Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.4, 2014

Determinants of Adoption Choices of Climate Change Adaptation Strategies in Crop Production by Small Scale Farmers in Some Regions of Central Ethiopia

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Abstract
In Sub-Saharan Africa, climate change is set to hit the agricultural sector the most and cause untold suffering particularly for smallholder farmers. Adoption of climate change adaptation strategies aims to minimize adverse effects of climate change on crop yields. However, the capacity of smallholder farmers to choose from appropriate climate change adaptation strategies in SSA is limited. It is therefore imperative to identify and analyze factors that determine the capacity of these farmers to choose appropriate climate change adaptation strategies. Such effort will help policy makers and development practitioners design policies that would help to tackle the problem of food insecurity and poverty afflicting majority of the local people in various regions in the continent. In this study, household data on crop farming systems in central Ethiopia was used and binary and multinomial logit models developed to analyze the data. The binary logit model was used to identify determinants of farmers' decision to adapt to climate change at all. The multinomial logit model was employed to analyse factors that affect farmers' adoption choices. Results indicate that farmers´ decisions to choose from several climate change adaptation strategies are influenced by various factors such as access to information on climate change, input and output market, credit facility, extension services and social capital. The implication is that policy makers and development practitioners should focus on improving information flow, access to input and output market, the education level of the household head, and informal social networks that can speed up the adoption of adaptation strategies. The multinomial logit model also shows that farmers´ decision to choose among climate change adaptation strategies is influenced by the type of risk factor they faced and the occurrence of drought or flood. Accordingly, policy makers and development practitioners should play a significant role by promoting adaptation methods appropriate for particular climate change risk factor such as drought or flood.
Key words: *climate change, adaptation strategies, crop production, small scale farmers*

1. Introduction

Various studies show that climate change would significantly reduce agricultural production in sub-Saharan Africa (SSA). In this part of the world climate change could reduce suitable land area for agriculturally; some rain-fed crop yields are projected to reduce to as much as 50 percent by 2020 (IPCC 2007). In SSA agriculture is practiced by millions of small scale and poor farmers who produce food crops for subsistence. Low land productivity and harsh weather conditions (high average temperature, and scarce and erratic rainfall) combined with low capacity to adopt climate change adaptation strategies characterize the crop production environment (McCarthy *et al*. 2001& Cline 2007).

Ethiopia, a country in SSA, is listed as one of the Countries most vulnerable to climate change with the least capacity to respond (Orindi *et al*. 2006; Stige *et al*. 2006 & Di Falco *et al*. 2011). Climate change manifested in the form of frequent droughts and floods has been found to severely reduce the annual growth potential of this country. For instances, the 1984-85 drought reduced Ethiopia's agricultural production by 21 percent, which led to a 9.7 percent fall in the GDP (World Bank 2006). Crop and livestock losses over North-Eastern Ethiopia, associated with droughts during 1998-2000, were estimated at US$266 per household, which is greater than the average annual income for 75 percent of households in this region (Stern 2007). In this country climate change is predicted to further continue. Annual minimum temperature has been increasing by about 0.37 degrees Celsius every 10 years over the past 55 years (Di Falco & Veronese 2012). These findings point out those climatic variations have already happened in Ethiopia. The mean annual temperature is projected to increase by 1.1 to 3.1˚C by the 2060s, and 1.5 to 5.1˚C by the 2090s (FAO 2010).Thus, given the nature of Ethiopia's economy which largely depends on weather-sensitive and small scale agricultural practices and the low adaptive capacity of poor farm households, the potential adverse effects of climate change on crop agriculture and food security will be increasing through time.

Adoption of climate change adaptation strategies is believed to minimize the negative impacts of climate change on crop yields. In Ethiopia the capacity of smallholder crop producers to adopt\choose among climate change adaptation strategies is low. Evidence on factors affecting the adoption\choices of climate change adaptation strategies by these smallholder farmers in crop production in this country is little (Mohamed *et al*. 2008; Di Facalo *et al*. 2011; Di Falco & Veronese 2012). Therefore, analysis of such factors is important to provide policy makers with information on intervention areas to reduce the vulnerability of smallholder farmers to the negative effects of climate change. Accordingly, this aimed at investigating factors that determine the decisions made by small scale farmers to adapt to climate change in their crop agriculture and the factors influencing their choice of particular adaptation methods to climate change. To do this, relevant household data from 899 randomly selected households in some parts of central Ethiopia were collected and analyzed.

2. Literature Review

2.1 Climate Change Adaptation

Adaptation to climate change is generally defined as the process of adjusting or intervening in natural or human systems intending to respond to actual or anticipated climate change or its effects. It is the process of improving society's ability to cope with climate change and its effects across time scales, from short term. It is a mechanism that helps in managing the losses or exploiting beneficial opportunities presented by climate change. Adaptive capacity is defined as the ability of a system to adjust to climate change and its effects, to moderate potential damages and to take advantage of opportunities (IPCC 2001).

Adaptation in agriculture is identified as one of the policy options to reduce the negative impact of climate change on agricultural productions (Kurukulasuriya & Mendelsohn 2006). Adaptation in agriculture occurs at two main scales: household-level (micro) and national level (macro). Micro-level analysis of adaptation in agriculture focuses on tactical decisions that farmers make in response to seasonal variations in climatic, economic, and other factors. These micro-level tactical decisions of households in crop agriculture include using different adaptation options. The most common micro-level adaptation options in crop agriculture include crop diversification, using irrigation, mixed crop-livestock farming systems, using different and new crop varieties that are better suited to drier conditions, changing planting and harvesting dates, and mixing less productive, drought-resistant varieties and high-yield water sensitive crops (Temesegen *et al*. 2008). On the other hand, national level or macro-level analysis is concerned with agricultural production at the national and regional scales and its relationships with domestic and international policy (Bradshaw *et al*. 2004 & Nhemachena & Hassan 2007). For example, crop adaptation measures can be supply-side measures (such as providing more water), demand side measures (such as reuse of water) and combinations of both. While some measures may be taken at the individual or farm level, others require collective action (e.g. rain water harvesting), or investments at the agency or government level (e.g. building dams, releasing new cultivars that are more water efficient) (Jawahar and Msangi 2006).

2.2 Determinants of adoption choices of climate change adaptation strategies

Factors that affect the decision of farm households to use/choose among crop adaptation strategies can include access to information, households financial capacity, lobar, education, age, marital status, gender , farm (plot) characteristics, and access to extension and credit, and input and output markets (Temesegen *et al*. 2008 & Di Falco *et al.* 2011). Availability of better climate and agricultural information helps farmers make informed and comparative decisions among alternative crop management practices and this allows them to better choose strategies that make them cope well with changes in climatic conditions (Nhemachena & Hassan 2007). Lack of information (about seasonal and long-term climate changes and agricultural production) can constraint farmers from adopting different climate change adaptation strategies thereby increasing high downside risks arising from failures associated with non-uptake of new technologies and adaptation measures. Lack of money (income) and other resource limitations and poor infrastructure are also likely to limit the adaptive capacity of most rural farmers.

Farmers that lack money and other resources will fail to cover costs necessary to take up adaptation measures and thus may not make beneficial use of the information they might have. The availability and quality of labor can affect the involvement of households in other income (money) generating activities. Farm households with more available and quality labor can have higher probability to get involved in other income generating activities (Kandlinkar & Risbey 2000). Shortage of labor is also deemed as an important input constraint. Households with more labor are believed to be better able to take adaptation measures in response to changes in climatic conditions compared to those with limited labor. In this sense, family size is one important variable that can determine the availability of labor (Temesegen *et al.* 2008). On the other hand, education is an important source of information for farm-level management activities. Similarly, age can also affect the quality of lobar as it is connected with experience. Elder household heads are expected to have more experience in farm practices and management (Nhemachena & Hassan 2007; Temesegen *et al*. 2008 & Di Falco *et al*. 2011). Limited market access also can negatively affect the potential for farm-level adaptation. Farmers with access to both input and output markets are likely to have more chances to use adaptation measures. Input markets allow farmers to acquire the necessary inputs required to take adaptation measures. Such inputs include different seed varieties, fertilizers, and irrigation technologies. On the other hand, access to output markets provide farmers with positive incentives to produce cash crops that can help improve their resource base and hence their ability to respond to changes in climatic conditions (Mano *et al*. 2003; Nhemachena &Hassan, 2007).

2.3 Estimation strategy , data and sampling procedures

This study framed the estimation strategies (econometric models) within the general theory of utility/profit maximization framework. The economic model of utility maximization theory assumes that a decision on whether to or not to adopt a technology depends on the expected benefit to be obtained from adopting the technology (Norris & Batie 1987).

In the study, the adaptation to climate change at all is binary case to adapt or not to adapt (0, 1), while strategies (that is postulated adaptation options) are multinomial cases where there are more than two alternatives as [0, 1, 2, …, *J*]. Smallholder subsistence farmers are likely to adapt to climate change only when the perceived benefit from adapting is significantly greater than the case not to adapt. In analyzing adaptation options it can be assumed that a risk facing representative farm household is to choose a mix of crop adaptation strategies intending to maximize the expected utility (benefit) to be obtained from crop production at the end of the production period. The assumption is that, a farm household i will choose adaptation strategy Y_j over any adaptation option, if and only if the expected benefit to be obtained from using adaptation strategy Y_j is greater than that from any other adaptation strategy different from option j (Di Faclo 2011).

In any given occasion, given a set of J mutually exclusive and collectively exhaustive discrete alternatives, it is expected that the i^{th} rational economic decision maker (in this case a farm household) would follow the decision rule to choose the j^{th} adaptation option with highest benefit $R_{ij} > R_{ik}$, where $k \neq j$ (Tmesegen *et al.* 2008).

2.4 Binary Logit Model: Farmers' decision to undertake any adaptation at all

In order to analyze factors that affect the decision of households to adapt to climate change at all, a probability model is used where the binary dependent variable is a dummy for undertaking any adaptation at all (i.e. Y_i has only two possible values, *1*or *0*, for either adapting or not adapting to climate change). Thus,

$$Y = Z_i\beta + \varepsilon_i \qquad (1)$$

It is assumed that the probability of observing farmer i undertaking any adaptation at all.

($Y_i = 1$) depends on a vector of independent variables (Z_i), unknown parameters (β), and the stochastic error term (ε_i) (Gujarati 2003; Komba & Muchapondwa 2012).

The probability of observing farmer i undertaking any adaptation at all $P(Y_i=1|Z_i)$ has empirically been modeled as a function of independent variables such as climate change related risk factor, household and household head characteristics, plot characteristics, institutional and infrastructural access and social capital. Climate change related risk factors include incidences of droughts and floods. Household and household head characteristics include family size, household head education, age, gender and so on. Plot characteristics include plot slope, soil fertility, and soil depth and so on. Institutional and infrastructural access includes access to climate information, input and output market, agriculture extension and credit facility. Social capital includes number of friends\relatives to rely on in times of need, membership to any farmers group found in the village and so on.

Assuming that the cumulative distribution of ε_i is logistic, the probability that a farmer adapts to climate change is estimated using the logistic probability model specified (Woodridge 2001). The model is specified as,

$$p(Y = 1/Z) = \Lambda(Z'\beta) = \frac{e^{Z'\beta}}{\left(1 + e^{Z'\beta}\right)} \qquad (2)$$

Where Λ is the logistic cumulative distribution function.

This model implies diminishing magnitude of the marginal effects for the independent variables (Komba & Muchapondwa 2012). The parameter estimates of the logit model provide only the direction of the effect of the independent variables on the dependent (response) variable; estimates do not represent either the actual magnitude of change nor probabilities (Schmidheiny 2007). Fortunately, differentiating equation (2) with respect to the explanatory variables provides marginal effects of the explanatory variables. The derivation of the equation is given as:

$$\frac{\partial P(Y = 1/Z)}{\partial Z_k} = \frac{\partial \Phi(Y = 1/Z)}{\partial Z_k} = \Lambda(Z'\beta)[1 - \Lambda(Z'\beta)]\beta_k \qquad (3)$$

In the above equation, the independent variable Z_k is continuous. The marginal effect of a dummy variable Z_k

is the difference between two derivatives evaluated at the possible values of the dummy i.e. *1* and *0*, and given by;

$$\frac{\partial P(Y=1/Z)}{\partial Z} = [\Lambda(Z'\beta)][1-\Lambda(Z'\beta)]Z_K = 1-[\Lambda(Z'\beta)][1-\Lambda(Z'\beta)]\beta_\kappa]Z_K = 0 \tag{4}$$

2.5 The multinomial logit model

Multinomial logistic (MNL) regression model was applied to model the adoption options of climate change adaptation strategies, and the parameters were estimated by using maximum likelihood method of estimation. The advantage of MNL model is that it allows the analysis of adoption options across more than two alternatives (Tmesegn *et al.* 2008). The MNL model can be derived from a latent model (Wooldridge 2002). Let Y^* denote a latent dependent variable (adoption options) taking on the values *j* (*j=1, 2, ..., J*) for *j ≥ 0* and *j≤ 1*. The latent variable model can be specified as shown in equation (5) below.

$$Y_{ij}^* = Z_i\beta_j + \varepsilon_{ij} \tag{5}$$

$$Y_{ij} = \begin{cases} =1 \text{ iff the net benefit from using strategy } Y_{i1} > Y_{ij}, Y_{i1} \neq Y_{ij} \\ \\ = J \text{ iff the net benefite from using strategy } Y_{iJ} > \text{any} Y_{ij}, Y_{iJ} \neq Y_{ij} \end{cases}$$

With

It is assumed that that the covariate vector z_i is uncorrelated with ε_{ij}, i.e.,

$$E(\varepsilon_{ij}|z_i) = 0 \tag{6}$$

Under a multivariate normal distribution assumption, each observation records one of the *J* possible values for the dependent variable Y (in this case the adaptation strategy). Under the assumption that ε_{ij} are independent and identically distributed, that is under the Independence of Irrelevant Alternatives (IIA) hypothesis, the latent variable model (5) leads to a multinomial logit model (Wooldridge 2002). For the multinomial logistic regression model, we equate the linear component to the log of the odds of a j^{th} observation compared to the J^{th} observation. That is, we will consider the J^{th} category to be the omitted or baseline category, where logits of the first $J-1$ categories are constructed with the baseline category in the denominator (Czepiel 2007). That is,

$$\log\left(\frac{\pi_{ij}}{\pi_{iJ}}\right) = \log\left(\frac{\pi_{ij}}{1-\sum_{j=1}^{J-1}\pi_{ij}}\right) = \sum_{k=0}^{K} z_{ik} \tag{7}$$

Where *i=1,2,…,N* and *j=1,2,…J-1*

Solving for π_{ij} we have

$$\pi_{ij} = \frac{\exp z_i\beta_j}{1+\sum_{h=1}^{J-1}\exp(z_i\beta_h)} \tag{8}$$

As the binary logit model, the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable; estimates do not represent either the actual magnitude of change nor probabilities (Schmidheiny 2007). Differentiating equation (8) with respect to the explanatory variables provides marginal effects of the explanatory variables. The derivation of the equation is given as:

$$\frac{\partial p_j}{\partial z_k} = P_j\left(\beta_j - \sum_{j=1}^{J-1}\left(P_j \beta_j\right)\right) = P_j\left(\beta_{jk} - \beta_k\right) \quad (9)$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean. Thus, the marginal effect of an independent variable z_k on the choice probability for alternative strategy *j* depends not only on the parameter β_{jk} but also on the mean of all other alternatives as shown in equation (10) Koch 2007 & Temesegn 2008).

$$\beta_k = \frac{1}{\sum_{j=1}^{J-1}\beta_{jk}} \quad (10)$$

In our case, *J* is the reference category for comparisons (it represents the choice of farm households not to use any crop adaptation strategy. Therefore, a positive parameter β_{jk} means that when an independent variable z_k increases by one unit from the mean, the relative probability of choosing adaptation strategy *j* increases relative to the probability of choosing alternative *J*. That is, the increase by a unit of the independent variable z_k from its mean value will increase the probability of choosing adaptation strategy j by β_{jk} relative to the baseline category J (not to use any adaptation methods). The parameters β can be estimated by maximum likelihood (Czepiel, 2007).

3. Study sites and data needs for the study

The data used for this study was derived from a farm household survey conducted during the period October–December 2010 by the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT). The sample covers a total of 899 farm households. A multistage sampling procedure was employed to arrive at the households from which the data was collected. First, based on their crop production potential, nine districts were selected from three regional states of Ethiopia namely: Benshaguel, Gumez, Oromia and SNNRP Regions. Based on proportionate random sampling, Peasant Associations (PAs) from each of the sampled districts and farm households from each PA were selected. A semi-structured questionnaire was prepared, and the sampled respondents were interviewed by experienced interviewers under close supervision by researchers from CIMMYT and EIAR.

4. Results and discussion

In this section, both descriptive and econometric results generated in this study are presented and discussed. In the first section, description of the variables used and their descriptive statistics are presented and discussed. In the second section, model results are presented and discussed.

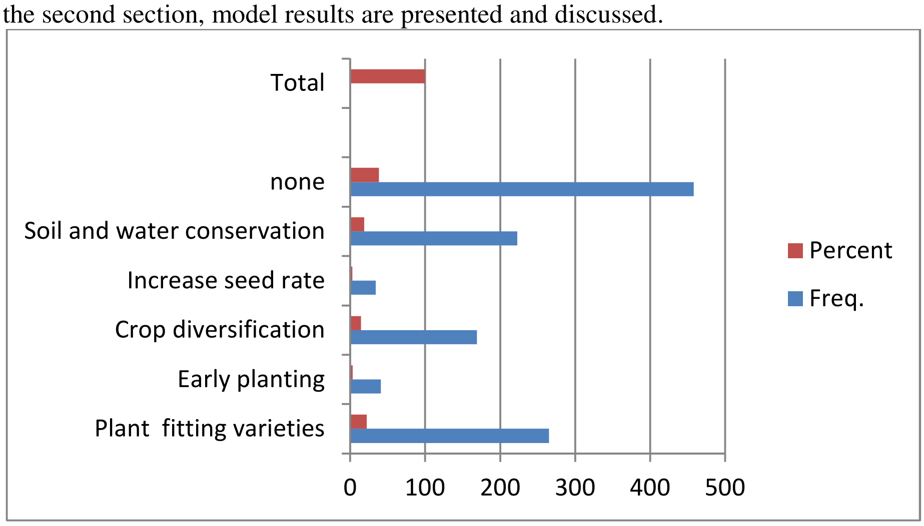

Figure 1. Adaptation strategies used to cope with the climate risk factors

The majority (about 52%) of the sampled farm households did not take any yield related strategy in any of their cropped plot. The most commonly practiced method of crop adaptation in the district was planting fitting seed varieties, whereas use of increasing seed rate was the adaptation method least practiced among the major adaptation methods. This could indicate that farm households had a better access to use fitting seed varieties, or it may be also due to the fact that farmers thought that practicing this method of adaptation is better in terms of optimizing their crop yields. Similarly, the reason for having less farmers practicing increased seed rate as a crop adaptation strategy could be the higher costs associated with buying more seeds. Alternatively, it could be also due to farmer´s perception that use of increased seed rate as a method of crop adaptation could result in less benefits in terms of maximizing crop yields.

4.1.3 Determinants of adoption options

On the basis of both economic theory and past empirical literature, this study identified some key explanatory variables in the econometric models developed and tested herein. This study divides factors (independent variables) that affect the decision of farm households to adopt\choose among crop adaptation strategies into four major types. These are climate change related risk factors, household characteristics, farm/plot characteristics, institutional and infrastructural level factors and social capital (Table 1).

Table 1. Description of variables and results of descriptive statistics

Variable Names	Variable description	Total sample		Adopter (48%)		Non-adopter (52%)	
		Mean	stdev	Mean	stdev	Mean	stdev
Dependet Variable							
Adaptation	Dummy: = 1 if a household adopt adaptation strategy and 0 otherwise	0.49	0.5	1	0	0	0
Explanatory variables							
Climatic risk factor							
Risk factor1	Farmers´ perception that they faced flood in the last production season : dummy takes value 1if yes and 0 otherwise	0.37	0.48	0.59	0.49	0.16	0.37
Risk factor2(reference category)	Farmers´ perception that they faced draught in the last production season : dummy takes value 1 if yes and 0 otherwise	.23	.42	.34	.48	.12	.33
Frequency of risk 1 in the last 10 years	Number of times a farmer perceived flood t in the last ten years	0.64	1.6	0.92	1.9	0.19	0.82
Frequency of risk 2 in the last 10 years	Number of times a farmer perceived draught in the last ten years	2.1	2.0	1.99	2.2	2.33	1.62
Household and household head characteristics ;-							
Family size	Total family size (number)	6.6	2.7	6.5	2.8	6.7	2.74
Education	Education level of household head (years of schooling)	3.86	3.3	3.3	3.5	3.6	3.5
Main Occupation	Dummy: 1 = farming and 0 otherwise	0.81	0.40	0.79	0.40	0.80	0.40
Climate change experience	number of times a house hold has been exposed to the risk factors in the last 10 years	2.9	2.2	2.5	1.6	2.8	2.0
Age	Age of household head (years)	41.0	13.0	42.1	13.1	41.4	13.12
Gender	Dummy: 1 = male and 0 otherwise	0.89	0.31	0.89	0.32	0.89	0.31
Marital status	Dummy: 1 = married and 0 otherwise	0.83	0.37	0.84	0.37	0.84	0.37

Income	Households total income per year(in birr)	14219	33853	10808	18802	12382	26861
Asset	Total material assets of a house hold (in birr)	18842	35015	17284	42643	18245	38108
Livestock ownership	Total number of livestock s a house hold has measured in TLU	2.6	2.54	2.3	2.5	2.5	5.52
Farm plot characteristics							
Soil/plot slope	Weighted average of all crop farms a household has	.097	.071	.1	.08	.098	.076
Soil fertility	Weighted average of all crop farms a household has	.12	.076	.123	.096	.120	.084
Soil depth	Weighted average of all crop farms a household has	.14	.01	.165	. .112	.15	. .01
Crop farm size	Total crop farm a household has(in hector)	9.2	9.6	9.5	6.3	9.3	8.5
Plot location	Distance from residence(measured in minutes)	16.3	21.4	15.9	17.5	16.2	20
Instutational and Infrusturactural access							
Information	Dummy: 1 if a household had information and 0 otherwise	0.56	0.50	0.42	0.50	0.51	0.50
Market access	Walking minute to input and output market	103.5	72.3	120.6	80.2	110	75.8
Agricultural extension access	Walking minute to the agricultural center	25.6	23	27.6	29.8	26.4	25.9
Confidence on the skills of extension workers	Dummy: 1= Complain and 0 otherwise	0.77	0.43	0.71	0.45	0.74	0.44
Cerdit constrain	Dummy 1= faced constrain and 0 otherwise	.059	.24	.068	.251	.062	.242
Social capital or social network							
Friends/relatives in government offices	Dummy: 1= have and 0 otherwise	.56	.5	.52	.5	.56	.5
Kinship	Number of friends/ relatives to ask support in time of needs	6.2	10.4	4.4	5.7	5.4	8.2
Membership to any farmer groups in the village	Dummy: 1= member and 0 otherwise	.48	.50	.30	.42	.41	.50

4.1.4 Climate change related risk factors

The environmental variables used in this study are incidences of droughts and floods; the sampled households were asked what climate change related risk factor they faced in the last production season and how many times they faced it in the last ten years. Accordingly, about 70 percent of the sampled households reported that they faced draught in the last production season while 26% reported they faced flood. The remaining 4 % reported that they faced both draught and flood in the last production season. The average occurrence (frequency) of draught in the last ten years for those households that used at least one adaptation strategy was about 2 and this for those that did not use any adaptation strategy was 2.3. The average flood experience in the last ten years for those that adapted was about 1 and this for non-adapters was about 0.2. This may imply that farmers were more responsive to flood than draught. These variables are important as they help give comprehendible signs of climate change at the farm level.

4.1.5 Household characteristics

Household characteristics considered in this study include family size, household head´s formal education level, main occupation, age, gender, marital status, income and asset and livestock holding. The results of the descriptive statistics show that there were remarkable differences between the average formal education, experience, income, asset and livestock holding of households that adopted and those that did not. The average formal education level of household heads (in years) that adopted at least one adaptation strategy in at least one of their cropped plots was about 4 while this declines to 3.3 for those that did not use any yield related adaptation strategy in any of their cropped plots. This may imply that households that have higher educational level had a better access to climate change information.

The average annual income from other activities of households that used crop adaptation strategy was about 14219 Ethiopian birr, this turns down to 10808 Ethiopian birr to those that did not use any crop adaptation strategy. The implication is that households with more annual income from other activities might have the financial capacity required to employ the adaptation strategies. The average asset of households that used crop adaptation strategy was about 18842 Ethiopian birr, this was about 17284 for those that did not adapt. The average livestock holding (measured by Tropical Livestock Unite (TLU)) to adapters was about 2.6 and this goes dawn to 2.3 for no adapters. These differences in the average asst and livestock holding between adapters and non-adapters may imply the importance of wealth to respond to climate change.

4.1.6 Plot characteristics

Plot level characteristics considered in this study include plot slope, soil fertility, soil depth, plot size and plot location. As households have different pieces of crop farms and each piece may have different plot characteristics, in this study the weighted average were taken for plot slope, soil fertility and soil depth. The weight was calculated based on the size of each crop plot. Accordingly, the descriptive statistics show that there was remarkable difference in the weighted averages of soil depth between adapters and non-adapters. The weighted average of soil depth to non-adapters was about 0.2 and this was about 0.1 for those that adapted. The implication is that the deeper the soil of a crop farm the less the interest of household to use crop adaptation on that crop farm.

4.1.7 Institutional and infrastructural access

This study also considered the importance institutional and infrastructural access to determine the capacity of stallholder farmers to adopt\choose among crop adaptation strategies. Institutional and infrastructural factors considered in this study include access to climate information, input and output market, agriculture extension and credit constrain. The descriptive statistics results show that regarding these there were notable differences between adapters and non-adapters. The average access to climate information (1=had access being the reference category) was about 0.6 for those households that adapted and this was about 0.4 for non-adapters. The average walking minute to the nearest input and output market for adapters was about 104 and this for non-adapters was about 121.

The average walking minute to the nearest agricultural extension center was about 28 for adapters and 30 for non-adapters. Since the confidence of household heads on the skills of agriculture extension workers is believed to affect the decision of households to use\or not to use the extension services farmers were asked if they had confidence. The result shows that the average confidence of adapters (1= had confidence is the reference category) was about 0.8 and for non-adapters this declines to about 0.7. To assess the availability of credit facility farmer households were asked if they had faced any constraint to obtain credit from government. Accordingly, the average credit constraint (1= had faced constraint is the reference category) was about 0.7 for non-adapters and 0.6 for adapters. Thus, the descriptive statistics results imply that institutional and infrastructural could affect the capacity of farmer households to adopt\choose among crop adaptation strategies.

4.1.8 Social capital

This study also tested the importance of social capital (social network) in determining the capacity of households to adopt\choose among crop adaptation strategies. Social capital in this study was represented by the availability of friends/relatives in government offices, the number of friends\relatives to rely for support in times of need and by household heads´ Membership to any farmer groups in the village. The average availability of friends/relatives in government offices (1= had friends/relatives in government offices is the reference category) was about 0.6 for adapters and 0.5 for non-adapters. The average number of friends\relatives to rely for support in times of need was about 6 for adapters and 4 for non adapters. The average membership to any farmers group found in the village (1= member is the reference category) was about 0.5 for adapters and 0.4 for non-adapters. Therefore, the findings imply that social capital (social network) could affect the capacity of smallholder farmers to adopt\choose among crop adaptation strategies.

4.2 Model results and discussions

A binary logit model was run to investigate the factors influencing adaptation to climate change in general. Table 2 reports the results from the logit model estimating the probability of a typical farmer undertaking adaptation to climate change in Ethiopia. The log-likelihood ratio test strongly rejects the null hypothesis: we therefore conclude that the variables included in the model explain the variation in the regressand.

Table 2. The estimated coefficients and marginal effects of binary logistic regression model

Dependent variable Climate change adaptation	Coefficient	Marginal effect (dy/dx)
Independent Variable		
Climate variables		
Past drought experience	0.11**(0.05)	.009** (.005)
Past food experience	0.11*(0.1)	.01** (.011)
Current Flood incidence	1.9***(0.35)	.32*** (.07)
Household and household head characteristics		
Family Size	0.003(2.9)	.0003 (.002)
Age	-0.01(0.07)	-.0007 (.001)
Education	0.007(2.4)	.0006(.002)
gender	0.34(0.3)	.033 (.034)
marital status	0.003(0.10)	.0002(.009)
main occupation	-0.023(0.047)	-.002(.004)
Asset	1.0(2.7)	8.5(.00000)
Income from other activities	8.8(2.4)	-7.4(.00000)
Livestock	0.08**(0.037)	.01**(.004)
Farm plot characteristics		
soil fertility	3.3**(1.7)	.28*(.18)
soil depth	-3.6**(1.2)	-.30**(.159
soil slope	1.1(1.6)	.093(.14)
plot size	-0.03***(0.011)	-.003**(.001)
Waling minutes to crop plot	-0.003**(0.004)	-.0002***(.0003)
Institutional and Infrastructural access		
climate information	0.34***(0.15)	.032**(.019)
walking minute to input\output market	-0.004***(0.001)	-.004** (.0002)
Walking minutes to extension center	-0.0002(0.003)	-.00002(.0002)
confidence on the skill of extension workers	0.14**(0.2)	0.13**(.02)
credit constraint	-0.014(0.33)	-.0012**(.028)
Social capital or social network		
Kinship	(0.036***)(0.012)	.003 (.002)
friends\relative in government office	-0.12*(0.1)	-.010**(.01)
Membership	0.63***(0.16)	.07***(.03)
_cons	-0.5(0.6)	
Observations	940	
Log likelihood	537.40363	
LR $\chi 2$ (25)	213.96	
(p-value)	0.0000	
Pseudo R2	0.1660	
Base rate		.90766009

Note:
Dependent variable is Undertaking any adaptation at all
Heteroskedasticity-robust standard errors in brackets;
, **, and * imply 10%, 5% and 1% significance levels respectively.*
Base category for current flood incident is current draught incident
(#) dy/dx is for discrete change of dummy variable from 0 to 1

The results of the logit model suggest that the probability of a typical Ethiopian farmer adapting to climate change increases with climate information, larger livestock number, a better soil fertility, the frequency of drought and flood experienced during the past 10 years, farmers´ confidence on the skills of government extension workers, larger kinship, and membership to farmers groups found in the village. The results also suggest that the probability of undertaking adaptation to climate change decreases with larger plot size, walking minutes required to arrive at the nearest input and output market, walking minutes required to arrive at crop plot from residence, credit constraint, and with having friends and relatives in government office position. Farmers located far from input and output market tends to do less adaptation compared with farmers located near to input and output market.

The logit model parameters are estimable up to a scaling factor. The coefficients of the logit model give the change in the mean of the probability distribution of the dependent variable associated with the change in one of the explanatory variables, but these effects are usually not of primary interest. The marginal effects on the probability of possessing the characteristic can be of more use. The marginal effects vary across individuals and in this case, indicate by how much the probability of a farmer undertaking adaptation to climate change changes with changes in the explanatory variables. Table 2 also reports the marginal effects.

The marginal effect for facing current flood incident is 32 percent. This implies that farmers who have faced flood in the last production season have a 32 percent higher probability of adapting to climate change above those who faced draught. The implication is that relative to those who faced flood the probability of undertaking climate change adaptation by farmers who faced draught decreases by 32 percent. This result implies that farmers are more active to respond to flood than draught. Farmers´ confidence on the skills of government extension workers largely increases the probability of adapting to climate change. Farmers who had confidence on the skills of government extension workers had 13 percent more probability to adapt to climate change than those who did not have confidence on the skills of government extension workers.

With respect to membership to any of farmers groups found in the village, farmers who are members of farmers groups were more likely to undertake adaptation to climate change than those who are not members of any farmers group found in the village. On average, being a member of any farmer groups found in the village increases the probability of adapting to climate change by 7%percent. Compared to farmers who did not have climate information those farmers who had climate information had higher probability to undertake climate change adaptation. Having climate information increases the probability of undertaking adaptation by 3.2 percent.

On average a 1 unit increase in livestock holding increases the probability of adapting to climate change by 1 percent. Farmers who had one additional livestock had a 1percent more probability to adapt to climate change. Similarly, having friends or relatives in government office position decreases the probability of adapting by 1 percent. Farmers who have friends or relatives in government office position had a 1 percent less probability to adapt to climate change than those farmers who do not have. Farmers who experience an additional flood incident have a 1 percent higher probability of adapting to climate change, and farmers who experience an additional draught incident have a 0.9% higher probability to adapt to climate change.

A one person increases of a farmer´s friends or relatives on whom the farmer can rely for support in times of need increases the probability of adapting to climate change by 0.3 percent. Credit constraint faced in the last production season decreases the probability of undertaking climate change adaptation strategy by 1.2 percent. Farmers who faced constraints to obtain credit had 1.2 percent less probability to adapt to climate change. On average a 1 hectare increases of a farmer´s crop plot decreases the probability of adapting to climate change by 0.3 percent. Farmers who had larger crop plot had less probability to adapt to climate change. Similarly a 1 minute increase of walking time to input and output market decreases the probability of adapting to climate change by 0.4%. Farmers who had to go an additional minute to arrive at the nearest input and output market had 0.4 percent less probability to adapt to climate change. On average a 1 minute increase required to arrive at a crop plot from farmers´ residence decreases the probability of adapting to climate change by 0.02 percent. Farmers who had to walk for 1 additional minute to arrive at their crop land had 0.02 percent less probability to adapt to climate change.

Undertaking some adaptation to climate change is a step in the right direction by farmers in Ethiopia since climate change occurs in the country. However, different adaptation methods have different effectiveness hence some methods might be preferred over others. Furthermore, particular adaptation methods might be more appropriate for particular crops or agro-ecological zones. The government can play a significant role by promoting adaptation methods appropriate for particular circumstances. In order to do so, the government would require information about the key drivers of the current choice of adaptation methods. This information gives two useful hints: the social characteristics of farmers who are likely to voluntarily adopt particular adaptation methods, and the environmental, institutional and economic conditions influencing their adoption of particular adaptation methods. The first set of information gives guidance in targeting farmers’ recruitment into initiatives aimed at enhancing adaptation to climate change using particular methods. The second set of information gives guidance about the environmental, institutional and economic conditions which need to be changed to promote particular adaptation methods.

We ran the multinomial logit model of a farmer's choice of a specific adaptation method to climate change. The results in **Table 3** indicate the parameter estimates and marginal effects from the multinomial logit model. The results show that the direction and the magnitude of the effect of different factors on farmer' choice of a particular adaptation method from up to five alternative adaptation methods used by Ethiopia farmers vary across the adaptation methods.

Table 3. Parameter estimates and marginal effects of explanatory variables from multinomial logit model

Dependent variables (Adaptation strategies)	Method1 Planting fitting seed varieties	Method 2 Soiland water conservation method	Method3 Crop choice method	Method 4 Early\late planting method	Method 5 Increasing seed rate method
explanatory variables					
Climate variables					
past drought incidents	0.18*** (.04***)	-0.22 (-.016*)	0.09 (.02*)	-0.05 (-.001)	-0.18 (-.003)
past flood incidents	0.24* (.034*)	0.2 (.01**)	0.15 (.01*)	0.13 (.001)	0.12 (.0004)
current flood incident	-0.9* (-.23***)	4.0*** (.64***)	-0.6 (-.15***)	0.2 (-.011)	1.1 (.004)
family size	0.011 (.0015)	0.002 (.0002)	0.02 (.003)	-0.03 (-.001)	-0.09 (-.001)
Age	-0.012* (-.002)	-0.01 (-.0004)	-0.01 (-.001)	0.2 (.01*)	-0.004 (4.9)
education	-0.002 (-.002)	0.01 (.0005)	0.01 (.001)	0.11* (.03*)	0.03 (.0004)
Gender	0.63* (.1*)	-0.15 (-.02)	0.03 (-.013)	-0.7 (-.03)	1.7 (.014*)
marital status	-0.2 (-.035)	0.35 (.025)	-0.15 (-.016)	0.17 (.005)	-0.4 (-.006)
main occupation	0.27 (.04)	-0.065 (-.012)	0.25 (.025)	-0.16 (-.007)	0.02 (-.001)
Asset	-1.24 (2.8)	1.8 (2.2)	-6.7 (-9.4)	2.0 (8.8)	-3.7 (-3.5)
income from other activities	6.8 (-5.3)	7.6 (3.2)	2.1 (2.4)	4.4 (9.7)	4.0 (-4.6)
Livestock holding	0.04 (.0025)	0.11** (.006*)	0.07 (.006)	-0.01 (-.001)	0.12* (.001)
soil fertility	3.6* (.25)	5.2* (.19)	4.1* (.28)	5.7 (.085)	28*** (.40***)
soil depth	-6.3*** (-.84***)	-2.1 (.045)	-5.0** (-.37*)	-2.3 (.01)	-13** (-.15*)
soil slop	1.8 (.39)	-0.6 (-.054)	1.1 (.16)	0.6 (.012)	-28.2*** (-.43***)
plot size	-0.03** (-.005**)	-0.023 (-.001)	-0.003 (.001)	0.04** (.002**)	0.015 (.0003)
walking minute to crop plot	0.005 (.0008)	-0.002 (-.0003)	0.004 (.0004)	0.01 (.0002)	-0.007 (-.0001)
climate information	0.5** (.05*)	0.51* (.02*)	0.53* (.05*)	0.2 (-.002)	0.80* (.008)
walking minute to input\output market	-0.004*** (-.0003*)	-0.002 (.0001)	-0.007*** (-.001***)	-0.1** (-.01*)	-0.003 (-3.8)
walking minute to extension center	-0.001 (-.000015)	-0.004 (-.0003)	0.001 (.0003)	-0.01 -.0003	-0.01 (-.0001)
confidence on extension workers	0.31* (.03*)	0.75** (.035**)	0.05 (-.022)	1.9** (	1.0* (.01*)

				.033***)	
credit constraint	-0.42 (-.09*)	0.7 (.063)	0.16 (.02)	0.6 (.02)	0.3 (.004)
kinship	0.054*** (.007***)	0.032* (.001*)	0.04** (.002*)	0.04* (.005*)	0.06*** (.001*)
friends\relatives in government office position	-0.021 (.016)	0.20 (.02)	-0.60*** (- .09***)	0.3 (.01)	-0.14 (-.0007)
membership	0.54*** (.04*)	1.3*** (.073***)	0.70*** (.06**)	0.8* (.011*)	-0.33 (-.0101)
_-cons	-1.31**	-4.0***	-0.46	-5.5***	-3.6*

Note:

Base category for adaptation methods is "No adaptation"

Base category for current flood incident is current draught incident

the numbers at the top of each sell are parameter estimates ; Marginal effects of explanatory variables are in bracts

*P values are represented by *, **, *** , which imply significance level at 10%, 5%, and 1% respectively*

(#) dy/dx is for discrete change of dummy variable from 0 to 1

4.3 Fitting seed varieties method

The results for Method 1 suggest that the probability of using "fitting seed varieties" relative to "no adaptation' increases with incidences of drought; incidences of flood; household head gender; soil fertility; climate information; number of friend\relatives to rely on for support in times of need; household head´s confidence on the skills of government extension workers; and household head´s membership to any of farmer groups found in the village. The results also suggest that the probability of using this method decreases with soil depth, current flood incidence, plot size, and credit constraints. While experiencing one more incident of drought results in a 4 percent higher probability of using fitting seed varieties, experiencing one more incident of floods results in a 3.4 percent higher probability of using this method. However, relative to current draught, current occurrence of flood decreases the probability of using seeding seed varieties by 23 percent. Farmers who faced flood in the last production season had a 23 percent lower probability to use fitting seed varieties method compared to those who faced draught in the last production season. Gender increases the probability of using this method by 10 percent. Households led by male had a 10 percent higher probability to use this method of adaptation. Climate information increases the probability of using this method by 5 percent.

Households that had climate information had a 5 percent higher probability of using this method of climate change adaptation compared with those that did not have information. Having an additional friend or relative who to rely on for support in times of need increases the probability of using fitting seed varieties method by 0.7 percent. Farmers' membership to any of farmers group found in the village also increases the probability of using this method by 4 percent. Farmers who are members of farmers group found in the village had a 4 % higher probability to use this method of climate change adaptation compared to those who are not member of any group found in the village. Famers´ confidence on the skills of government extension workers also increases the probability of using this method by 3 percent. Farmers who had confidence on the skills of extension workers had a 3 percent higher probability of using this method than those who did not have confidence. On average a 1 unit increase in weighted average of soil depth of farmers´ crop plot decreases the probability of adapting to climate change by suing fitting seed varieties method by 84 percent. Credit constraint decreases the probability of using fitting seed varieties method by 9 percent. Farmers who faced constraint to obtain credit had a 3 % decrease in probability of using this method compared to those farmers who did not face credit constraint. On average a 1 hectare increase of households´ crop farm size decreases the probability of using fitting seed varieties method by 0.5 percent. Similarly a 1 minute increase required to arrive at input and output market decreases the probability of using fitting seed varieties method by 0.03 percent. Farmers who are located near to input and output market had higher probability to use this method.

4.4 Soil and water conservation

The results for method 2 imply that the probability of using "soil and water conservation method' relative to "no adaptation' increases with current flood incidence, experience to past flood incidence, number of livestock, climate information, confidence on the skills of government extension workers, number of friends or relatives to rely on for support in times of need, and membership to any of farmers group found in the village. The results also suggest that the probability of soil and water conservation method relative to "no adaptation" decreases with past draught incidence, and current draught incidence. The marginal effect of flood incidence faced in the last production season was about 64 %. Famers who faced flood in the last production season had a 64 percent higher probability to use soil and water conservation method compared to those who faced draught in the last production season. On average famers who are the member of one or more farmers group found in the village had a 7.3 percent of higher probability to soil and water conservation method than those who are not the member of any farmers group found in the village.

Farmers who have confidence on the skills of government extension workers had a 3.5 percent higher probability to adapt to climate change using this method of adaptation than those who do not have confidence. Farmers with climate information had a 2 percent higher probability to use this method of climate change adaptation than those who were without climate information. On average, an additional livestock increases the probability of using soil and water conservation method by 0.6 percent. Farmers with an extra number of livestock had a 0.6 percent of higher probability to adapt to climate change using this method. Similarly, having an additional friend or relative on whom farmers can rely for support in times of need increases the probability of using this method by 0.1 percent. On average an additional experience to draught decreases the probability of using soil and water conservation method by 1.6 percent, while an additional experience to flood incidence increases the probability of using this method by 10 percent. Farmers who have 1 additional experience to draught incidence had 1.6 percent lower probability to use this method of adaptation, whereas farmers who have 1additional experience to flood incidence had a 10 percent higher probability to use this method. Relative to those farmers who faced flood incidence in the last production season, those farmers who faced draught in the production season had a 64 % lower probability to use soil and water conservation method. The implication of these results is that farmers are more interested to use this soil and water conservation method when they expect or face flood.

4.5 Crop choice method

The results from Method 3 show that the likelihood of using crop choice method relative to “no adaptation’ increases with past experience to draught and flood incidences, current draught incidence, climate information, number of friends\relatives to rely on for support in times of need and membership to any of farmers´ groups found in the village. The results also suggest that the probability of adapting to climate change by using crop choice method decreases with current flood incidence, soil depth, walking minute to input and output market and availability of friends or relatives in government office position.

While experiencing one more incident of drought results in a 2 percent higher probability of using fitting seed varieties, experiencing one more incident of floods results in a 1 percent higher probability of using this method. However, relative to current draught incidence, current flood incidence decreases the probability of using crop choice method by 15 percent. Farmers who have a extra exposure to draught had a 2 percent higher probability to use crop choice method, and farmers who have 1 extra exposure to flood had a 1 percent higher probability to use this method of adaptation. The implication is that farmers who have 1 extra exposure to any of the incidences in the past had higher probability to adapt to climate change using crop choice method. Yet, compared to the effect of current draught incidence, current flood incidence has a negative effect on the probability of using this method.

Farmers who experienced flood in the last production season have a 15 percent lower probability of using crop choice method compared with those who faced draught in the last production season. Farmers who are members of any farmers´ group found in the village have a 6 percent higher probability to adapt to climate change by using crop choice method than those farmers who are not members of any farmers´ group found in the village. Similarly, on average, farmers with climate information have a 5 percent higher probability to adapt to climate change by using crop choice method than those farmers without climate information. Having 1 extra friend or relative whom a farmer can rely on for support in times of need increases the probability of using crop choice method by 2 percent.

However, on average having any friend or relative in government office position decreases the probability of using crop choice method by 9 percent. Farmers who have one or more friends or relatives in government office position have a 9 percent lower probability of using crop choice method compared to those who do not have any friend or relative in government office position. Soil depth has the largest effect on the probability of adapting to climate change using crop choice method. A 1 unit increase in weighted average soil depth decreases the probability of adapting to climate change by suing this method by 37 percent. Farmers who have crop farms with soil depth increased by 1 unit had 37 percent lower probability of adapting to climate change using crop choice method. A 1 minute increase required arriving at input and output market decreases the probability of using this method by 0.1 percent. The implication is that farmers who are located far from input and output market have lower probability of adapting to climate change by using crop choice method.

4.6 Early or late planting method

The results from method 4 suggest that the likelihood of “changing planting dates’ relative to “no adaptation’ increases with household head age, education, plot size, confidence on government extension workers, number of friend or relative to rely for support in times of method also suggest that walking minute to input and output market results in decreasing probability of adapting to climate change by using this method of climate change adaptation. On average a 1 year additional age of household heads increases the probability of adapting to climate change by using early\late planting method by 1 percent. Similarly, a 1 year increase of a household

heads formal education increases the probability of using this method of climate change adaptation by 3 percent. Farmers with a 1 year more education have a 3 percent higher probability of adapting to climate change by changing planting dates. Confidence on the skills of government extension workers also increases the probability of adapting to climate change by using this method by 3.3 percent.
Farmers who have confidence on the skills of government extension workers have a 3.3 percent additional probability to use this method of adaptation than those who do not have confidence. On average a 1 hectare increase of farmers´ crop plot results in a 0.2 percent increases of the probability of adapting to climate change by using early\late planting method of adaptation. Similarly, 1 additional friend or relative on whom farmers can rely for support in times of need increases the probability of adapting to climate change by using this method by 0.5 percent, on average. Membership to any of farmers´ groups found in the village has the highest influence on the decision of households to adapt to climate change by using early\late planting method. Farmers who are members of any farmers group found in the village have 11 percent higher probability of adapting to climate change using this method of adaptation than those who are not members of any farmers group. On average a 1 minute increase in the walking time required to arrive at input and output market decreases the probability of adapting to climate change by using early\late planning method of adaptation by 10 percent. Farmers who had to walk for an additional 1 minute to arrive at the nearest input and output market have a 10 percent lower probability to adapt to climate change by changing planting dates. The implication is that farmers who are located near to input and output market have higher probability of adapting to climate change by changing planting dates.

4.7 Increasing seed rate method

The results from Method 5 show that the probability of increasing seed rate as an adaptation method to climate change relative to "no adaptation' increases with climate information, soil fertility, gender, confidence on the skills of government extension workers, and number of friends or relatives whom farmers ask support in times of needs. The results from this method also show that the probability of using increasing seed rate decreases with soil \plot slope and soil depth. Having climate information increases the probability of adapting to climate change by using increasing seed rate method by 80 percent.
Framers with climate information have a 80 percent higher probability to adapt to climate change by using this method than those farmers who are without climate information. A 1 unit increase in the weighted average of soil fertility also increases the probability of adapting to climate change by using increasing seed rate method by 40 percent. On average households led by men have a 1.4 percent higher probability of adapting to climate change by using this method than those households led by women. Farmers with confidence on the skills of government extension workers have a 1 percent higher probability of adapting to climate change by suing increasing seed rate methods than those who do not have confidence on the skills of government extension workers. 1 additional friend or relative whom farmers can depend on for support in times of need increases the probability of adapting to climate change using this method by 0.1 percent. On average a 1 unit increase in soil \plot slope of farmers´ crop plot decreases the probability of adapting to climate change by using increasing seed rate method by 43 percent. Similarly, a 1 unit increase of soil depth of farmers´ crop plot decreases the probability of adapting to climate change by using this method by 15 percent.

5. Conclusions

The main purpose of this study was twofold, namely to analyze factors that limit the decision of smallholder farmers to adapt at all to climate change in their crop agriculture activities, and to investigate factors influencing their choice of particular adaptation households to climate change. The study collected and analyzed data from 898 randomly selected smallholder farming households from three regional states of Ethiopia: Benshanguel, Oromya and Southern nations and nationalities regional states. It included 9 representatives administrative districts selected based on their crop production potential. Farmers were asked which climate change related risk factors they faced in the last production season, and they were asked if they had taken any crop adaptation strategy to counteract the negative effect of the risk factors on their crop yields. Accordingly, about 70 percent of the sampled households mentioned that they faced draught, while 26 percent mentioned they faced flood in the last production season. The remaining 4 percent indicated that they faced both draught and flood in the last production season. The survey instrument also show that about 52 percent of the sampled households did not take any yield related climate change adaptation strategy to minimize the negative effect of climate change related risks on their crop yields.
To analyze the data, two models (binary logit and multinomial logit regression models) were used. The results of the binary logit model of a famer's decision to undertake any adaptation at all to climate change suggest that the probability of undertaking any adaptation increases with climate information, larger livestock number, a better soil fertility, the frequency of drought and flood experienced during the past 10 years, farmers´ confidence on the skills of government extension workers, larger kinship, and membership to farmers` groups found in the village. The results also suggest that the probability of undertaking adaptation to climate change at all decreases with

larger plot size, walking minutes required to arrive at the nearest input and output market, walking minutes required to arrive at crop plot from residence, credit constraint, and with having friends and relatives in government office position.
Farmers were also asked to mention the strategy they used to counteract the negative effect of climate change on their crop yields. Accordingly, they indicated that they used fitting seed varieties, soil and water conservation, fitting crop varieties (crop choice), changing planting dates (early\late planting) and increasing seed rate as the methods they have used to deal with the climate change. The study used a multinomial logit model to investigate the factors influencing farmers' choice of specific adaptation methods. The probability of using "fitting seed varieties" method relative to "no adaptation' increases with incidences of drought; incidences of flood; household head gender; soil fertility; climate information; number of friend\relatives to rely on for support in times of need; household head´s confidence on the skills of government extension workers; and household head´s membership to any of farmer groups found in the village. The results also suggest that the probability of using this method decreases with soil depth, current flood incidence, plot size, and credit constraints. The probability of using "soil and water conservation method' relative to "no adaptation' increases with current flood incidence, experience to past flood incidence, number of livestock, climate information, confidence on the skills of government extension workers, number of friends or relatives to rely on for support in times of need, and membership to any of farmers group found in the village. The results from this method also suggest that the probability of soil and water conservation method relative to "no adaptation" decreases with past draught incidence, and current draught incidence.
The likelihood of using "crop choice" method relative to "no adaptation' increases with past experience to draught and flood incidences, current draught incidence, climate information, number of friends\relatives to rely on for support in times of need and membership to any of farmers´ groups found in the village. The results also suggest that the probability of adapting to climate change by using crop choice method decreases with current flood incidence, soil depth, walking minute to input and output market and availability of friends or relatives in government office position. The probability of "changing planting dates' relative to "no adaptation' increases with household head age, education, plot size, confidence on government extension workers, number of friend or relative to rely for support in times of need , and membership to any of farmers´ groups found in the village. The results from this method also suggest that walking minute to input and output market results in decreasing probability of adapting to climate change by using this method of climate change adaptation. Finally the results from the multinomial logit model show that the probability of using "increasing seed rate "as an adaptation method to climate change relative to "no adaptation' increases with climate information, soil fertility, gender, confidence on the skills of government extension workers, and number of friends or relatives whom farmers ask support in times of needs. The results from this method also show that the probability of using increasing seed rate decreases with soil \plot slope and soil depth.
The results from both models imply that the first and foremost role that the Ethiopian government needs to occupy itself with surrounding the effects of climate change on smallholder agriculture is to help smallholder farmers overcome constraints they face in taking up adaptation to climate change. The government needs to improve farmers´ access to climate information, input and output market, credit facilities, agriculture extension services, and education. Furthermore, the government needs to facilitate informal social networks among smallholder farmers. The governments can also play a significant role by promoting adaptation methods appropriate for particular climate change related risks e.g. draught or flood.

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