Climate change adaptation strategies of maize producers of the Central Rift Valley of Ethiopia

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Abstract

The impacts of climate change are considered to be strong in countries located in tropical Africa that depend on agriculture for their food, income and livelihood. Therefore, a better understanding of the local dimensions of adaptation strategies is essential to develop appropriate measures that will mitigate adverse consequences. Hence, this study was conducted to identify the most commonly used adaptation strategies that farm households practice among a set of options to withstand the effects of climate change and to identify factors that affect the choice of climate change adaptation strategies in the Central Rift Valley of Ethiopia. To address this objective, Multivariate Probit model was used. The results of the model indicated that the likelihood of households to adapt improved varieties of crops, adjust planting date, crop diversification and soil conservation practices were 58.73 %, 57.72 %, 35.61 % and 41.15 %, respectively. The Simulated Maximum Likelihood estimation of the Multivariate Probit model results suggested that there was positive and significant interdependence between household decisions to adapt crop diversification and using improved varieties of crops; and between adjusting planting date and using improved varieties of crops. The results also showed that there was a negative and significant relationship between household decisions to adapt crop diversification and soil conservation practices. The paper also recommended household, socioeconomic, institutional and plot characteristics that facilitate and impede the probability of choosing those adaptation strategies.

Keywords: climate change, adaptation strategies, multivariate, maize, Ethiopia

1 Introduction

The main challenge for agriculture in the twenty-first century is the need to nourish increasing numbers of people while conserving the ongoing soil degradation and water depletion in the face of limited resources and growing pressures associated with an increasing global population and changing diets (Tubiello, 2012). Climate change is already putting extra pressure on agriculture and its effects are expected to become more vital in the future (Apata *et al.*, 2009; Lobell *et al.*, 2011b; Rosenzweig *et al.*, 2014). Despite technological advancements that have already been reached, the agricultural system is still highly dependent on the climatic condition in many areas of the world (Müller *et al.*, 2011). For example, Parry (2007) has indicated that, by 2020, agricultural production would decline by 50 % in some countries with rain-fed agriculture due to climate change.

Climate change affects agriculture directly and indirectly. Directly, it affects by influencing the weather variables such as rainfall, temperature, solar radiation, wind speed and humidity (Sowunmi, 2010; Pryor *et al.*, 2014; Arimi, 2014). Indirectly, it affects through disease and pest outbreak as well as favoring the development of climate related diseases like malaria that affect the workforce (Newton *et al.*, 2011).

Studies on global climate change indicated that developing nations are expected to withstand the worst of

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the associated damages (Ericksen *et al.*, 2011; Skoufias *et al.*, 2011). Africa will be one of the continents that will be hard hit by the impact of climate change, though the continent represents only 3.6 percent of emissions (Parry, 2007; Alemneh, 2011). Sub-Saharan Africa (SSA) is arguably the most vulnerable region to many unpleasant effects of climate change due to a very high dependence on rain-fed agriculture (Cooper *et al.*, 2008). Thus, the impacts of climate change are likely to fall unreasonably on poorer nations and on poorer households. Ethiopia is among the most vulnerable countries in SSA due to its great reliance on climate vulnerable economy (Conway & Schipper, 2011).

Ethiopian economy is an agrarian economy as agriculture comprises about 41.3 % of GDP, generates 90 % of foreign exchange earnings, and employs more than 80 % of the population (MoFED, 2012). Currently, however, the performance of this sector is seriously eroded due to climate change induced problems. It is estimated that in Ethiopia, one drought event in 12 years lowers GDP by 7 to 10 % and increases poverty by 12 to 14 % (Makombe *et al.*, 2011). The projected reduction in the Ethiopian agricultural productivity due to climate change can reduce average income by 30 percent over the next 50 years (Gebreegziabher *et al.*, 2011). Climate change can also have a significant impact on the urban dweller in terms of higher food prices, limited job opportunities in the agro-processing industries and expensive imported food items due to foreign exchange shortages (Aragie, 2013). In addition to this, it can cause a decline in biodiversity, increases in human and livestock health problems, rural-urban migration and dependency on external supports (Daniel, 2008). Therefore, adaptation strategies that minimize the negative outcomes associated with changing climate are urgently needed. Because a society with high adaptive capacity will be less susceptible in the future than other communities to the potentially detrimental and often unpredictable effects of climate change (Petheram *et al.*, 2010). However, most of the farmers in the country have low access to education, information, technology, and basic social and support services, and, as a result, have low adaptive capacity to deal with the consequences of climate variability and change (The World Bank Group, 2010).

The Central Rift Valley of Ethiopia (CRV) where this study was conducted is evidently the hardest hit region of the country in terms of drought (Emana *et al.*, 2010). In CRV, fluctuations in precipitation and temperature rates are directly affecting the production and productivity of the agricultural systems (Deschênes & Greenstone, 2007). In the area, poverty and degrada-

tion of natural resources are absolutely intertwined. On the one hand, the harsh poverty forces people to exhaust natural resources in their fight for survival, on the other hand, degraded natural resources worsen poverty (Jansen *et al.*, 2007). In general, the land, water resources and ecosystem of the valley have been affected by rapid population growth, deforestation, overgrazing and soil erosion (Bekele & Drake, 2003; Legesse *et al.*, 2004). This diverse climate change in the study area influences the livelihood activities of the farming community. However, farmers in the study area have been responding to climate change through various adaptation strategies. Nevertheless, there was no empirical data that substantiate or support the relationship between existing adaptation strategies practiced by the farmers in the area. The purpose of this study was, therefore, to identify the nature of the relationship that exist between the adaptation strategies that have been used by maize producing farmers of the CRV. Alongside this, the paper also analyzed the factors that jointly facilitate and impede the probability of choosing a particular adaptation strategy.

2 Hypothesis of the research

H1: Climate change adaptation strategies of smallholder maize producers of the Central Rift Valley of Ethiopia are interdependent and farmers adopt them as complements, substitutes or supplements.

H2: The decision by the maize producers of the Central Rift Valley of Ethiopia to adapt a climate change adaptation strategy is influenced significantly by the plot, household, socioeconomic, institutional and environmental characteristics.

3 Maize production in Ethiopia

Maize is the most widely distributed cereal crops in the world. According to The World Bank Group (2011), in developed countries 70 % of maize is destined for feed, 3 % is consumed directly by humans and the remaining is used for bio-fuels, industrial products and seed. While in SSA outside of South Africa, 77 % of maize is used as food and only 12 % serves as a feed. Maize covers 25 million ha in SSA, largely by smallholder farmers that produced 38 million tons in 2008, primarily for food. Despite the importance of maize in SSA, yields remain low (Shiferaw *et al.*, 2011). While

maize yields in the top five maize producing countries in the world (USA, China, Brazil, Mexico and Indonesia) have increased three-fold since 1961 (from 1.84 t ha^{-1} to 6.10 t ha^{-1}), maize yields in SSA have stagnated at less than 2 t ha^{-1}, (Cairns *et al.*, 2013).

In Ethiopia, maize accounts for the largest share of production by volume and is produced by more farms than any other crop. CSA (2012a) indicated that about nine million smallholders were involved in maize production in the 2011/12 production season. The same source also indicated that maize covered about 2.05 million ha of land at the national level that is equivalent to 21.43 % of the total area covered by all cereals. Out of this area, 30.64 % of the land was covered by improved seed varieties and 23.26 % and 27.7 % of the land had utilized organic and inorganic fertilizer, respectively. The total output of maize in the same year at national level was 60.69 million qt that is 32.27 % of the total cereal production in the same year.

Maize is more susceptible to climate change compared to other crops (Schlenker & Lobell, 2010). About 40 % of Africa's maize producing areas face irregular drought stress in which yield losses are 10–25 % and 25 % of the maize crop suffers recurrent drought, with losses of up to half the harvest (CIMMYT, 2013). The findings of Slingo *et al.* (2005) indicated that maize crops, tend to have the highest water requirement when the maximum leaf area index combines with the highest evaporative demand. Thus, maize crop is very susceptible to water shortfall during its critical period for two reasons: high water requirement in terms of evapotranspiration and high physiological sensitivity when determining its principal yield components such as the number of ears per plant and number of kernels per ear (Omoyo *et al.*, 2015). Specifically, in Africa, under non-drought conditions 65 % of the area that is under maize cultivation would experience yield losses from a uniform 1°C warming. Under drought conditions, this figure will increase to 100 %, with 75 % of this area suffering yield losses of at least 20 % (Lobell *et al.*, 2011a).

4 Methodology

4.1 Description of study areas

This study was undertaken in the Central Rift Valley Ethiopia (CRV), explicitly in Arsi-Negele district. Geographically, it is situated at 7° 09′–7°41′ N and 38° 25′–38° 54′ E. The study area covers three agro-ecological zones (low, mid and high land) based on temperature, rainfall, altitude and vegetation (ICRA, 2002). The temperature of the area ranges from 16°C to 25°C and an-

nual rainfall ranges between 500–1150 mm. The topography of the area is a gentle slope or flatter. Some parts of the highlands in the study area are covered by natural forest, bush and shrub. The main crops grown in the area include wheat, maize, *teff*, barley, sorghum, onion and potato. The rainfall of the area is a bimodal, with short rain occurring from February to April and the main rain from June to October. The short rain allows farmers to grow potato early and later replace by small cereals specifically wheat. Livestock are an important component of the farming system and a source of intermediate products in the district. The area is intensively cultivated and private grazing land is unavailable. Communal pasture and straw from crops are the main source of feed for livestock production. According to CSA (2012b), the district has a total population of 303,223 of which 150,245 are male and 152,978 are females.

4.2 Data sources and collection methods

A combination of purposive and random sampling techniques was employed to draw sample respondents for this study. Firstly, Arsi Negelle district was selected since it is one of the major maize producing areas in CRV. A two-stage random sampling technique was then applied to select sample households. In the first stage, three Kebeles namely, *Refu-Hargisa*, *Meko-Oda* and *Aliweyo* were selected from the district. In the second stage, 135 household heads were selected randomly using probability proportional to size. The data were collected by preparing and distributing semi-structured questionnaire. The schedule was first pre-tested; and based on the result of the pre-test some modifications were made on the questionnaire before the execution of the formal survey. Enumerators who are familiar with the study area, who can understand the local language and who have prior experience in data collection were recruited.

4.3 Methods of data analysis

Descriptive statistical tools and econometrics model were employed to analyze the collected data. Descriptive statistics such as mean, percentage and frequency were used to explain the different socioeconomic characteristics of the sample respondent households. In the econometrics part, Multivariate Probit model (MVP) was used to identify factors that are determining the choice of adaption strategies of farmers. This model was also used to examine the tradeoffs and complementarities that exist between the strategies that have been adopted by farmers. This technique simultaneously models the influence of the set of explanatory variables on
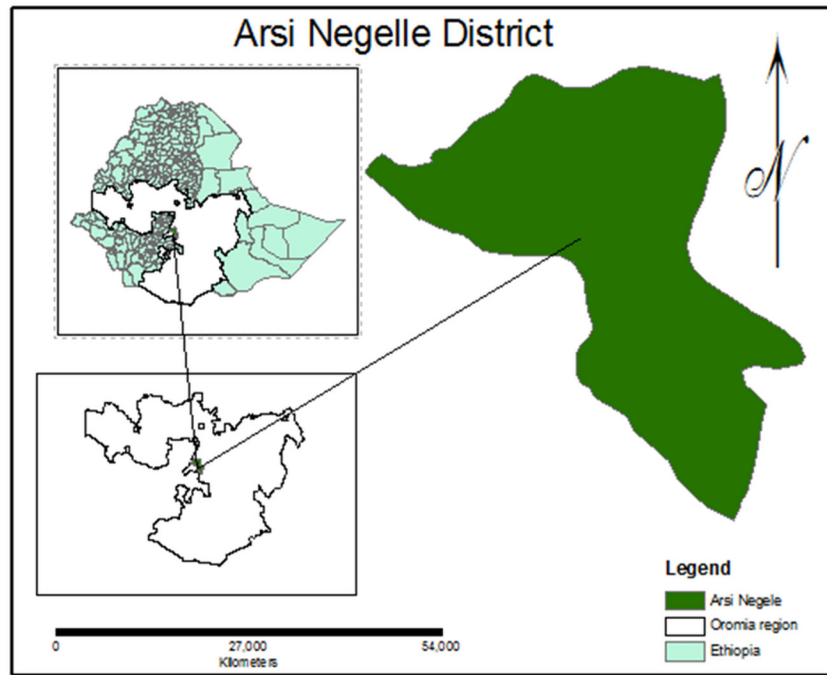
Fig. 1: *Location of the study area in Oromia Regional State of Ethiopia*

each of the different strategies while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the strategies of different practices (Kassie *et al.*, 2009). The results on correlation coefficients of the error terms indicate that there is complementarity (positive correlation) and substitutability (negative correlation) between different adaptation options being used by farmers. Failure to capture unobserved factors and interrelationships among adaptation strategies will lead to bias and inefficient estimates (Greene, 2008).

Following Lin *et al.* (2005), the MVP model for this study is characterized by a set of m binary dependent variables Y_{hj} such that:

$$Y_{hj}^* = X'_{hj}\beta_j + u_{hj} \quad \text{and} \quad (1)$$

$$Y_{hj} = \begin{cases} 1 & \text{if } Y_{hj}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Where $j = 1, 2 \ldots m$ denotes the type of adaptation strategy available; X'_{hj} is a vector of explanatory variables, β_j denotes the vector of parameter to be estimated, and u_{hj} are random error terms distributed as multivariate normal distribution with zero mean and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, Y_{hj}^* which captures the unobserved preferences or demand associated with the jth choice of adaptation strategy.

5 Results and discussion

5.1 Characteristics of the sample respondents

The mean age of the sample farmers was about 42 years with a range of 22 to 70 years (Table 1). On average, the sample respondents have cultivated maize for about 20 years. The family size of the sample respondents ranged from one to 13 with a mean of 5.73 persons per household. Concerning their literacy level, the mean educational level of sample respondents was 4.56. The minimum size of land cultivated by the respondents was 0.50 ha while the mean was 1.85 ha. On average, respondent farmers owned livestock of 8.46 TLU ranging from zero to 81.11 TLU. The survey result showed that 44 % of the sample farmers accessed credit from different sources.

All of the sample respondents reported that they received extension services though the frequency of contact differs. About 65 % of respondents have indicated that they had extensive contact on a weekly basis. While a nearly quarter of the sample respondents had contact with extension workers twice a month. Forty percent of respondents indicated that they have social responsibilities such as religious, administrative and/or community leadership roles. The mean distance from the nearest market to the homestead was 3.80 kilometres. On average, the plots are 0.84 kilometres far from homestead.

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Table 1: *Summary of the explanatory variables hypothesized to affect adaptation to climate change*

Variable	Mean	Std. Dev.	Min	Max
Age	42.46	11.21	22	70
Education	4.56	4	0	12
Family Size	5.73	2.24	1	13
Experience	20.3	10.63	2	50
Off/nonfarm income	460.12	1592.55	0	10800
Social responsibility	0.40	0.49	0	1
Size of cultivated land	1.85	1.25	0.50	7
Tropical Livestock Unit (TLU)	8.46	11.57	0	81.11
Extension contact	38.04	13.68	12	48
Credit	0.44	0.5	0	1
Distance to market	3.80	1.94	0.10	9
Plot to home distance	0.84	0.97	0.01	5

Source: Survey results

5.2 Climate change adaptation strategies

The sampled households were asked if they have used adaptation strategies to reduce the impact of climate change. Accordingly, they reported that they were using different adaptation strategies to reduce the negative impact of climate change. These include, use of improved crop varieties, soil conservation techniques, crop diversification and adjusting planting dates. These strategies, however, are mostly used in combination with one another (Table 2).

Table 2: *Summary of adaptation strategies used by farmers*

Adaptation strategies	Number of respondents (n= 135)	Percent *
Use of improved crop varieties	80	59.26
Adjusting planting date	79	58.52
Crop diversification	48	35.56
Soil conservation practices	56	41.48

Source: Survey results
* Percentage cannot be added to 100 as a farmer can have more than one adaptation strategy

One of the most commonly used adaptation options used to cope with the adverse effect of climate change in the study area is using improved crop varieties. About 60 % of farmers used improved crop varieties (such as drought resistant and short maturing varieties of crops) as adaptation strategy to reduce the adverse effect of climate change. Around 58 % of sample households used adjusting planting date (from early planting to late planting or vice versa) as adaptation strategy to reduce the adverse effect of climate change on their farm.

Crop diversification is also a common practice in the study area. From the total sampled households, 35.56 % of them used crop diversification as adaptation strategy to reduce the adverse effect of climate change on farm. Out of the total sampled households, 41.48 % of them also used soil conservation as adaptation strategy to reduce the adverse effect of climate change on farm.

5.3 Relationship between the climate change adaptation strategies

The results of the correlation coefficients of the error terms are significant for any pairs of equations indicating that they are correlated (Table 3). The correlation coefficients are statistically different from zero in 3 of the 6 cases, confirming the appropriateness of the MVP specification. The result of the model shows that the likelihood of households to adapt improved varieties of crops, adjusting planting date, use of crop diversification and soil conservation practices were 58.73 %, 57.72 %, 35.61 % and 41.15 %, respectively. The result also shows that the joint probability of using all adaptation strategies was only 7.74 % and the joint probability of failure to adopt all of the adaptation strategies was 14.56 %.

Table 3: *Correlation matrix of the adaptation strategies from the MVP model*

	Crop Diversification	Adjusting planting date	Improved crop varieties	Soil conservation
Rho2	0.22 (0.156)			
Rho3	0.32 (0.148) [**]	0.38 (0.142) [***]		
Rho4	–0.34 (0.156) [**]	0.11 (0.159)	0.18 (0.164)	
Predicted probability	0.3561	0.5772	0.5873	0.4115
Joint probability (success)	0.0774			
Joint probability (failure)	0.1456			
Log likelihood	–278.86			
Likelihood ratio test of $Rho_{ij} = 0$, $P > \chi^2(6)$	0.0011			

Numbers in the parentheses are standard errors
[***] and [**] significant at 1 % and 5 % probability level, respectively.

The Simulated Maximum Likelihood estimation of the MVP results suggested that there was positive and significant interdependence between household decisions to adapt crop diversification and using improved varieties of crops; and between adjusting planting date and using improved crop varieties. The Simulated Maximum Likelihood estimation results also suggested that there was negative and significant interdependence between household decisions to adapt crop diversification and soil conservation practices.

5.4 Determinants of farmers' choice of adaptation strategies

Though farmers adopt a combination of strategies to reduce the impact of climate change, there would be a number of factors that can influence their decision to choose a particular strategy. This section has identified those variables, which determine the use of various adaptation strategies using MVP (Table 4). The selection of those explanatory variables for the model was done through literature review. The results of the model shows that the adaptation decisions of households to different strategies are quite distinct and largely factors governing the adaptation decision of each of them are also different indicating the heterogeneity in the adaptation strategies.

The square of age of the household head was found to have an inverse relationship with crop diversification strategy. Thus, middle age farmers are more interested in crop diversification strategy than the very young and older ones. Since farming as any other professions need to accumulate knowledge, skill and physical capability, it is decisive in determining the right cropping portfolio. The knowledge, the skills as well as the physical capability of farmers are likely to increase as their age increases. However, this tends to decrease after a certain age level. Moreover, older farmers may be more interested in following traditional methods that are familiar to them rather than adapting new practices (Acquah, 2011; Quayum & Ali, 2012).

The educational level of household head was found to have positive and significant relation with the use of crop diversification and adjusting time adaptation strategies. This result showed that education increases the awareness of farmers about the consequence of climate change on productivity and the benefit of crop diversification and adjusting of planting time to reduce the impact of climate change. This finding is in line with the investigation of Deressa *et al.* (2008), Uddin *et al.* (2014) and Zuluaga *et al.* (2015).

The model result showed that family size has negative and significant impact on the likelihood of using improved crop varieties and soil conservation as adaptation strategy to reduce the negative impact of climate change. The possible reason for the inverse relationship between family size and using improved crop varieties is that increase in family size would increase expenditure for home consumption and creates financial constraints for other inputs such as improved crop varieties. This finding is in line with the investigation of Tazeze *et al.* (2012) and Zuluaga *et al.* (2015).

Table 4: *Multivariate probit simulation results for households' climate change adaptation decisions*

Variables	Crop Diversification		Adjusting planting date		Improved crop varieties		Soil Conservation	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age^2	0.0006 **	0.0003	–0.0005	0.0003	–0.0002	0.0003	–0.0003	0.0003
Education	0.1645 ***	0.0353	0.0628 *	0.0328	0.05068	0.03246	–0.0099	0.0306
Family size	–0.0792	0.0666	–0.0962	0.0651	–0.10692 *	0.06244	–0.1284 **	0.0627
Experience	–0.0162	0.0272	0.0646 **	0.0287	0.02203	0.02748	0.0269	0.0267
Off/nonfarm income	0.0001	0.0001	–0.0001	0.0001	0.00002	0.00009	0.0001	0.0001
Social responsibility	–0.8033 ***	0.2892	–0.4880 *	0.2701	–0.0264	0.25903	–0.6041 **	0.266
Cultivated land	–0.27	0.18	–0.0447	0.1805	–0.2185	0.17194	0.1404	0.1596
Tropical Livestock Unit (TLU)	0.025	0.0184	0.012	0.0181	0.04358 *	0.02386	0.0081	0.0172
Extension contact	0.0842	0.1296	0.5037 ***	0.1387	0.50489 ***	0.12766	0.1487	0.1252
Credit	0.5112	0.2738	0.5347 **	0.2646	0.0387	0.25839	0.0349	0.2554
Distance to market	–0.104	0.068	–0.1733 **	0.0737	–0.0337	0.06635	0.2401 ***	0.0638
Plot to home distance	–0.0689	0.1334	–0.5577 ***	0.1862	–0.31852 **	0.15236	–0.1851	0.1664
_cons	–1.1518	0.6432	–0.3176	0.6873	–0.4767	0.62627	–0.8194	0.6182

Log likelihood = –272.76792; Prob > χ^2 = 0.0000

***, **, and * significant at 1 %, 5 %, and 10 % probability level, respectively.

The negative relation between family size and soil conservation adaptation strategy may be due to the fact that households with larger family size may be forced to switch part of the labor force to off-farm or non-farm activities in an effort to earn income in order to ease the consumption pressure imposed by a large family. This finding is in line with the finding of Legesse *et al.* (2013).

An increase in the experience of a household head has positive relationship with adjusting planting dates. This is because as the farming experience of the household head increases, the farmer is expected to acquire more experience in weather forecasting. Therefore, they can easily adjust themselves to climate change stresses. This result is consistent with Hassan & Nhemachena (2008).

The results also indicated that frequency of extension visit to the households has a positive and significant impact on adjusting planting date and use of improve crop varieties. An extension service is an important source of information on climate change as well as agricultural production and management practices in the country (Nhemachena & Hassan, 2007). This implies that

farmers with more access to information and technical assistance on agricultural activities have more awareness about the consequence of climate change. This result is consistent with Nhemachena & Hassan (2007), Deressa *et al.* (2009), Deressa *et al.* (2011), Di Falco *et al.* (2011), Fosu-Mensah *et al.* (2012) and Zuluaga *et al.* (2015).

Distance from the market center is associated with soil conservation and use of adjusting planting date as an adaptation strategy with opposite signs. The negative relation between market distance and adjusting planting dates as adaptation strategy is plausible because the market serves as a means of exchanging information with other farmers (Maddison, 2007). Better access to market enable farmers to obtain information on climate change and other important inputs they may need if they are to change their practices to cope with predicted changes in future climate. When farmers are far from the market, the transaction cost for acquiring input will be high, and this will in turn, reduce the relative advantage of adapting new technologies/ strategy. This finding is in line with the investigation of Tazeze *et al.* (2012).

The positive relationship between soil conservation strategy and distance to the market implies farmers who are far from the market choose soil conservation strategy and this may be due to the fact that as the farmer become far from the market, getting inputs such as improved seed from the market become costly for them. This will force them to choose labor-intensive adaptation measures such as soil and water conservation. The other reason for this relationship may be since they are far away from the market, they will have less opportunities to participate in off-farm or non-farm activities, which will in turn allow them to invest in labor-intensive adaptation measures such as soil and water conservation.

Distance between the farm where maize was cultivated and the residence of the respondents was found to have a negative relation with adjusting planting date and using improved crop varieties as adaptation strategies to mitigate the impact of climate change. This is reasonable because as the farm becomes far from the homestead it will receive less attention as the farmer requires longer time to visit the farm and manage it properly.

Livestock ownership is an important variable affecting adaption decision at the farm level. The ownership of livestock of the households has a positive and significant impact on use of improved crop varieties as adaptation strategy. The possible reason could be if the farmer possesses more number of livestock will have better capacity to purchase agricultural inputs as income obtained from livestock serves for investment on crop production. The result is in line with the finding of Deressa *et al.* (2011) and Okonya *et al.* (2013).

The results also indicated that access to credit has a positive and significant impact on the likelihood of adjusting planting date. With more financial and other resources at their disposal, farmers are able to change their management practices in response to changing climatic and other factors and are better able to make use of all the available information they might have on changing conditions both climatic and other socioeconomic factors. The finding is in line with the investigation of Nhemachena & Hassan (2007), Deressa *et al.* (2011), Di Falco *et al.* (2011), Fosu-Mensah *et al.* (2012), Temesgen *et al.* (2014) and Zuluaga *et al.* (2015).

Meanwhile, social responsibility was found to have an inverse relation with crop diversification, adjusting cropping date and soil conservation. This is plausible because household who spent more time on social responsibility may not carry out major farm activities on time.

6 Conclusion and policy implications

The study attempted to identify factors affecting the choice of climate change adaptation strategies used by maize producing farmers of CRV based on data collected from 135 sampled households. Adaptation strategies used by farmers in the study area include adjusting planting date, use of soil conservation techniques, use of improved crop varieties and crop diversification.

This study examined determinants of household level climate change adaptation strategies using MVP model. The model allows the simultaneous identification of the determinants of all adaptation options, thus limiting potential problems of correlation between the error terms. Correlation results between the error terms of different equations were significant indicating various adaptation strategies tend to be used by households in a complementary or substitute fashion. The results of the model showed that the likelihood of households to adapt improved varieties of crops, adjust planting date, use crop diversification and soil conservation practices were 58.73 %, 57.72 %, 35.61 % and 41.15 %, respectively. The results also showed that the joint probability of using all adaptation strategies was only 7.7 % and the joint probability of failure to use all of the adaptation strategies was 14.56 %.

The model results also confirmed that square of the age of the farmers, educational level of the household head, family size, maize production experience, size of Livestock units, frequency of extension contact, credit utilization, social responsibility, distance to the nearest market and distance between plot and home have significant impact on the choice of farmers' climate change adaptation strategies.

Thus, the results of the study provide information to policy makers and extension workers on how to improve farm level adaptation strategies and identify the determinants for adaptation strategies. These findings stress the need for appropriate policy formulation and implementation which enables farmers to reduce the impact of climate change as this is expected to have multiplier effects ranging from farm productivity growth to economic growth and poverty reduction at the macro level.

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Appendix Table 1: *Conversion factors used to estimate tropical livestock unit (TLU) equivalents*

Animal Category	TLU
Calf	0.25
Donkey (young)	0.35
Weaned Calf	0.34
Camel	1.25
Heifer	0.75
Sheep and Goat (adult)	0.13
Cow and Ox	1
Sheep and Goat (young)	0.06
Horse	1.1
Chicken	0.013
Donkey (adult)	0.7

Source: Storck *et al.* (1991)