Original Article

Determinants of the Adoption of Land Management Strategies against Climate Change in Northwest Ethiopia

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Abstract

Agriculture is one of the sectors most vulnerable to climate change in Ethiopia. The ability of farming households to adapt is determined by many factors. The objective of this article is to examine the determinants of adaptation to climate change based on a survey of farming household heads in three agro-ecological settings of northwest Ethiopia. The survey results revealed that significant numbers of households are more likely to adopt different land management strategies to reduce the negative impact of climate change. However, there are important differences in the propensity of households living in different agro-ecological settings to adapt. The most statistically significant determinants of adopting land management strategies were agro-ecological zone, family size, livestock ownership and access to climate information. For building a more climate-resilient community those households who failed to respond may require particular support to do what is in their own best interests.

Key words: *climate change, adaptation, land management strategies, Northwest Ethiopia*

Introduction

Agriculture is one of the sectors most vulnerable to climate change impact in Africa (Ajibade, 2013). Agrarian communities in many African countries including Ethiopia are particularly vulnerable to climate change as they are largely based on rain-fed farming systems. Adaptive capacities are the lowest and technological changes are the slowest (Maddison, 2006; Bryan et al.,

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2011; Ajibade, 2013). Across Ethiopia, several millions of people are already experiencing changing seasonal patterns of rainfall and increased temperature (NMA, 2001, 2007; Hassan & Nhemachena, 2008; Bryan et al., 2011) which are expected to depress crop yields in many places during the coming decades. Prolonged droughts in Ethiopia, interspersed with periods of flooding have underscored the agricultural sector's capacity to adequately respond to weather shocks (Madison, 2006; Bryan et al., 2011). Severe erosion is also a risk affecting many people. However, the impact of weather shocks is to some extent internally determined by household decisions with respect to adoption of risk-reduction strategies (NMA, 2007; Bryan et al., 2011).

Communities have many ideas on how to prepare for future climate change with a strong motivation to move out of poverty. However, their ability to adapt to climate change is determined by many predictor variables which are social, cultural, economic and institutional in nature (Maddison, 2006; Mentez et al., 2008; Temesgen et al., 2009; Bryan et al., 2011). In order to identify these variables climate change researchers traced their methods from agricultural technology adoption and other related models involving decisions on whether to adopt a given course of action (Madison, 2006; Yesuf et al., 2008; Gbetibouo, 2009; Temesgen, 2009; Barungi & Maonga, 2011). Agricultural technology adoption methods are based on farmers' utility or profit maximizing behaviors (Madison, 2006). The assumption is that farmers may adopt a new technology only when the perceived utility from using this modern technology overweighs the traditional or the old method (Barungi & Maonga, 2011).

Probit and logit models are the most commonly used models in the analysis of agricultural technology adoption research. Binary probit or logit models are employed when the number of choices is two (whether to adopt or not). The extensions of these models, often referred to as multivariate models, are employed when the number of choices are more than two. The most commonly cited multivariate choice models in unordered choices are multinomial logit (MNL) and multinomial probit (MNP) models. These models have also been employed in climate change studies pertaining to the conceptual similarities in agricultural technology adoption and climate change studies. For example, Nhemachena and Hassan (2007) employed the multivariate profit model to analyze factors influencing the choice of climate-change adaptation options in Southern Africa. Temesgen et al. (2009) employed the multinomial logit model to see the determinants of adaptation to climate change in the Blue Nile Basin of Ethiopia.

By using these different methods, climate change research communities have identified many adaptation strategies to counterbalance climate change impact and enhance livelihoods in different spatial scales (Madison, 2006; Yesuf et al., 2008; Temsegen, 2010). Studies in Africa (Madison, 2006), in the Sahel region (Mentez et al., 2008), and in Ethiopia (Yesuf et al., 2008; Temesgen et al., 2008, 2009; Temesgen, 2010) identified different climate change adaptation strategies.

Several studies identified different determinants of farmers' decision to adapt to climate change. The major ones are: gender, age, farming experience, education, wealth status, farm income, access to technology, poverty, environmental awareness, farm size, tenure status, access to extension services, market and credit, climatic conditions, topography, information on climate and adaptation options, family size, labor, and access to water resources (Burton et al., 2006; NMA, 2007; Ghebetibouo, 2009). Therefore, the objective of this paper is to examine the determinants of households' decision to adopt land management strategies that can reduce their exposure to climatic shocks in selected sites of northwest Ethiopia.

Study Area, Data Set and the Econometric Model

Site Selection and Description

This study was conducted in three purposely selected *woredas* of Northwest Ethiopia, namely Dabat, Dembia and Simada based on the agro-ecological zones they are situated. The purpose was to examine whether or not there is significant variation among agro-ecological zones in the adoption of different land management strategies by farming households to reduce the impacts of climate change.

Both Dabat and Dembia are located in the North Gondar Zone of the Amhara Regional State. The *woreda* capital, Dabat, is located 255 km North of Bahirdar city (Dabat Woreda Communication Office, 2011). The Dembia *Woreda* capital, Kolladiba, is located 750 Km North of Addis Ababa. It is 35km away from Gondar city. Simada *woreda* is located in South Gondar Zone about 774 km north of Addis Ababa and 209 km southeast of Bahirdar city (*Woreda* Office of Agriculture, 2011). It is clear that the three study sites are situated in northwest Ethiopia stretching from the Abay-Beshilo Basin to the northern (Semien) highlands highly differing in agroecological setting (See Fig.1)

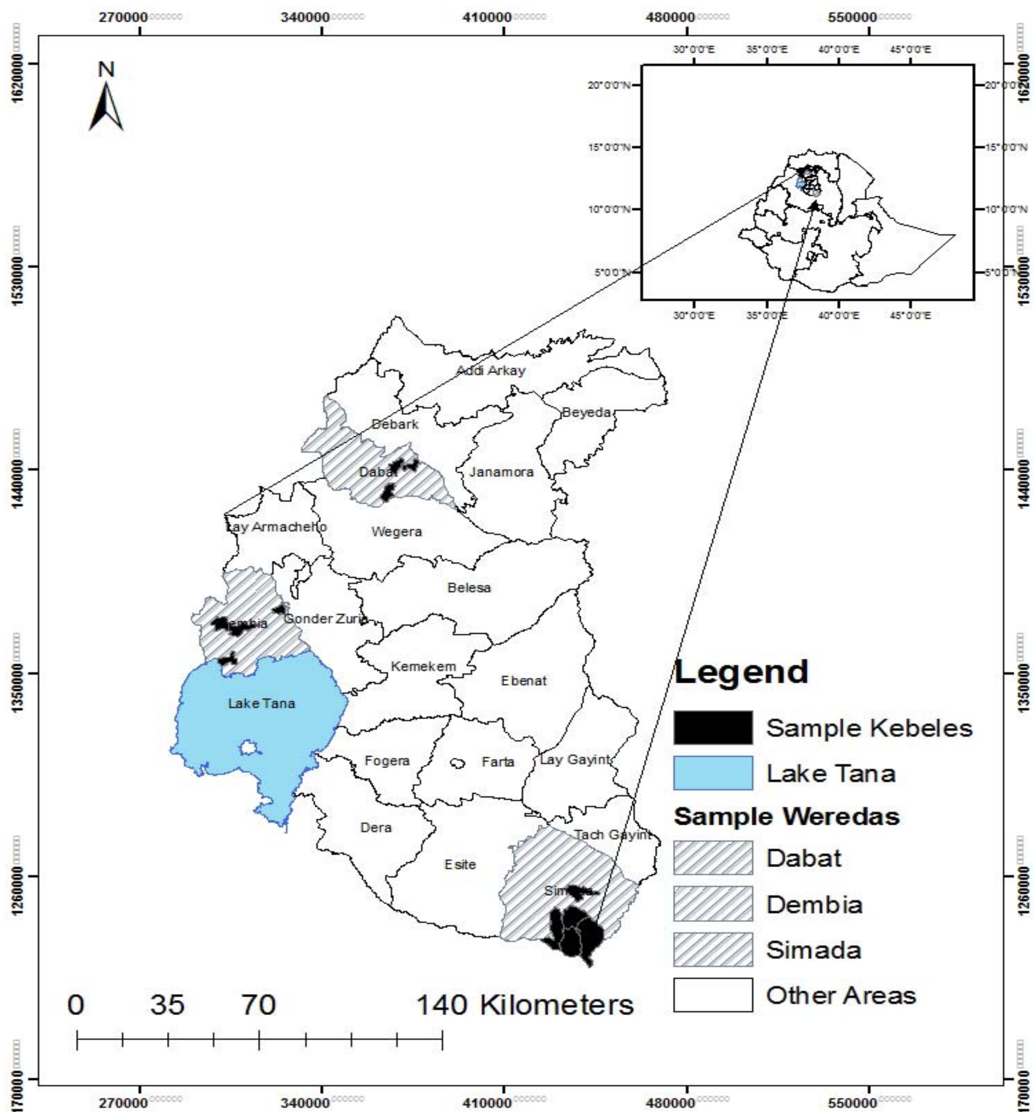

Figure 1: Location of the studied *woredas* (Ethio GIS Database)

The selected *woredas* are not entirely placed in the same agro-ecology, except Dembia *woreda*, which lies almost entirely in the *weyna dega* agro-ecological zone. Therefore, in the second sampling stage: (1) Dembia *woreda* as a whole is taken to represent the *weyna dega* zone, (2) Dabat *wereda's dega* area is taken as sampling area for the *dega* zone (3) and Simada *woreda's kolla* area is taken as sampling area for *kolla* zone. Then, three *kebeles* (the lowest administrative tier in Ethiopia) from *dega* and eight *kebeles* from *kolla* and *weyna dega* together (four from each) were selected using simple random sampling technique.

Dega kebeles of Dabat are located in the north highland wheat-barley -sheep livelihood zone of the flat highland topography near the highest peak of Ethiopia. The altitude of the study sites ranges from 2500 to 4517m above sea-level. The *weyna dega* site is situated in Dembia *woreda* with an elevation ranging from 1500 to 2500m above sea-level. The topography of the area is characterized by flat terrain. The *woreda* is also entirely located in the Tana zuria livelihood zone (*Woreda* Office of Agriculture, 2011). The *kolla* site is located in the dissected landscapes of Abay-Beshilo Basin where land degradations, drought, food insecurity and famine are serious problems. It is totally included in the Abay River Basin with elevations ranging from 854 m to 1500 m A.S.L (see Table 1).

Table 1: Sampling frame by elevation, temperature and rainfall limits

Agroecology	Elevation limit	Range of temperature (0C)	Range of rainfall (mm)
Dega	2500 – 4517m	10–17/18	1200 – 2200
Weyna dega	1500 – 2500m	17/18–20/24	900 – 1200
Kolla	854 –1500m	20/24–28	200/500 – 900

Source: Based on FAO, 2003

The Israel (1992) statistical formula was checked within the determination of the sample household size for a better representation of the population. The formula provided 387 sample populations which represent 3.29% of 11,732 households of the eleven *kebeles*. Feige & Marr (2012) contend that assuming the calculated sample size as sufficient to comply with the requirements is a typical mistake. The non-response and incomplete responses are mentioned as some of the reasons so that same authors suggest a compensation for such effects by increasing the calculated sample size by some proportion. Accordingly, the sample size for this study was increased to 576 (5%). Then, the 576 households were distributed to each *kebele* using probability proportional to size (PPS) method to ensure equal representation as there are different household sizes in each *kebele*.

The lists of rural households were taken from the *kebele* offices as a sampling frame from which, 576 households (263 from *kolla*, 181 from *weyna dega* and 132 from *dega*) were drawn using systematic random sampling technique. In doing so, sampling interval (K) was determined by dividing the total number of households in the population by the desired sample size of each *kebele*. Next, a number was selected between one and the sampling interval (K) using lottery method, which is called the random start that was used as the first number included in the sample. Then, every K^{th} household head after that first random start was taken until reaching the desired sample size for each *kebele*.

Data Collection Methods

This study used primary data collected using household survey, focus group discussion, field observation, and interview to bring the study to fruition.

The household survey was employed to collect a range of quantitative data on household characteristics and adaptation strategies used by the households. The data sets are very important for running binary logistic regressions to identify the most vital determinants of households' adaptation choices. The household survey was conducted in the period between March and September 2012. Household heads were approached, but if he/she were not available, the spouses were contacted. The actual household surveys were administered by data collectors with close supervision of the researchers and assistants. The former university students of the corresponding author had played paramount role in data collection. They also played an important role in choosing the data collectors who have been working in the community in the areas of agriculture, health, and teaching.

In order to further maintain the validity and reliability of the data, the questions were extensively reviewed by experts from different disciplines, working in the Offices of Agriculture, and Food Security and Disaster Prevention. Additional pilot-tests of questions were made by distributing questionnaires to 10 farmers in each site to assess whether the instruments were appropriate and suited to the study at hand. Necessary amendments were made based on the comments obtained from experts and responses from farmers to ensure reliability and validity. Data collectors were trained with respect to the survey techniques and confidentiality protocol. Internal quality control procedures were established during the training. For example, in case survey questions contained ambiguous language that might lead to different answers depending on respondent's interpretation, data collectors were told to have common understanding. After training, the data collectors acquired practical experience while we were making face-to-face interview in the actual data collection in the field.

The survey data was checked through qualitative data collection methods such as focus group discussions (FGDs), in-depth interviews and field observation. The uses of these methods are recognized by Creswell (2012) who states that qualitative inquirers triangulate among different data sources to enhance the accuracy of a study. Triangulation is the process of corroborating evidence from different individuals, types of data, or methods of data collection in qualitative research. This ensures the accuracy of study because the information draws on multiple sources of information. This helps to develop accurate and credible report.

The Econometric Model and Variable Description

Econometric analysis was done to examine the factors influencing the land management strategies. The logistic regression model, the natural logarithm of an odds ratio, was used to examine the household heads' decision on the choice of land management strategies. Since the probability of an event must lie between 0 and 1, it is impractical to model probabilities with linear regression techniques, because the linear regression model allows the dependent variable to take values greater than 1 or less than 0 (Agresti, 2007; SPSS 16.0.0). This model is well suited for describing the relationships between categorical response variables (adoption) and one or more categorical or continuous predictor variables (Tarling, 2009; SPSS 16.0.0). This condition calls for the use of logistic regression by identifying both dependent and independent variables.

(a) Dependent variables: The dependent variables for various adaptation options were created for this study. The dependent variables are dummy variables equal to 1 if the farmer adopted that particular adaptation option and 0 otherwise.

(b) Independent variables: we have analyzed whether a household adopted any adaptation strategy or not using dummy variables. Different social, economic, and physical factors were included as independent variables in the estimation procedure. The choice was based on experience and previous studies (Maddison, 2006; Yesuf et al., 2008; Temesgen et al., 2010). Analysis of the dependent variables requires a binary response model as:

$$\text{Logit}(y) = \text{In}(\text{odds}) = \text{In}\left(\frac{P}{1-P}\right) = B_0 + B_1x_{i1} + B_2x_{i2} \ldots + B_px_{ip}$$

where, *y* is the binary response variable (adaptation),

B_1 is the constant or the intercept of *y*,

$B_0 + B_1x_{i1} + B_2x_{i2}$ are regression coefficients,

P is the predicted probability to adopt which is coded with 1,

1−P is predicted probability of the decision to adopt a particular adaptation option,

$x_{i1}+x_{i2}+x_{ip}$ are the predictor variables included in the model.

In the binary logistic regression if the Exp(B) (odds ratio) is less than one, the independent and dependent variables have negative relationships and if it is greater than one their relationship is positive (SPSS 16.0). Explanations on the relationship of independent and dependent variables are presented in the discussions to come.

Male-headed households are more likely to get information on climate change and new technologies and undertake risky businesses than female-headed households. It is also argued that having a female-headed household may affect the adoption of soil and water conservation measures, as women may have limited access to information, land, and other resources due to socio-cultural barriers. In the light of this, Temesgen et al. (2009) found out that male-headed households were 9% more likely to conserve soil, 11.6% more likely to change crop varieties and 10% more likely to plant trees. Barungi and Maonga (2011) also showed that the probability of adopting soil management technologies by male-headed households was 15% higher than by female-headed households. Other studies reported contrary results, arguing that female-headed households are more likely to take up climate change adaptation methods. The reason was that women are responsible for much of the agricultural work in southern Africa region and therefore have greater experience and access to information on various farm management practices. Thus, the adoptions of new adaptation methods appear to be context specific (Nhemachena & Hassan; cited in Temesgen et al., 2009).

Age of the household head can be used to capture farming experience. Studies in Ethiopia have shown a positive relationship between years of experience in agriculture and the adoption of improved agricultural technologies (Yesuf et al., 2008; Temesgen et al., 2009). Older people were more likely to adopt climate change adaptation measures than of younger households. A unit increases in the age of the household head results in a 0.5% increase in the probability of planting trees and a 0.06% increase in irrigation (Yesuf et al., 2008; Temesgen et al., 2009). Other authors asserted a negative relationship between age and adoption of improved soil conservation practices. For example, Barungi and Maonga (2011) found that the age of the household head lowers the adoption of land management technologies.

There are two assumptions regarding the influence of the household size on the use of adaptation strategies. The first theory is that households with large families may be forced to divert part of the labor force to off-farm activities in order to earn income for buffering the consumption pressure imposed by a large family (Temesgen et al., 2009). The other assumption is that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks.

For instance, households with a larger labor size are more likely to adopt land management strategies and use them more intensively as they have surplus labor at peak times. Similarly, it is expected that households with large families are more likely to adapt to climate change (Yesuf et al., 2008; Temesgen et al., 2009) highlighting the role of household labor on the adaptation decisions. For this study, it is hypothesized that family size has positive relationships with labor intensive adaptation measures, such as application of manure, compost, terracing, planting trees and tapping underground water.

Farmland size, income and livestock ownership represent wealth. Studies on adoption of land management strategies indicated that farm size has both negative and positive effects on adoption, showing that the effect of farm size on technology adoption is inconclusive (Temesgen et al., 2009; Temesgen, 2010). However, because farm size is associated with greater wealth, it is hypothesized to increase adaptation to climate change. Studies that investigated the impact of income on adoption found a positive correlation (Temesgen et al., 2009). It is indicated that farm income of the surveyed households has a positive and significant impact on conserving soil. When the main source of income is farming and the size of farm land is limited, farmers tend to invest on adaptation options such as soil conservation instead of planting trees which competes with the limited land available.

Livestock plays a very important role by serving as a store of value and by providing traction and manure required for soil fertility maintenance (Barungi & Maonga, 2011). Thus, for this study, income and livestock ownership are hypothesized to increase adaptation to climate change. Availability of money households own ease the financial constraints households face and allow them to purchase inputs such as fertilizer, seedlings and irrigation facilities.

Extension services on agricultural production and information on climate, policies, and adaptation options represent access to information needed to make the decision to adapt to climate change. Various studies report a strong positive relationship between access to information and the adoption behavior of farmers (Yesuf et al., 2008; Temsegen et al., 2009; Luk, 2011), and that access to information through extension services increase the likelihood of adapting different climate change offsetting measures (Madison, 2006; Temesgen et al., 2009).

Social capital plays significant roles in adoption of adaptation strategies: they act as conduits for financial transfers which may ease farmers' credit constraints, provide information about new technologies, and facilitate cooperation among farmers. Social capital is represented by the number of relatives of a household in the local area and farmer-to-farmer extension (Temesgen et al., 2008). Yesuf and colleagues (2008) argue that households with good access to farmer-to-farmer extension tend to apply adaptation measures on their farms in comparison with those households who do not have this access. Hence, this study hypothesizes that social capital positively influences adopting adaptation measures to offset climate change impact.

There is significant difference in the likelihood of households' employing climate change adaptation strategies across different agro-ecologies. They found that households in *dega* and *weyna dega* were less likely to take climate change adaptation measures than in *kolla* (Yesuf et al., 2008). It is also hypothesized that different households living in different agro-ecological settings use varied adaptation methods. This is because climatic conditions, soil, and other factors vary by agro-ecologies, influencing farmers' perceptions of climate change and their decisions to adapt. Access to water increases the likelihood of adopting adaptation measures. However, financial resources constrain farmers for accessing the necessary technologies. Thus, poor farmers cannot afford to invest in irrigation for adaptation, or sustain their livelihoods during drought seasons.

Perception of climate change affects the probability of adopting different adaptation strategies depending on the type of adaptation. Households who perceive increasing temperature were more likely to adapt to climate change. For example, high perception in temperature change increases the probability of using different crop varieties, changing planting dates and irrigation. Similarly, decreased precipitation increase the probability of using soil conservation methods and irrigation (Temesgen et al., 2010).

Evaluation of the Model and Test of Significance

First, we verified the data to ensure whether or not the questionnaires had been filled up properly and accurately. Then the data was coded, entered, and analyzed using a statistical package for social sciences (SPSS 16.0).

The model evaluation and tests of significance were done to see whether the selected model better fits to the data collected on the chosen variables. The robustness of the model to the data was measured by applying the SPSS classification table, the Hosmer-Lemshow test and colinearity and multicolinearity statistics. To do so, the data collected through households survey on the questions asked whether households adopt or not the given alternative land management strategies were entered into SPSS 16.0 against independent variables. In the process of running the model, the binary logistic regression was run for each dependent variable with the same independent variables. In the SPSS command, the dependent variables were inserted to dependent variable box and the independent variables were inserted to covariates box and then the categorical variables were taken into the categorical variables list box. After entering the variables in the appropriate boxes, the necessary statistics such as classification plots, Hosmer-Lemeshow goodness-of-fit, correlation of estimates and confidence interval (CI) for Exp(B) were checked and then run at 95% confidence.

The classification tables of the SPSS output shows that 525 selected cases were included in the analysis having no missed cases for each dependent variable. In the constant-only model, without any other information, the model helped to provide the percentage correct from 58%–92.6% for different dependent variables (adaptation strategies). This values have been compared with the changes in percentage correct that gained by including independent variables in the model (67.9% – 93.7%). It was this difference that made the logistic regression model provides a better fit to the data over the null model (the model only with the constant; SPSS 16.0).

The fit of the model resulted from the incorporation of the predictor variables is also observed from the Hosmer-Lemeshow Test which is the inferential goodness-of-test statistic that gives a Chi-squared values with a small value of degree of freedom. The test statistics for each dependent and independent variable are insignificant when the p-values are greater than 0.05 levels. This condition suggests that the model adequately fits the data since the null hypothesis of a good model fit to the data was tenable. The Hosmer-Lemeshow statistic indicates a poor fit if the significance value is less than 0.05 (SPSS 16.0). By doing this, independent variables with significant p-values (<0.05) were excluded from entering in the model. For example, in the run of the model, the independent variables, namely gender, land fertility levels, oxen ownership, access to training, and number of relatives in a village were excluded for the land management practices as they had p-values less than 0.05.

The third way of checking the robustness of the model was assessing the multicolinearity (correlation between predictor variables). The study assessed colinearity and multicolinearity using two ways: using correlation matrices and variance of inflation factors (VIF). If the value of the correlation is close to 1 or -1, it indicates that there is colinearity. The results of the analysis indicated that there was no correlation between two variables whose correlation value more than 0.8.

The variance inflation factors (VIF) were also checked to detect multicolinearity in the same way as can be done for the linear regression. Since logistic regression model has no way to examine multicolinearity, the study ran a linear regression with the same predictors and dependent variables of the logistic regression model. The value of variance inflation factors of each variable was seen to detect whether there is multicolinearity or not. If the value of VIF is more than 10, there is multicolinearity among predictors but the results of this thesis indicated that there was no multicolinearity problem because the value of VIF for all variables were much less than 10 (1.062 – 2.278 (Refer Annex 1).

Model Results

From a number of independent variables, some have influenced the decision of household heads to use land management strategies. The binary logistic regression results are presented in Table 2 below.

Table 2: *Determinants of farmers' adoption of land management practice*

Predictor variables	Manure-compost		Modern fertilizer		Irrigation-water harvesting		Terrace building		Tree planting	
	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp (B)	Sig.	Exp (B)	Sig.	Exp (B)
Agroe–*dega*	.000*		.000*		.01*		.000*		.000*	
Agroe-*w/d*	.000*	.032	.950	1.028	.386	.651	.000*	.09	.000*	.06
Agroe-*kolla*	.442	.550	.000*	.239	.04*	2.24	.098	.44	.003*	.35
Age _ HH	.903	1.002	.193	1.014	.603	1.01	.004*	.97	.922	1.00
Family size	.000*	4.343	.004*	1.718	.785	.98	.046*	1.48	.035*	1.31
Education	.949	1.008	.544	1.037	.498	1.05	.250	.92	.116	1.11
Clim_info(1)	.023*	2.887	.296	.769	.428	1.28	.006*	2.24	.777	1.07
Farm size	.419	1.362	.002*	2.362	.808	1.05	.744	1.07	.033*	1.36
Acc_water(1)	.767	1.246	.001*	.312	.00*	48.6	.375	1.48	.049*	2.53
TLU	.000*	1.780	.001*	1.252	.641	1.03	.388	1.06	.24	1.06
Farm_inco	.864	1.000	.583	1.000	.552	1.00	.036*	1.00	.006*	1.00
Nonfarm incom	.889	1.000	.234	1.000	.621	1.00	.808	1.00	.978	1.00
F-to-F exten(1)	.080	2.271	.039*	1.741	.929	.971	.118	1.59	.019*	1.76
Exten_serv(1)	.926	1.047	.357	.787	.00*	2.37	.792	.93	.000*	2.30
Perc_ temp(1)	.534	1.595	.128	.524	.804	.886	.563	1.30	.337	.70
Percep_RF*(1)	.988	1.011	.397	1.490	.009*	2.296	.485	.68	.065	2.13
Constant	.214	.153	.212	.356	.056	.173	.008	13.40	.452	.57

Source: Households survey, March–September 2012;
Note: The reference category is not adopt; *RF=rainfall *TLU = Tropical Livestock Unit, F-to-F extension = farmer-to-farmer extension

Manure-compost

The logistic regression result revealed that agro-ecology, family size, access to climate information and livestock ownership were statistically significant determinants of adoption of manure-compost (significant at 0.05 level) [see Table 2].

By agro-ecological setting, *kolla* (0.55 times) and *weyna dega* (0.032 times) households were less likely to adopt manure-compost than those in *dega. In dega, modern batteries installed in the houses are the most important sources of lighting for 64% of the surveyed households as compared to 12% both for kolla and weyna dega households. In addition, an increasing trend of forest supply was reported by the dega households.* An increase in one person in the family increases the probability of the adoption of manure-compost by 4.34 times. Those households who had access to climate information were 2.89 times more likely to adopt it on their farmland as a land management practice. As expected, a unit increases in the households' livestock ownership increases their probability of adopting manure-compost by 1.78 times.

Modern Fertilizers

The logistic regression estimates indicated that agro-ecology, family size, farmland size, access to water for irrigation, livestock ownership, and farmer-to-farmer extension were statistically significant with the application of modern fertilizers having p-values less than the threshold (0.05) level (Refer to Table 2). All of these variables signify positive relationship with fertilizers application as they have parameter values greater than zero, except access to water for irrigation having a parameter value of less than zero.

In terms of agro-ecology, *weyna dega* households were 1.03 times more likely to apply modern fertilizers than those in *dega* whilst *kolla* households were 0.24 times less likely to adopt fertilizers. Family size positively enhances the application of modern fertilizer. For example, an addition of a person in the family members increases the probability of adopting fertilizer by 1.72 times. Every additional unit of farmland and tropical livestock unit increase the probability of adopting modern fertilizers by 2.362 and 1.252 times respectively. The households who have access to farmer-to-farmer extension[3] were also 1.74 times more likely to adopt fertilizer on their farmlands. On the contrary, households who have access to water for irrigation were 0.312 times less likely to adopt modern fertilizers. Age of the household head, education, farm income, non-farm income, number of relatives in a village, and perception of rainfall change signified positive correlation with households' fertilizer adoption decision. However, these variables are statistically not significant.

Irrigation-Water Harvesting

Irrigation-rainwater harvesting application is determined by several factors. The regression analysis presented in Table 2 indicated that agro-ecology, access to water, extension services, and perception of rainfall change signifi-

[3] In the farmer-to-farmer extension approach, innovative farmers can inspire and teach other farmers to incorporate the method they developed against climate change impact and found successful.

cantly influence the application of irrigation against climate change. In aggregation, *kolla* households were 2.24 times more likely to use irrigation-water harvesting than *dega* households while those in *weyna dega* were 0.65 times less likely to adopt this strategy than *dega* households. More importantly, access to water increases the probability of adopting irrigation by 48.649 times within the households. However, when irrigation and water harvesting are disaggregated, *dega* and *weyna dega* households were more likely to adopt irrigation than *kolla* households who showed higher propensity to use water harvesting than *dega* and *weyna dega* households. Households who have access to extension services were also 2.37 times more likely to adopt irrigation-water harvesting than those households who have no access to such valuable services. Households who perceived climate change were 2.30 times more likely to apply irrigation-water harvesting strategy.

Constructing Terraces

The adoptions of terraces have been determined by a number of factors. The logistic regression model results indicated that agro-ecology, age, family size, farm income, and access to climate information were statistically significant determinants in the decisions of households to construct terraces on their farms. *Weyna dega* and *kolla* households were 0.09 and 0.44 times less likely to build terraces on their farmland than *dega* households (See Table 2). For every year increase in age (which can capture farming experience) of the household head decreases the probability of adopting terraces by 0.97 times.

Family size signified positive relationship with terrace construction. For example, a one person increase in the family can increase the probability of constructing terraces by 1.48 times. Households who had access to climate information were 2.24 times more likely to adopt terraces on their farmland. Even though not statistically significant, farm size, access to water, livestock ownership, farmer-to-farmer extension and farmers' perception of temperature changes showed positive contribution for the adoption of terraces by farmers (see Tab1e 2).

Planting Trees

Planting and survival rates of planted seedlings have been determined by different factors. Agro-ecological zones, family size, farm size, access to water, farm income, farmer-to-farmer extension, and extension service were statistically significant in determining households' adoption of planting trees for adapting to climate change. There is significant difference across agro-ecologies in the adoption of planting trees. For example, *weyna dega* and *kolla* households were 0.06 and 0.35 times less likely to plant trees than those households in *dega*. Like any other land management strategies, family size, farm size, and access to water positively influences the adoption of planting trees. For instance, a one person increase in the family, a unit increase in the farm size, and access to water resources show 1.31, 1.36, and 3.53 times probability of planting trees respectively. Although farm income is statistically significant, its impact is very low on the adoption of planting trees. Access to farmer-to-farmer and formal extension services increase the probability of adopting planting trees by 1.76 and 2.30 times, respectively (See Table 2).

Discussion

Results from the discrete choice model indicated that the different factors have determined the farmers' choice of the alternative land management strategies. The detail for each land management strategy is presented in the discussions to come.

Manure-compost: manure-compost application is a practice of spreading animal manure and related decomposed materials in the field for soil fertility maintenance for enhancing sustainable agriculture. In the study areas, the use of animal manures combined with straws is important for soil fertility management. Most of the time, farmers apply manure near the homestead, rather than to land at a distant place. Compost is also prepared from animal manures, weeds, plant leaves as well as crop residues. However, the largest proportion of the inputs comes from animal manure. Several factors influence households' decision to use manure-compost in response to perceived changes in environment and climate.

Significant differences in the likelihood of households' application of manure-compost across agro-ecologies were observed. Although severe land degradation was reported in *kolla*, *weyna dega* households were less likely to adopt manure-compost respectively than those in *dega.* The reason is attributed to the fact that *kolla* and *weyna dega* households mostly use animal dung as a major source of fuel than *dega* households. This finding challenges the purpose of "climate-smart" agricultural development initiated by the Ethiopian government which involved establishing agricultural activities that included existing techniques and knowledge to increase the organic content of soils in addition to reducing erosions (Leulseged et al., 2013). This adds a fuel on the lives of *kolla* households in addition to the severely degraded environment and tough climatic conditions, which have discouraged them to use modern fertilizers and other modern agricultural inputs.

In *dega,* modern batteries installed in the houses are the most important sources of lighting for over half of the surveyed households as compared *to* 12% both for *kolla* and *weyna dega* households. In addition, an increasing trend of forest supply was reported by the *dega* households, which in turn may help them to refrain from using animal dung and crop remnants for fuel. Most *weyna dega* households own relatively fertile farmlands which may not need manure-compost. Moreover, the area is suitable for modern fertilizers and that the households have relatively better capacity than those of *kolla* households. This finding contradicts with the findings of Yesuf et al. (2008) as it pointed out that *dega* households were less likely to take climate change adaptation measures than *kolla* households.

Access to climate information increased the likelihood of adopting manure-compost as land management strategy. The households have already understood that application of manure-compost can facilitate the growth of crops so as to save them from being damaged by the expected drought conditions. Since livestock is the main source of soil fertility management input, a unit increases in the livestock ownership increases their probability of adopting manure-compost.

Modern fertilizers: the very important focus of the extension system in Ethiopia is to increase production by using more modern fertilizers on agricultural lands. However, its application has been determined by several factors. Agro-ecological zones have created significant variation among the rural households in the adoption of modern fertilizers. For example, *weyna dega* households were more likely to apply modern fertilizers than those in *dega* whilst *kolla* households were less likely to adopt fertilizers. This result is expected because in the *kolla* sites, environmental conditions are so unfriendly to apply modern technologies like modern fertilizers and improved seeds. Instead, many farmers opt for use of conservation tillage, mixed cropping, and crop rotation to maintain farmland fertility. These adaptation strategies are consistent with the principle of 'climate-smart' agricultural development initiated by the Ethiopian government. In addition, integrated soil fertility management could lower fertilizer costs, increase soil carbon and improve yields. These 'multiple wins' are the centre of the concept of smart agriculture (Leulseged et al., 2013). However, same authors stated that a triple win approach requires adjusting institutions, policies, financing and markets to strengthen capacities for changing agriculture systems at various scales.

The result found that family size positively enhances the application of modern fertilizer, indicating that the larger the size of the household, the better the chance of adapting to climate change. Although there are controversial results on the role of family size, this result is supported by Temesgen's et al. (2009) findings which indicated a positive relationship between family size and adoption of different climate change adaptation measures. Farmland and livestock ownership are measures of wealth status in the rural households. The results indicated that every additional unit of farmland and tropical livestock unit increase the probability of adopting modern fertilizers. Land has greater power in determining farmers' fertilizer application. In line with this, studies demonstrated that declining farm size has affected agricultural production in many parts of northern Ethiopia. The units of land divided up by each generation are declining to the level of insufficiency in size to apply new technologies and to support food security. On these small plots, many smallholder farmers are trapped in low productivity. As a result, they are forced to convert already low levels of assets (e.g. livestock) into cash to purchase food and hence many highland farmers have little capacity to adopt climate change adaptation measures even if they are willing to engage in agricultural intensification (Leulseged et al., 2013). Coupled with land shortage, rainfall variability and unpredictability persists, which is a key reason for now ranking Ethiopia as one of the countries at most 'extreme risk' from the effects of climate change.

The households who have access to farmer-to-farmer extension[4] were also more likely to adopt fertilizer, indicating the role of peer influence and social capital in climate change adaptation. On the contrary, households who have access to water for irrigation were less likely to adopt modern fertilizers as irrigation enables them to have sufficient production more than once per year. Age of the household head, education, farm income, non-farm income, number of relatives in a village, and perception of rainfall change signified positive correlation with households' fertilizer adoption decision. However, they are statistically not significant.

Irrigation-water harvesting: irrigation is an important adaptation strategy in drought prone communities though its application is determined by several biophysical and socio-economic factors. The binary logistic regression result indicated that agro-ecology, access to water, extension services, and perception of rainfall change significantly influence the application of irrigation against climate change. By agro-ecology, *kolla* households were more likely to use irrigation-water harvesting together than *dega* households while those in *weyna dega* were less likely to adopt it than *dega* households. More importantly, access to water increases the probability of adopting irrigation several times within the households. However, when irrigation and water harvesting are disaggregated, *dega* and *weyna dega* households were more likely to adopt irrigation than *kolla* households who showed higher propensity to use water harvesting than *dega* and *weyna dega* households.

Households who have access to extension services were also more likely to adopt irrigation-water harvesting schemes than those households who have no access to such valuable services. As perception of climate

[4] In the farmer-to-farmer extension approach, innovative farmers can inspire and teach other farmers to incorporate the method they developed against climate change impact and found successful.

change is a prerequisite for adaptation, households who perceived climate change and variability were more likely to apply irrigation-water harvesting strategy. That is, perceiving rainfall change has positive relationship with the use of irrigation which is consistent with the findings of Temesgen et al. (2009). Leulseged et al. (2013) expressed their concern in that the expansion of future irrigation is constrained by low levels of technology and the cost of energy and the authors acknowledged the recent focus of some key government initiatives in improving small-scale irrigation expansion at a household level.

Constructing terraces: there are long-term benefits to households from adopting various sustainable land management (SLM) practices in terms of reducing soil erosion, increasing yields, reducing variability of yields, and making the households more resilient to climate change. However, the adoptions of these methods have been constrained by a number of biophysical and socio-economic factors. The logistic regression results indicated that agro-ecology, family size, farm income, and access to climate information were statistically significant determinants in the decisions of households to construct terraces. In terms of agro-ecological setting, *weyna dega* and *kolla* households were less likely to use terracing as a land management strategy than *dega* households.

Age of the household head also affects terrace construction. As terrace construction requires more energy, young people were more active in constructing terraces than those of old age households. This finding is supported by Madison (2006) who argued that older farmers are often less likely to adopt soil conservation practices because of their shorter planning horizons and a less than perfect capitalization of such benefits due to underdeveloped land markets. However, this result is in contrary to the assumption that farming experience increases the probability of adopting land management technologies and adaptation measures to climate change.

Family size also signified positive relationship with terrace construction for the reason that terrace construction is a labor-intensive activity. Households who had access to climate information were more likely to adopt terraces on their farmland.

Planting trees: tree planting is another important component of sustainable land management in the rural communities. However, the planting and survival rates of planted seedlings have been determined by different factors. Agro-ecological zones, family size, farm size, access to water, farm income, farmer-to-farmer extension, and extension service were statistically significant in determining households' adoption of planting trees for adapting to climate change. The result implies the significant difference across agro-ecologies in the adoption of planting trees. For example, *weyna dega* and *kolla* households were less likely to plant trees than those households in *dega*. The interview results and field observations confirmed that *dega* households have changed their productive lands to eucalyptus trees. Low survival rates of trees have discouraged households to plant more trees, particularly in *kolla* and *weyna dega* agro-ecologies. Like any other land management strategies, family size, farm size, and access to water positively influences the adoption of planting trees. Although farm income is statistically significant, its impact is very low on the probability of planting trees. Income of households would be expected to have a positive influence on local level climate risk adaptation. It is argued that higher income farmers may be less risk averse and have more access to information, and a longer term planning horizon (Temesgen et al., 2009). However, it did not create variation in the households' land management decision. This may be attributed to some adaptation options that do not need financial expenses or some others being provided through credit as government packages. What makes the difference here is farmers' expectation of the gains of using the adaptation strategies, behavioral changes to use the adaptation technologies and to take credit risks. In this regard, Barungi and Maonga (2011), based on the rational choice theory, argue that the behavior of human beings is motivated by the possibility of gaining benefit. The farmers are rational consumers of new technologies and they will only adopt a technology if they anticipate it will result in increased productivity.

Access to farmer-to-farmer and formal extension services increase the probability of planting trees. However, beyond expectations, formal extension services indicated negative relationships with applications of modern fertilizers and terrace construction while it signified positive relationships with the use of manure-compost, irrigation-rainwater harvesting and planting trees. The interview results pinpointed three core inter-related problems which have resulted in technological and technical failures in the current extension approach. These are: lack of understanding extension as a profession, lack of maintaining the process of extension diffusion, and top-down approach without/limited participation of the beneficiaries.

Conclusions

The survey results revealed that significant numbers of households are more likely to adopt different land management strategies to reduce the negative impact of climate change. However, there are important differences in the propensity of households living in different agro-ecological settings to use different land management strategies. The most statistically significant determinants of adopting land management strategies were agro-ecological zone, family size, livestock ownership and access to climate information. In terms of policy implications, for building a more climate-resilient community those households who failed to respond may require particular support to do what is in their own best interests. Improved farmer education would do most to hasten adaptation. The provision of improved extension advice for example, plays a role in promoting adaptation to climate change. Further analysis would be required to understand the underlying factors for the observation of many location specific differences in the propensity of farmers to apply land management strategies against climate change impacts.

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