes of precipitation, 55% understood the increasing temperature and 63% recognized the occurrence of untimely rain. In addition, farmers perceived that climate change directly affects crop production, livestock health, land degradation and hence has negative impact on livelihoods.

Farmers noticed that, over the last ten to twenty years, rainfall variability has substantially increased, 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 twenty years before. About 43% of the farmers encountered frequent droughts leading to inadequate rain that is turn resulted in crop failure and severely stunted crops.

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 farmers perception and supported by the literature, it is the climate-related hazards that significantly increased household vulnerability to climate change. About 64% of the households reported that climate change has reduced farm productivity and household food security. Although farmers have been able to deal with past droughts 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.

The adaptation strategies farmers perceive and practically applied as the appropriate practice include crop variety, changing the planting and harvesting dates of different crops, using intensified irrigation and increasing the use of soil and water conservation techniques. Table 3 shows the different farmers' adaptation strategies for climate change.

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 *et al*. (2004), Maddison (2006) and, Nhemachena and Hassan (2007). From different categories of adaptation strategies, this study focus on those strategies predicted by farmers in the study area, these include a crop variety selection, changing cropping calendar, soil and water conservation, irrigation usage and no adaptation.

Farmers have made different adaptation choices to mitigate the exposure to climate change. However, this study has taken the base category that represents those who did not adopt any adaptation strategies. More than 35% of respondents are not adopt any adaptation strategies.

Four adaptation strategies including crop variety selection, different planting date, soil and water conservation and irrigation water use were considered to investigate the factors affecting these strategies in the study areas. The adoption status of sample households by agroecology is indicated in Table 3.

As shown in Table 4, the proportion of farmers using crop variety as adaptation strategy. In the two agroecologies 37% and 33% and for changing crop calendar the probability 44% and 24%, respectively. The probability of households using soil and water conservation of highland and lowland households were 62% and 44% and for irrigation 26% and 35% of the sample households, respectively. The lowlanders were relatively better off on adoption of crop variety and soil and water conservation, but the highlanders were better in changing crop calendar 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 are not yet using these very common adaptation strategies which have been introduced to the rural Ethiopian farmers since many years before.

3.2. Econometric Estimation Result

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable shown in Table 1. 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 (Green, 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. Then, the interpretations for each of the adaptive strategy are with respect to the base category (no adaptation).

Table 5 presents results of the estimates of the marginal effects for each outcome in the MNL model estimation. This analysis has 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 the agroecology promotes switching of crop variety selection and changing of planting date. The lowland has the strongest adaptation measure (33.8%) which results in an increase in the probability of crop variety selection and decrease in the probability of changing planting date (18.9%) as adaptation strategies to climate change. On the other hand, the highland farmers are better off in practicing change of planting dates as an adaptation strategy.

The nearest distance of market access is another 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 adapt alternative strategies. The longer the distance to the market, the lower the probability of adaption improved technologies. Therefore, in this study, distance to markets positively and significantly influenced the probability of using irrigation and negatively 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 irrigation by 1.6%.

Family size as a proxy to labor availability may influence the adaptation of new technology positively as its availability reduces the labor constraints (Legass *et al*., 2006). Therefore, 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. On the other hand, it was inferred from the result the more educated households were more likely to implement soil and water conservation adaptation strategies than the less educators.

Cultivated land had significant effect on the farmer's adaptation strategies. The marginal probability of the multinomial logit model indicates that increasing land size by 1% decreases the probabilities of using soil and water conservation by 48%, but increases the probability of crop variety selection by 36.3% as a strategy for adapting to climate change.

Better access to credit services seems to have a strong positive influence on the probability of adopting all adaptation strategies including changing of planting date, irrigation water use , soil and water conservation , and crop variety selection by 0.8, 47, 3.8 and 2.8 percent, respectively.

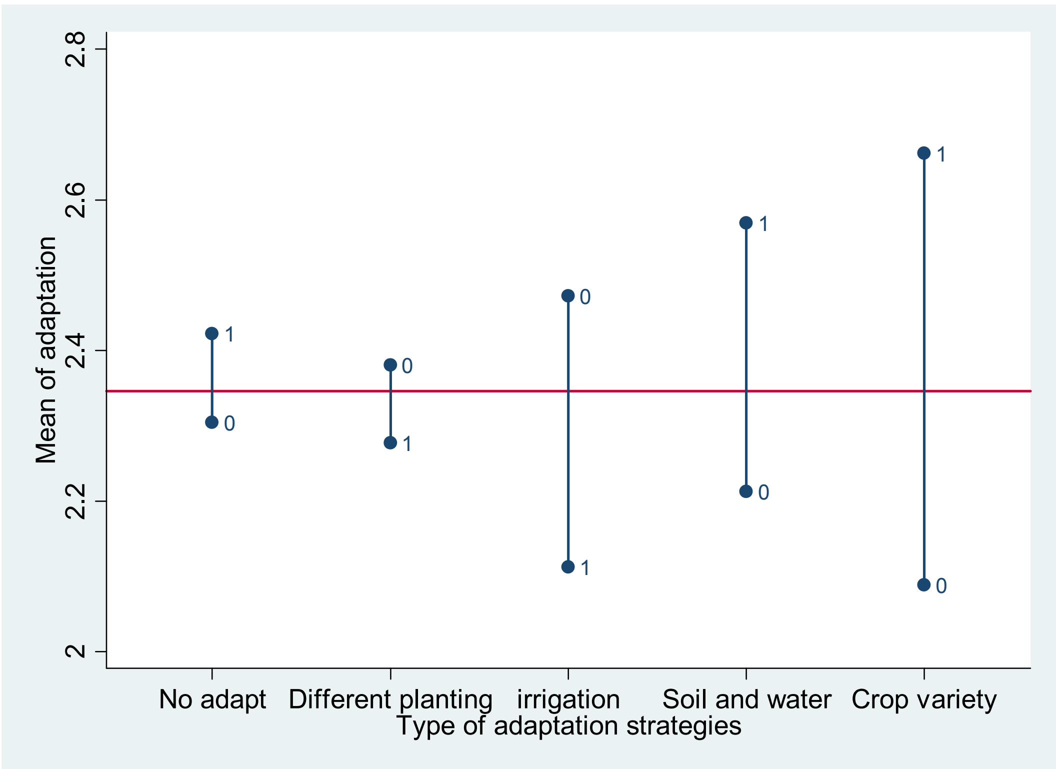
Social participation (a proxy of economic independence and organizational membership and participation in collective action) was found to significantly influence household adaptation decisions. Social participation increases the probability of farmers participating in crop variety selection by 13.5% while decreases the probability of using soil and water conservation by 0.9 percent.

The amount and the time of precipitation increases the probability of using variety selection by 30.5% while a unit increase in temperature increased the probability of using crop variety selection by 24.7%.

The predicted probabilities of adaptation strategies suggest that the livelihood of the sample households to use 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.

The adoption status of the five adaptation strategies to climate change is graphed to capture their possible relationships (Figure 1). Adopters of soil and water conservation and crop variety selection were more than those who adopted the remaining strategies. The adoption statuses of most adopters were below the mean value indicated by the horizontal reference line.

Figure 1: Adaptation strategies to climate change



Source: author's computation

4. Conclusions and policy Implications

This study has analyzed factors affecting the choice of 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 adaptation options which are believed to mitigate climate change impacts on agricultural production and implemented by farmers are considered in this study. A MNL model was used to analyze the determinants of farmers' choice of adapting strategies. Results from the MNL model showed that there are different socio-economic and environmental factors that affect farmess' strategies to adapt 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 amongst from different adaptive strategy alternatives, namely changing of planting date, use of irrigation, soil and water conservation and crop variety selection. The predicted model results indicated that while using these strategies, farm households will be better-off due to the decreased impact of climate change. The predicted values for changing planting date, irrigation water use, soil and water conservation and crop variety selection were 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 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 and 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 enhancing the ability to adapt to climate change should be strengthened.

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Table 1: Definition and notation of explanatory variables

Variable names	Notation	Measurement	Expected effect on dependant variables
Crop variety	Crovar	Binary (1 if adopt,0 otherwise)	+
Different planting date	Difpld	Binary (1 if adopt,0 otherwise)	+
Soil and water conservation	Swcn	Binary (1 if adopt,0 otherwise)	+
Irrigation	Irr	Binary (1 if adopt,0 otherwise)	+/-
Farm experience	exp	Continuous(years)	+
Land of cultivated	lan	Continuous (ha)	+
Credit access	cred	Binary (1 if participate, 0 otherwise)	+

Table 2: Farmers' perception of changes in climate indicators

Perception variables	Frequency	Percentage
Precipitation	234	71
Change of temperature	182	55
Untimely rain	209	63
Drought	141	43
Flood	151	46
Livestock disease	265	80
Land degradation	144	44
Decreasing crop yield	212	64

Source: author's computation

Table 3: Adaptation strategies used by farmers

Strategies	% of respondents
Crop variety selection	32
Changing planting date	21
Irrigation water use	12
Soil and water conservation	13
No adaptation strategy	22

Source: author's computation

Table 4: Proportion of users of different adaptation strategies by agroecology

Agroecology	Crop variety selection	Changing crop calendar	Soil and water conservation	Irrigation use
Highland (%)	33	44	44	35
Lowland (%)	37	24	62	26

Source: author's computation

Table 5: The marginal effects of explanatory variables from multinomial logit model

Variables	Changing of planting date	Irrigation 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(Km)	-1.440	.016**	-0.013**	-0.019**
Fertilizer usage (qt)	-0.006	-0.037	-0.343***	0.288***
Sex of household head	2.120	0.150	-0.142	0.011
Family size (number)	-6.860	-0.023	-0.006	-0.032**
Education of household head(Yr)	0.007	-0.056	0.187**	-0.066
Cultivated land(ha)	-0.005	0.994	-0.480**	0.363***
Off-farm income (Br)	5.260	-0.054	0.944	-0.015
Credit access (Br)	0.008*	0.47*	0.038**	0.028***
Social participation (%)	0.009	-0.009*	0.077	0.135***
Farming experience(Yr)	-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 *, respectively signify significance levels of 1%, 5% and 10%.