Climate change perception and choice of adaptation strategies

Empirical evidence from smallholder farmers in east Ethiopia

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Received 27 January 2014
Revised 22 September 2015
Accepted 27 September 2015

Abstract

Purpose – The purpose of this paper is to analyze smallholder farmers' perceptions of climate change and its adverse effects, identify major adaptation strategies used by farmers and analyze the factors that influence the choice of adaptation strategy by smallholder farmers in eastern Ethiopia.

Design/methodology/approach – The study was based on a cross-sectional survey of 296 sample households selected from three districts in east Ethiopia. Data were collected with the aid of a semi-structured questionnaire and review of literature, documents and databases.

Findings – The study provides empirical evidence that majority of farmers in the study area are aware of climate change patterns and their adverse effect on income, food security, diversity, forest resources, food prices and crop and livestock diseases. In response to these adverse effects, major adaptation strategies used by farmers include cultivating different crops, planting different crop varieties, changing planting dates, use of soil and water conservation techniques, conservation agriculture practices and engaging in non-farm income activities. Choice of adaptation strategies are influenced by gender of household head, household size, farm size, distance from market and number of farm plots.

Practical implications – The study suggests that developing more effective climate change adaptation strategies need support from the government. Such an effort needs provision of the necessary resources such as credit, information and extension services on climate change adaptation strategies and technologies, and investing in climate smart and resilient projects.

Originality/value – The study adopts multivariate probit model that models farmers' simultaneous adaptation choice behavior which has been rarely addressed by previous researches.

Keywords Climate change, Ethiopia, Multivariate probit, Perception, Adaptation

Paper type Research paper

1. Introduction

Evidence has showed that the global climate is changing and that greenhouse gases emissions are growing alarmingly (Maarten, 2007), leading to rise in the earth's temperature. This, intermingled with rapid population growth, threatens food and livelihood security for a large number of people, especially those in the developing countries. Increasing temperatures, declining and more unpredictable rainfall, more frequent extreme weather and higher severity of pests and diseases are among the drastic changes that impact food production (Parry *et al.*, 2007; Kotschi, 2007, Morton, 2007; Brown and Funk, 2008; Lobell *et al.*, 2008). Quantitative assessments also show that the most profound and direct impacts of climate change over the next few decades

International Journal of Climate Change Strategies and Management
Vol. 8 No. 2, 2016
pp. 253-270

1756-8692
DOI 10.1108/IJCCSM-01-2014-0017

will be on agriculture and food systems, and the poorest will be at risk (Brown and Funk, 2008; Schmidhuber and Tubiello, 2007). The most important adverse effects of climate change will be felt among smallholder farmers in developing countries (Morton, 2007). Developing nations, especially those in sub-Saharan Africa, will be more vulnerable to the effects of climate change because of their geographical and climatic conditions, high dependence on agriculture- and natural resources-driven activities and weak adaptive capacity to the changing climate (Eriksen *et al.*, 2008).

Ethiopia can be cited as a good example of a developing country whose economy is highly influenced by climate change (Negash, 2013). The country's economy is dominated by subsistence agriculture actor that plays the dominant role in the economic development of the country, accounting for about 42 per cent of the gross domestic product (MoFED, 2010). The nature-dependent agricultural sector of the economy, mingled with the country's geographical location, topography and low adaptive capacity, made the country highly vulnerable to adverse effects of climate change (Negash, 2013). The country has been historically suffering from natural catastrophes and is prone to extreme weather events. Rainfall in Ethiopia is highly erratic, and most rainfalls intensively, often as convective storms, with very high rainfall intensity and extreme spatial and temporal variability. Hence, food production has failed to keep up to high population growth rates, resulting in high levels of food insecurity. Decreasing farm size, decline in soil fertility, severe land degradation, fragile ecosystems and recurrent weather-induced shocks, such as drought, are the main causes of food production deficits and of high livelihoods vulnerability, especially in the densely populated areas in the eastern highlands.

Climate change adaptation has the potential to significantly contribute to reductions in negative impacts from changes in climatic conditions. Hence, adaptation measures are important to help vulnerable communities to better face extreme weather conditions and associated climatic variations. Despite the importance of the issue, there are a few empirical studies conducted in Ethiopia on farmers' perception of climate change and adaptation measures. Although some efforts are exerted to examine farmers' perception of climate change and farmer's choice of adaptation strategies to climate change in some place of the country, empirical work is scanty in east Ethiopia. Although farmers mostly apply strategies in combination with other strategies, previous studies failed to address this gap. There is, therefore, a need for a better understanding of farmer perceptions of long-term climatic changes, adaptation measures and factors influencing simultaneous choice of adaptation strategies. Knowledge on the adaptation methods and factors affecting farmers' choices of adaptation strategies will help in designing policies to tackle the challenges that climate change is imposing on Ethiopian farmers.

2. Research methodology

2.1 The study area

The study is conducted in eastern Hararghe zone, Oromia regional state of Ethiopia. The zone has a complex agroecological area in which heavy population density, high ratio of cash to food crops, unpredictable rainfall and significant differences between the agricultural practices within the three main altitude zones create a complicated agricultural profile and, at the same time, support a population that is in general highly vulnerable to food insecurity. Food shortages are often difficult to detect, as green fields tend to mask vulnerability, and pockets of extreme hunger may exist literally a few kilometers from areas of relative food stability. Fedis, Kersa and Babile districts were the focus of the study.

2.2 Data type and sources

Data used in this analysis were collected from a household survey conducted in Kersa, Babile and Fedis districts of east Hararghe zone. The districts have been chosen to take a representative sample for the study. Data were gathered at the household level on socio-economic and demographic characteristics, institutional and market characteristics, sources of income and livelihoods, crop production, geographic features, climate change perceptions and adaptation strategies. Secondary data were collected from district agricultural offices through desk review.

2.3 Sampling design

A multi-stage sampling technique was used to randomly select 296 households from the three districts. The selection of the districts was through purposive sampling taking into consideration the agroecological setting, location in the district, food security condition and farming system. Sample frame list was obtained from the district extension offices. Second, 14 rural villages (5 from Kersa, 4 from Babile and 5 from Fedis) were randomly selected from the two districts. Finally, proportional sample was taken from each village using a probability proportional sampling method.

2.4 Methods of data collection

Primary data were collected with the aid of a semi-structured household questionnaire (interview schedule). Before the actual survey, the questionnaires were pre-tested. For the data collection, enumerators were used and trained on the ways they approach the respondents and execute the interview. Secondary data were collected through desk review and review of empirical literature and databases.

2.5 Methods of data analysis

Data analysis was carried out using descriptive statistics and econometric models accompanied by SPSS and Stata statistical packages. Descriptive statistics tools such as mean, standard deviation and percentages were used to analyze and present socio-economic characteristics, perception of climate change and its adverse effects and climate change adaptation strategies. Analysis of variance, *t*-test, χ^2 (chi-square) and mean comparison tests were run to compare groups with respect to variables of interest.

2.5.1 Econometric model specification. Previous studies in Africa have used various empirical methods to analyze the determinants of adaptations to climate change and choice of adaptation strategies. Most commonly used analytical approaches in the literature include discrete choice regression models like binary probit or logit (Acquah-de Graft and Onumah, 2011; Fosu-Mensah *et al.*, 2010), multinomial probit or logit and multivariate probit (Hassan and Nhemachena, 2008; Deressa *et al.*, 2008; ACCCA, 2010; Sofoluwe *et al.*, 2011; Nzeadibe *et al.*, 2011; Aemro *et al.*, 2012). Other empirical studies used principal component analysis (Mandleni and Anim, 2011) and the Ricardian model (Kurukulasuriya and Mendelson, 2006). By nature, farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate-induced risks and constrains than a single strategy. A shortcoming of most of the previous studies on modeling choice of climate change adaptation strategies is that they do not consider the possible inter-relationships between the various strategies (Yu *et al.*, 2008). These studies mask the reality faced by decision-makers who are often faced with alternatives that may be adopted simultaneously and/or sequentially as complements, substitutes or supplements.

Some recent empirical studies of technology adoption and climate adaptation decisions assume that farmers consider a set possible practices and choose the particular practice bundle that maximizes expected utility (Marenya and Barrett, 2007; Nhemachena and Hassan, 2007; Yu *et al.*, 2008; Kassie *et al.*, 2009). Thus, the adoption decision is inherently multivariate and attempting univariate modeling excludes useful economic information contained in interdependent and simultaneous adoption decisions. Based on this argument, the study adopted multivariate probit econometric technique to simultaneously model the influence of the set of explanatory variables on major adaptation strategies (Belderbos *et al.*, 2004; Lin *et al.*, 2005). The study is based on the premise that there will be complementarity and/or substitutability between different strategies (Belderbos *et al.*, 2004).

The dependent variable in the empirical estimation for this study is the choice of an adaptation option from the set of adaptation measures (cultivating different crops, planting different varieties, changing planting dates and soil and water conservation measures). Following Lin *et al.* (2005), the multivariate probit econometric approach for this study is characterized by a set of n binary dependent variables y_{hpj} such that:

$$y^*_{hpj} = x'_{hpj}\beta_j + u_{hpj} \quad j = 1, 2, \ldots, \text{m. and} \tag{1}$$

$$y_{hpj} = \begin{cases} 1 & if \;\; y^*_{hpj} > 0 \\ 0 & otherwise \end{cases} \tag{2}$$

where $j = 1, 2, \ldots,$ m denotes the climate change adaptation strategies available; x'_{hpj} is a vector of explanatory variables; β_j denotes the vector of parameter to be estimated; and u_{hpj} are random error terms distributed as multivariate normal distribution with zero means and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, y^*_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term.

Given the latent nature of the variable y^*_{hpj}, the estimation is based on the observable variable y_{hpj} which indicates whether or not a household adopt a particular climate adaptation strategy. As adoption of several adaptation strategies is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity. The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic component of the j^{th} and m^{th} type of adaptation strategies. This assumption means that equation (2) gives a multivariate probit model that jointly represents decisions to adopt a particular adaptation strategy. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative adaptation strategies.

3. Results

3.1 Characteristics of the sample households

There is a statistically significant difference in gender of the household head, livestock owned, land owned, asset, farm income, number of crops grown, number of farm plots operated and number of trees planted on farms among households in the three sample districts. These characteristics are likely to cause differences in the choice of climate change adaptation strategies by households in these districts (Table I).

There is a statistically significant difference in membership in farmers' organizations, access to training, off-farm income, credit, fertilizer and chemical use, veterinary services and other institutional settings in the study districts. These are also likely to cause difference in the choice of climate change adaptation strategies in these districts (Table II).

3.2 Perception of climate change and its effects

Sample farmers were asked whether they had noticed any significant climate changes over the past 10-20 years. Results showed that, from the sampled households, more than 95 per cent perceived changes in temperature (especially rise in average temperature), although there is no statistically significant difference among districts. About 86 per cent of the respondents perceived decrease in precipitation over the years. On the other hand, more than 95 per cent of the respondents perceived that rainfall has become more unreliable (Table III).

Farmers were also asked to highlight the effects of climate change on their livelihoods. The result uncovers that effect of climate change is district (location) specific. In general, the effect of climate change is significant in Kersa and Fedis districts than in Babile. In these districts, climate change is reported to have a significant adverse effect on food security, income, livelihood, natural resources, crop yield, biodiversity, food prices and other variables (Table IV).

Another commonly mentioned impact of climate change is on agricultural production such as crop failure and outbreak of crop and animal diseases. Increased pests and crop diseases leading to crop failures and reduced crop production are common in countries and areas where arable farming is predominant (Yesuf *et al.,* 2008; Akponikpe *et al.,* 2010; Nzeadibe *et al.,* 2011; Gandure *et al.,* 2013). Livestock farmers reported that climate change and climate variability have led to decreased livestock weight and an increase in livestock death due to livestock disease.

Characteristics	Description	Kersa	Fedis	Babile	Total	F/χ^2
Gender of household head	Male (%)	79.8	92.9	85.1	85.8	7.11*
Age of household head	Years	38.20	36.38	38.32	37.64	1.84
Farming experience	Years	21.34	20.45	21.85	21.21	0.80
Family size	Number of persons	5.43	5.43	5.95	5.59	3.11
Household size	Adult equivalent	4.39	4.22	4.62	4.41	2.14
Education status of head	None (%)	60.6	69.4	58.5	62.8	13.29
	Primary (1-4)	16.3	17.3	28.7	20.6	
	Secondary (5-8)	18.3	12.2	11.7	14.2	
	High school and above	4.8	1.0	1.1	2.4	
Livestock owned	TLU	2.55	2.78	11.28	5.40	71.46*
Land owned	Ha	0.55	0.75	1.81	1.02	102.2
Asset value	Birr ('000)	11.97	22.24	34.69	22.60	25.73*
Farm income	Birr ('000)	8.762	4.066	26.803	14.168	82.56*
Marketed surplus	% of production	23.51	15.12	22.29	20.84	4.81***
Farm plots owned	Count	2.43	1.84	2.60	2.27	10.84***
Crops grown	Count	3.36	3.08	3.73	3.39	14.94***
Trees planted on farms	Count	82.59	5.01	501.2	203.43	2.89*

Table I. Summary of household characteristics

More than 70 per cent of the sample households indicated that climate change has a negative effect on environmental and natural resources causing decline in soil fertility, decline in forest resources and changes in biodiversity. Drought is reported to be severe in Kersa (about 80 per cent) and Fedis (about 74 per cent) districts which are fragile areas in the zone and affected by long-standing structural deficiencies (Piguet, 2003). Generally, farmers have agreed that lack of rainfall for an extended period caused drought which have damaging nature. Empirical studies in East Africa also showed

Table II. Institutional characteristics of sample households

Characteristics	Description	Kersa	Fedis	Babile	Total	F/χ^2
Farmer organization	% (member)	51.0	58.2	20.2	43.5	35.042***
Access to training	% (access)	91.3	81.6	73.4	82.4	11.04***
Climate information	% (access)	80.8	74.5	70.2	75.3	3.018
Social safety nets	% (yes)	42.3	51.0	40.4	44.6	2.519
Off-farm income	% (yes)	22.7	12.5	64.8	29.7	64.54***
Access to credit	% (access)	46.2	33.7	33.0	37.8	4.724*

Table III. Smallholder famer's perception of climate change

	% of respondents				
Climate change indicators	Kersa	Fedis	Babile	Pooled	χ^2
Temperature is changing	98.1	99.1	94.7	97.6	6.78
Temperature is rising	99.0	99.0	95.7	98.3	7.54
Weather is getting drier	90.4	98.2	88.3	92.9	12.28***
Precipitation is reduced	80.8	99.2	77.7	86.1	41.77***
Rainfall pattern is changing	99.0	99.4	89.4	96.3	18.70***

Table IV. Smallholders' perception of effects of climate change

	% of respondents who perceive				
Perceived effect	Kersa	Fedis	Babile	Total	χ^2
Plant date changes	92.3	89.8	68.1	83.8	25.734***
Rainfall do not support production	93.3	85.7	56.4	79.1	53.254***
Crop and animal disease outbreaks	93.3	85.7	85.1	88.2	6.116
Crop failure	87.5	61.2	53.2	67.9	45.53***
Forest resource decline	90.4	91.8	66.0	83.1	37.592***
Crop diversity changes	83.7	94.9	87.2	88.5	8.227***
Reduced soil fertility	90.4	75.5	35.1	67.9	98.441***
Frost, hails and heavy rains	73.1	50.0	30.9	52.0	40.05***
Flooding problem increased	78.8	49.0	28.7	53.0	68.869***
Increased incidence of drought	80.8	73.5	45.7	67.2	33.786***
Fuel scarcity	95.2	76.5	54.3	76.0	49.508***
Livelihood changes	93.3	88.8	58.3	80.7	44.897***
Poverty and food insecurity increased	96.2	89.8	74.5	87.2	22.927***
Gap between poor and rich widens	97.1	78.6	62.8	80.1	40.554***
Migration aggravated	94.2	74.5	76.6	82.1	20.568***
Income decline	95.2	92.9	75.5	88.2	22.719***
High food costs	91.3	90.8	60.6	81.4	57.601***

similar results (ACCCA, 2010; Mengistu, 2011; Gandure *et al.*, 2013). In sum, the majority of the respondents in the study area perceived that changes had adverse effects on their livelihood. In response, farmers have adopted adaptation measures or coping mechanisms to dampen the adverse effects of climate change.

3.3 Climate change adaptation strategies

Farmers adopt different practices which will reduce variability on economic livelihoods and food security. The major climate change adaptation strategies used by the farmers in the study areas include planting different crop varieties, cultivating different crops, soil and water conservation measures and changing planting dates. Other strategies including expanding land under crop production, use of chemical fertilizer, irrigation, seeking off-farm income sources and conservation agriculture practices (mulching, changing rotations and tillage practices) are reported by few farmers as important adaption strategies. Aemro *et al.* (2012) and Belaineh *et al.* (2013) reported same results. Owing to the differences in institutional settings, resource endowments and agroecology, different set of strategies are found to be effective in different districts (Table V).

3.4 Factors influencing households' choice of adaptation strategies

The study identified the important determinants of adoption of various adaptation measures using a multivariate probit model to provide policy information on which factors to target and how. The likelihood ratio test of the independence of the disturbance terms (independence of choice of multiple adaptation strategy) is strongly rejected, implying that the choice of multiple adaptation strategies is not mutually independent and supporting the use of a multivariate probit model. Results of the correlation analysis between the error terms indicate that there is complementarity (*positive correlation*) and substitutability (*negative correlation*) between different adaptation options being used by farmers. The correlation coefficients are statistically significant in five of the six cases (Table VI).

Farmers' decision to cultivate different crops as climate change adaptation strategy is influenced by gender of the household head, access to credit, distance from market, extension contact, access to social safety nets, farm size, number of farm plots and number of crops grown. Only a few factors influence whether farmers change crop variety as an adaptation option. Distance from market is found to favor the adoption of planting different crop variety as an adaptation strategy. Choice of changing planting

Adaptation strategy	Kersa	Fedis	Babile	Total
Planting different crop varieties	22.5	23.5	34.0	26.4
Cultivating different crops	28.8	18.4	13.8	20.6
Expanding land under crop production	12.5	0.0	0.0	4.4
Changing to irrigation	1.0	0.0	9.6	3.4
Use of chemical fertilizer	2.9	3.1	1.1	2.4
Changing planting dates	13.5	1.0	0.0	5.7
Changes in tillage and rotation practices	0.0	0.0	0.0	0.0
Mulching	0.0	2.0	0.0	0.7
Soil and water conservation measures	19.2	52.0	39.4	36.5
Leave farming or migration	0.0	0.0	2.1	0.7

Table V. Households' climate change adaptation strategies (% of respondents by ranks of a strategy) dates as a climate change adaptation strategy is determined by few variables (household size, fertilizer use, market distance, number of farm plots and agroecology). Household size, distance from market, social safety net, per capita income, number of plots and farm size influenced adoption of soil and water conservation in response to perceived climate change. Adoption also varies by districts and agroecology.

4. Discussions of findings

Results in general revealed that farmers in east Hararghe are aware that there is a significant change in climate change pattern. The result is supported by other studies in sub-Saharan Africa and Ethiopia (Nhemachena and Hassan, 2007; Yesuf *et al.*, 2008; Deressa *et al.*, 2008; Gbetibouo, 2009; Apata *et al.*, 2009; Mertz *et al.*, 2009; Fosu-Mensah *et al.*, 2010; Akponikpe *et al.*, 2010; Mandleni and Anim, 2011; Bryan *et al.*, 2011; Sofoluwe *et al.*, 2011; Nyanga *et al.*, 2011; Acquah-de Graft, 2011; Gandure *et al.*, 2013; Ogalleh *et al.*, 2012; Juana *et al.*, 2013).

4.1 Climate change adaptation strategies

The most common practices reported in empirical studies include cultivating different crops, changing crop variety, changing planting and harvesting dates, planting trees, irrigation, off-farm income diversification, conservation agriculture and soil and water conservation (ACCCA, 2010; Bryan *et al.*, 2011; Juana *et al.*, 2013).

4.1.1 Cultivating different crops. One of the possible adaptation strategies to climate change is to switch crops to something better suited to the new climates they face. Crop diversification has been identified as a potential farm-level adaptation to climatic change and variability (Smit and Wandel, 2006; Bradshaw *et al.*, 2004; Speranza, 2006). When climate changes, farmers could also switch what crops they grow because farmers' choices about what crops to grow depend on the climate. The highly variable climates of much of Africa induce poor risk-averse farmers to grow lower value but drought-tolerant crops such as cassava. In the study, about 29 per cent of the sample farmers in Kersa, 18 per cent in Fedis districts and about 14 per cent in Babile district selected cultivating different crops as the first important climate change adaptation strategy. The highest percentage in Kersa district indicates that crop diversification is common in mid-highland areas because they can choose crops which suit new climates and the lower percentages in relatively hotter areas (Fedis and Babile districts) shows that hot areas will not have alternatives to switch crops. The result is supported by Ogalleh *et al.* (2012), Degye *et al.* (2012), Wondimagegn *et al.* (2011) and Belaineh (2003).

4.1.2 Switching crop varieties. Beyond shifting among crops, farmers could also switch what varieties of crops they grow as the climate changes. Growing drought-tolerant crop varieties is an important adaptive strategy practiced by farmers in developing countries. Planting different crop varieties was ranked first by about 23 per cent of the sample farmers in Kersa and Fedis districts and 34 per cent in Babile. This result signifies that changing crop variety is a feasible climate change adaptation option in hotter areas such as Fedis and Babile. The result is consistent with the findings of Ogalleh *et al.* (2012).

Climate change suggests two primary adaptation alternatives for planting different varieties, the choice of which depends on whether moisture or heat is expected to be limiting. In low-rainfall areas such as Fedis where moisture stress is expected to remain a primary constraint on plant growth, a promising adaptation might be to plant faster-maturing varieties that avoid drought or heat stress during sensitive stages of plant growth.

Table VI. Coefficient estimates for the multivariate probit model

Variables	Different crop type		Different crop variety		Changing planting dates		Soil and water conservation	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Gender of head	−0.6094**	0.2874	0.6093**	0.2533	−0.1116	0.2532	−0.2029	0.3206
Education status	0.2807	0.1908	0.1203	0.1798	0.2419	0.1758	0.0768	0.2277
Farming experience	−0.0115	0.0129	−0.0131	0.0112	0.0175	0.0123	−0.0176	0.0145
Household size	0.0573	0.0740	−0.0464	0.0708	−0.1336*	0.0716	0.1611*	0.0828
Farmer organization	0.0840	0.1926	−0.0320	0.1800	−0.1385	0.1848	−0.0452	0.2278
Climate information	−0.0196	0.2132	−0.1932	0.2142	0.1383	0.2100	0.1185	0.2495
Fertilizer use	0.4505	0.2979	0.1068	0.2715	1.0392***	0.2907	0.1429	0.3487
Chemical use	−0.2818	0.2377	−0.0648	0.2170	−0.2667	0.2116	0.9694***	0.2874
Credit access	0.3336*	0.2000	0.1785	0.1953	0.1406	0.1906	−0.0961	0.2375
Off-farm income	−0.1442	0.2553	0.2694	0.2405	−0.0638	0.2428	0.0446	0.2944
Market distance	0.0431*	0.0220	0.1058***	0.0244	0.0624***	0.0207	−0.4145***	0.1015
Extension contact	−0.0044*	0.0023	−0.0004	0.0025	0.0014	0.0023	0.0003	0.0034
Social safety nets	−0.5669***	0.1848	0.0129	0.1793	0.0652	0.1758	0.4028*	0.2132
Per capita income	−7.95e-6	0.0000	−0.0001	0.0001	−1.2-e5	0.0001	−0.0001*	0.0001
Farm plots	0.4188***	0.1040	−0.0356	0.0855	0.1703*	0.0872	−0.2243**	0.1019
Farm size	−0.5287***	0.1859	0.1585	0.1949	−0.2425	0.1677	0.4734*	0.2784
Land fertility status	0.2734	0.1997	0.3054*	0.1841	−0.1307	0.1855	0.1155	0.2353
Crops grown	0.5429***	0.1258	−0.0889	0.1187	0.0501	0.1162	−0.0848	0.1331
Marketed surplus	−0.0113	0.0064	0.0024	0.0061	−0.0021	0.0058	−0.0238***	0.0084
Livestock holding	−0.0167	0.0182	−0.0128	0.0185	0.0063	0.0154	0.0217	0.0445
Fedis	−0.9267**	0.4666	0.5958	0.4606	1.4469***	0.4642	0.6238	0.6457
Kersa	2.2189***	0.6773	−0.2363	0.6187	2.0621***	0.6240	−0.1675	0.7929
Mid-highland	1.1707***	0.4265	1.1165***	0.4003	−1.4643***	0.4127	−1.8695***	0.4435
Constant	−1.0121	0.7682	−1.1519	0.7527	−2.2334***	−0.7543	2.7925**	1.1040

(*continued*)

Table VI.

Variables	Different crop type		Different crop variety		Changing planting dates		Soil and water conservation	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Correlation								
$\rho 21$	−0.45***	0.108						
$\rho 31$	0.23**	0.108						
$\rho 41$	−0.48***	0.126						
$\rho 32$	−0.32***	0.103						
$\rho 42$	−0.24*	0.132						
$\rho 43$	−0.09	0.142						
Predicted probability	0.60	0.016	0.56	0.016	0.45	0.014	0.47	0.022
Joint probability (success)	0.018	0.002						
Joint probability (failure)	0.014	0.002						
Number of observations						296		
Number of simulations						5		
Log likelihood						−536.35		
Wald χ^2 (95)						288.48		
Probability $> \chi^2$						0.0000		
Likelihood ratio test of $\rho_{ij} = 0, p > \chi^2 (6) = 46.16$						0.000		

Note: ***, ** and * indicate significance at 1, 5 and 10% levels, respectively

Developing such kind of varieties for areas with short and variably rainy seasons (i.e. much of Africa) is a common goal of many breeding programs, and such a strategy would seem promising anywhere climate change is expected to shorten growing seasons.

In areas where moisture regimes exhibit little change, a move growing longer-maturing varieties might be preferred because warmer temperatures tend to speed development and lower yields. In areas with recurrent droughts but where temperatures will warm (i.e. most of Africa), the optimal option is to choose a shorter-maturing variety that avoids big losses in very dry years or a longer-maturing variety that might maintain average yields as the climate warms. Tubiello and Rosenzweig (2002) also reported that switching to longer-maturing winter wheat varieties in areas with plentiful moisture fully offsets the 15 per cent projected yield losses under climate change.

4.1.3 Changing planting dates. One of the most straightforward on-farm climate adaptation strategies is the option to shift when in the year crops are planted. Year-to-year shifts in planting dates are already a demonstrated farmer adaptation in the face of climate variability, particularly for farmers in rainfed environments who often must wait for the onset of the rainy season to plant. Farmers in most parts of Africa routinely shift planting dates by a month or more from year to year in response to variability in rainfall (Falcon and Naylor, 2004; Tadross and Hewitson, 2005).

It is found that systematically shifting planting two weeks earlier transforms what would have been 20-25 per cent yield losses into modest gains (Tubiello and Rosenzweig, 2002). This is because cold temperatures limit early planting in current climate, subjecting the crop to heat and drought stress during critical stages of plant growth, and warmer climates appear to allow earlier planting and less stress during sensitive growth stages. Shifting planting dates might benefit farmers in areas with frequent temperature extremes in the current growing season as the climate warms, provided that irrigation is possible for much of the year.

4.1.4 Soil and water conservation. Soil and water conservation techniques has been linked with addressing climate change because they conserve the soil and improve water availability for crops by conserving water and the soil structure and, thus, reducing erosion (Dumanski *et al.*, 2006). Soil and water conservation techniques reduce soil loss from farmers' plots, preserving critical nutrients and increasing crop yields. It is evident that land degradation and soil fertility decline are critical problems in Ethiopia which aggravate poverty and food insecurity. Climate change is one of the causes for land degradation and soil loss. Soil and water conservation technologies serve not only the social good but also increase on-farm yields; hence, they are considered "*win-win*". A significant proportion of sample farmers in Fedis district (52 per cent) and Babile districts (39.4 per cent) ranked it as the first important climate change adaptation option.

4.2 Factors influencing households' choice of adaptation strategies

The negative coefficient for gender shows that female-headed households are more likely to take up crop diversification as an adaptation option. This might be due to the fact that women will get more experience and information on various management practices acquired while doing much of the agricultural work. Hence, they can easily adjust themselves to respond to shocks based on the available information on climatic conditions and other factors such as markets and food needs of the households. This result is consistent with the findings of Nhemachena and Hassan (2007). The negative effect of extension contact on cultivating different crops is more probably because of the fact that the extension system is much more concerned with profitability, giving less emphasis to climate risk management. Aemro *et al.* (2012) and Wondimagegn *et al.* (2011) reported similar findings. Better access to credit services is found to have a strong positive influence on the probability of adopting cultivating different crops as an adaptation measure and abandoning the relatively risky monocropping systems. Access to credit is another important determinant enhancing the adoption of various technologies (Kandlinkar and Risbey, 2000; Tizale, 2007). With more financial and other resources at their disposal, farmers are able to make use of all their available information to change their management practices in response to changing climatic conditions. Same results were found by Nhemachena and Hassan (2007). The positive effect of market distance on the adoption of crop diversification indicates that remoteness from markets tends to favor multiple cropping over specialized crop cultivation. This is an indication that more market integration promotes specialization; hence, it is an important area for public investment in adaptation infrastructure (Nhemachena and Hassan, 2007).

Only a few factors influence whether farmers change crop variety as an adaptation option probably because of the fact that planting crop variety decisions are autonomous decisions taken by farmers. Household's choice of crop varieties as climate change adaptation strategy is found to be dictated by gender of household head, market distance, land fertility status and agroecology. Male-headed households are more likely to plant different crop varieties as a climate change adaptation strategy. Aemro *et al.* (2012) found the same results. Farmers with access to fertile soils and located far from market centers are more likely to change crop variety (Bryan *et al.*, 2011).

Distance from market favors planting different crop variety as an adaptation strategy possibly because households located far from market centers are likely to plant crops of different varieties. The result is consistent with that of Bryan *et al.* (2011) and Nhemachena and Hassan (2007).

Choice of changing planting dates as a climate change adaptation strategy is negatively affected by household size. This is likely to be due to the fact that changing planting dates is an autonomous decision and does not require more labor. Farmers who use fertilizer are more likely to change planting because fertilizer can help in growing crops earlier than they need. Farmers located at distant from market centers are also more likely to change planting dates in response to adverse effects of climate change. Farmers having more number of plots also change planting dates.

Households' decision to take up soil and water conservation in response to perceived climate change is more likely to increase with farm size. Empirical adoption studies have found that farmers with larger farms have more land to allocate for constructing soil bunds and improved cut-off drains (Anley *et al.*, 2007; Nhemachena and Hassan, 2007; Negash, 2013). The positive effect of household size on adoption of soil and conservation measures is due to the labor-intensive nature of soil and water conservation (Nyangena, 2007; Anley *et al.*, 2007; Nhemachena and Hassan, 2007). Farmers who market large proportion of their produce are less likely to adopt soil and water conservation measures. A possible explanation is that subsistence farmers are more likely to notice climate and adapt to it than others kinds of farmers (commercialized).

Households in different agroecological settings use different adaptation methods because of differences in climatic conditions, soil and other factors. Farmers in the highlands and mid-highlands are more likely to choose cultivation of different crops, planting different crop varieties but less likely to change planting dates and use soil and water conservation measures compared to those in the lowlands. These results likely reflect unobservable spatial differences.

5. Conclusions and recommendations

5.1 Conclusion

Most farmers in the study area are aware that the area is getting warmer, precipitation has decreased and rainfall patterns have changed. The most pronounced effects of climate change are decline in income and yield, food insecurity, crop and livestock diseases and pests, high food prices, decline in forest resources and change in livelihood patterns of the households. These adverse effects are found to be more severe in Kersa and Fedis districts. Important adaptation options being used by farmers in response to adverse effects of climate change include crop diversification, planting different crop varieties, changing planting dates, use of water and soil conservation techniques, increased use of irrigation, conservation agriculture and diversifying from farm to non-farm activities.

Robust evidence was found that adoption decision of different adaptation strategies are interdependent because of complementarity or substitutability between the strategies. Female household heads are more likely to choose cultivating different crops as an adaptation strategy, whereas male heads will plant different crop varieties. Household who have access to credit, residing farther from market and with less frequent extension contact also will choose this strategy. Besides, farm size is found to negatively influence the choice of crop diversification. However, crop diversification will be favored by households operating more number of plots. Use of different crop varieties as an adaptation strategy is governed by household, institutional, farm characteristics and agroecology. Decision to change planting dates is influenced by household size, fertilizer use, market distance, number of farm plots and agroecology. Use of soil and water conservation measures as climate change adaptation strategy was influenced by household size, use of chemicals, distance from market, food aid, per capita income, farm pots, farm size and agroecology. In sum, gender of household head, household size, market distance, farm plots, farm size and agroecology are the significant determinants of households' choice of climate change adaptation strategies.

5.2 Recommendation

Strengthening efforts on enhancing farmers' adaptive capacity to climate change should be at the top of the agenda. Designing policies that aim to improve the barriers to adaptation for smallholder farming systems have a great potential to improve farmer adaptation to changes in climate. Programs aimed to reduce impacts of climate change need to encourage investment on soil and water conservation measures and development of disease- and drought-tolerant crop varieties. Supporting farmers through training on climate change adaptation options such as soil and water conservation measures, changing planting dates and crop diversification can improve adaptation practices. It also believed that better access to inputs like credit, fertilizer, chemicals extension service and information has to be improved. Targeting women groups and associations in smallholder rural communities can have significant positive impacts for increasing the uptake of adaptation measures by smallholder farmers. Government policies need to support research, development and diffusion of appropriate technologies to help farmers adapt to changes in climatic conditions.

Increased diversification of crops, through the cultivation of crops that are drought-tolerant and resistant to temperature stresses, as well as activities that make efficient use of the prevailing water and temperature conditions will serve as an important form of climate insurance against rainfall or temperature variability. Growing a number of different crops on the same plot or on different plots also reduces the risk of complete crop failure, as different crops are affected differently by climatic events. It is important to note that these adaptation measures should not be taken as independent strategies but should be used in a complementary way.

The government needs to include climate change adaptation policies in the development agenda. There is also the need for governments and non-governmental organizations to invest in climate-resilient projects.

Further research is required regarding vulnerability of rural households to climate change and its adverse effects and the impact of the adaptation strategies they opt for increasing their adaptive capacity. In addition, further research is called upon the impact of climate-resilient projects and government's investment on climate change adaptation strategies on farmers' adaptive capacity and livelihoods.

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