# Determinants of smallholder farmers' adaptation strategies against climate change stresses in Raya Azebo District, Northern Ethiopia: Multivariate analysis

**Haftu Kelelew[1], Jema Haji[3] and Abbadi Girmay2**

[1]Abergelle Agricultural Research Center, P. O. Box 44 AbiAdi, Northern Ethiopia

[2]Tigray Agricultural Research Institute, P. O. Box 492 Mekele, Northern Ethiopia

[3]School of Agricultural Economics and Agri business, Haramaya University, P. O. box 138 Dire Dawa, Ethiopia. P. o. box 138 Dire Dawa, Ethiopia

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Abstract

Climate change is a threat to the environment as the whole and to agriculture in particular. It aggravates drought, pests, diseases, and other related environmental shocks and impacts the dimension of food security. This study has been depended on cross-sectional data that was collected from 155 sample households from November to December, 2016. Thus, the main objective of the study was to identify determinants of farmers' adaptation strategies to climate change in Raya Azebo district, Northern Ethiopia, and SML estimator of Mvprobit model was employed. Based on the model output, the predicted probability of the farmers to adopt agro forestry, soil and water conservation, small scale irrigation, adjusting planting/sowing date, improved technologies and temporary migration were 44.2%, 56.5%, 45.8%, 48.7%, 51.3% and 47.4% respectively. Furthermore, sex, literacy status, agro- ecology, family size, land holding, livestock number, access to climate information, extension contact, age, on-farm income, off/non-farm income, and market distance are identified as significant factors affecting CCAS in the study area. Therefore, policy should focus on awareness creation on climate change through different sources, strengthen adult education service, opening up other options and strengthen family planning programs to build up adaptive capacity against climate change anxieties.

**Key words:** Adaptation strategy; climate change;Mvprobit; Raya Azebo

## INTRODUCTIO

In Ethiopia, agriculture accounts about 42 percent of the GDP, employs about 85 percent of the labor force and contributes around 90 percent of the total export earnings of the country. The sector is dominated by over 15 million smallholders producing about 95 percent of the national agricultural production (CSA, 2016). This shows that the overall economy of the country and the food security of the majority of the population depend on small holder agriculture. The growth of agricultural sector is taken as an engine and the last resort to take-off the national economy. Food security issues in Ethiopia are extremely complex because of large variations across space and over related to agro ecologies, weather shocks, widespread poverty, and economic governmental policies, and other factors. It is often perceived as a country of drought stagnation (Dorosh and Rashid, 2012). Abbadi*et al*. (2013) explained that the Ethiopian climate has shown a drastic spatiotemporal climate change from 1946 to 2006 which evident the impact of global warming at local climatic condition. Climate change impacts the four key dimensions of food security: - availability, stability, accesses, and utilization. Availability of agricultural product is affected by directly through its impact on crop yields, crop pests and diseases, and soil fertility and water holding properties. In addition stability of crop and food supplies, physical, economic and social accesses to food is affected by Climate Change (CC) as agricultural product declines (Edan*et al.*, 2011).

The Ethiopian climate is characterized by a history of climate extremes, such as drought and flood, and increasing and decreasing of temperature and precipitation, respectively, and this history, especially drought is not new phenomenon in Ethiopia (ACCFP, 2010). The production sectors are among the most important units from the perspective of economic impacts of climate change. Understanding the impact of climate change is very essential since developing countries generate the major portion of Gross Domestic Product (GDP) from the agricultural sector (Dorosh and Rashid, 2012). A larger segment of population in Ethiopia are chronically and seasonally food insecure because of recurrent drought, and Ethiopia's vulnerably to climate change is hand in hand with poverty, although some regions of the country are more vulnerable other than ( Nigus, 2011).

Ethiopia is already suffering from variability and extremes of climate. Climate change is therefore a threat to the Ethiopian economy and livelihoods of millions of the poor. The available option for Ethiopia to reduce the wide-ranging impacts of climate change is to adapt to changing climate. Addressing long-term climate change is thus required to reduce the impacts on livelihoods in general and major economic sectors such as agriculture, which is the mainstay of the country. Ethiopia is expected to be hardest hit by climate change and the most vulnerable sectors are agriculture, water resources and human health. It is predicted that climate change could lead to increased water stress, overall reduction in agricultural productivity and yields, and expansion of vector habitats (spatial ecology) of diseases such as malaria. Climate change can significantly reverse the progress towards poverty reduction and food security in Ethiopia (Abbadi, 2015).

In Raya Azebo district, temperature is increasing from time to time. Drought (is recurring at short intervals) and floods are the two major climate related hazards. Population growth, increased settlements and expansion of cropping land, thus changing the environment into hot and dry conditions, deforestation resulting from charcoal burning and other uses, cultivation of steep slopes and hilltops without appropriate soil and water conservation measures and increasing livestock pressure on grazing lands and the traditional grazing land management system i.e. free grazing are the characteristics of the district (CCAFS, 2015). Thus, Farmers are trying adapt different mechanisms to reduce the negative influences of climate change. This study aimed to identifyfactors that affects smallholder farmers' adaptation strategies against climate change stresses in Raya Azebo district, Northern Ethiopia.

## Research Methodology

The study district is characterized by having a bimodal type of rainfall pattern with light rains during the February to April period and heavy rains between Julys to September. The mean annual rainfall is about 724 mm with range of 400-700 mm per annum.Based on the Ethiopian central statistics Agency population census report (2007), the total population of thedistrict is 137,870, of whom 68183 (50.2%) are women and 67687 (49.8%) are men.The study used cross-sectional data that was collected from 155sample farm households fromNovember to December, 2016 which were selected from fourKebeles, Two stage sampling procedure was employed to draw sample households. In the first stage, kebeles[1] of the district were stratified into two strata on agro ecology basis, lowland (kola) and dry midland (woinadega), and of these agro ecologies 1 and 3 Kebeleswas randomly selected from 4 low land("Kola") and 14 mid land ("Woinadega") kebeles respectively. In the second stage, a total of 33 from lowland and 122 household heads from midland of farm households wereselected from each strata using Proportional Probability to Size (PPS).

[1]The smallest administration unit with its own jurisdiction

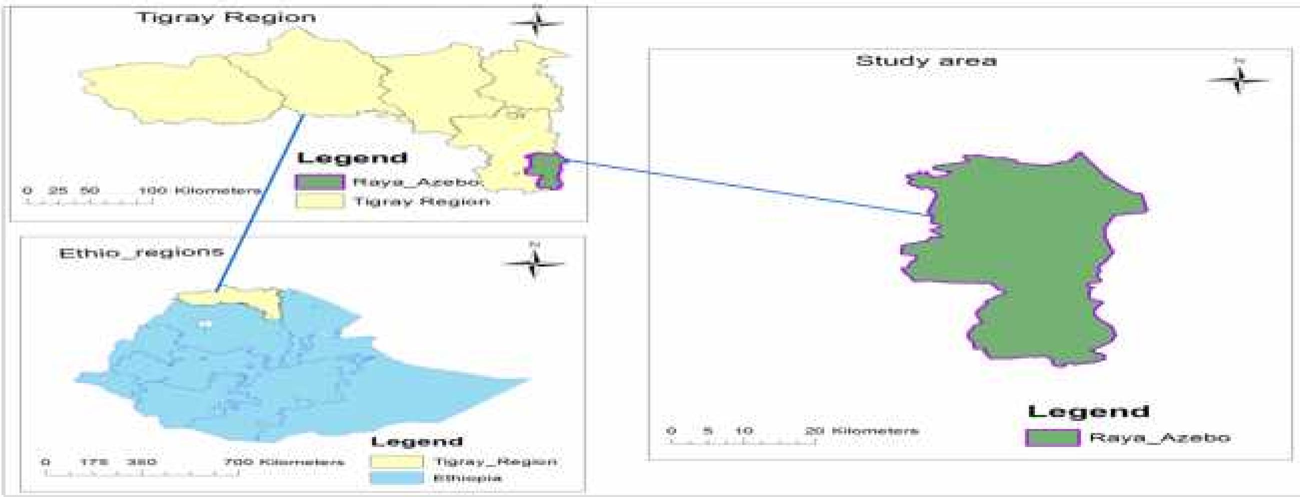


Figure 1: Location of the study area

**Econometric Model**

In this study, Multivariate probitregression model was employed to analyze an individual's decision over a set of alternatives and the determinants of farmers' choice of adapting strategies in the study area. Data were analyzed using STATA version13 statistical software package.The multivariate probit model assumes that each subject has N distinct binary responses, and amatrix of covariates that can be anymixture of discrete and continuous variables. Specially, let $Y_i = Y_{i1}$….., $Y_{iN}$, denote the Ndimensional vector of observed adapting strategies 0/1 responses on the $i^{th}$ subject, i= 1…, n let $X_i$ be a N×P design matrix which is vector of independent factors, and $Z_i = Z_{i1}$…, $Z_{iN}$denote N variate normal vector of latent variables such that

$Z_i = X_i \quad + £_i, i = 1...N$ (1),The relationship between $Z_{ij}$ and $Y_{ij}$in the multivariate probit model is given by

$Y_{ij} = 1$ If $Z_{ij} > 0$, 0 otherwise (2) , Where j= 1,2…N denotes availability of climate change adaptation strategy and $X_i$ is vector of explanatory variables, $\beta_i$ denotes the vector of parameter to be estimated, and $\epsilon i$ are vector of residual error distributed or random error terms distributed as multivariate normal distribution with zero mean and unitary variance. It is assumed that a rational $i^{th}$ farmer has a latent variable, Zij which captures the unobserved preferences or demand associate with the $j$th choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term (A.Tabet. 2007).

## Results and Discussion

### Adaptation Strategies against Climate Change in the Study Area

The descriptive analysis result revealed that sampled households of the study area respond to change in climate stresses by using mutually inclusive adaptation strategies such as agro forestry, soil and water conservation practice, small scaled irrigation, improved crop and livestock varieties, adjusting planting/sowing date and seasonal migration as climate change major adaptation strategies (Table 1).

Table 1: type of adaptation strategies against climate change in the study area

| Type of strategy | Number of sample | Percent (%) |
|---|---|---|
| Agro-forestry | 68 | 43.9 |
| Soil and water conservation | 87 | 56.5 |
| Small-scale irrigation | 71 | 45.8 |
| Adjusting planting date | 75 | 49.3 |
| Improved varieties | 79 | 51 |
| Temporary migration | 73 | 47.1 |

### Predicted and joint probability

Result of Multivariate probit model has shown that the predicted probabilities to adopt agro- forestry, soil and water conservation, small- scaled irrigation, adjusting planting/sowing date, improved varieties and temporary migration were 44.2%, 56.5%, 46.1%, 48.7%, 51.3% and 47.4% respectively. Moreover, farmers of the study area can be succeed in adapting all adaptation strategies and fail to adapt all strategies at a time is probably 2.19% and 2.74% respectively (Table2).

Table 2: Multivariate probit simulations results for households' CCAS

| Explanatory variables | Agro-forestry | Soil and water conservation | Small-scale irrigation | Adjusting planting date | Improved varieties | Temporary migration |
|---|---|---|---|---|---|---|
| | Coefficient (Robust Std.Er) | Coefficient (Robust Std.Er) | Coefficient (Robust Std.Er) | Coefficient (Robust Std.Er) | Coefficient (Robust Std.Er) | Coefficient (Robust Std.Er) |
| Intercept | -6.99(2.594)*** | -3.354(2.575) | -4.806(2.639)* | -5.393(2.317)** | 1.234(0.909) | -0.394(2.382) |
| Agro-ecology | 0.220(0.344) | -0.202(0.298) | -0.640(0.296)* | 0.638(0.326)* | -0.397(0.293) | 0.012(0.271) |
| Sex of hh | 1.271(0.362)*** | 0.968(0.330)*** | 1.505(0.357)*** | 0.750(0.320) | -0.538(0.311)* | -0.368(0.309) |
| Education level | -0.034(0.044) | 0.078(0.042)* | 0.018(0.042) | 0.072(0.042) | 0.108(0.043) | -0.024(0.039) |
| Livestock size | -0.014(0.017) | 0.036(0.022)* | -0.019(0.018) | 0.032(0.017)* | 0.031(0.018)* | -0.044(0.018)** |
| household size | 0.090(0.079) | 0.314(0.086)*** | -0.008(0.074) | -0.039(0.070) | 0.017(0.072) | 0.174(0.074)** |
| Landholding size | 0.518(0.297)* | -1.10(0.29)*** | 0.146(0.273) | -0.305(0.269) | 0.125(0.266) | 0.105(0.259) |
| Credit access | -0.030(0.374) | 0.290(0.361) | -0.462(358) | -0.215(0.339) | -0.293(0.367) | 0.162(0.340) |
| Market distance | -0.005(0.011) | -0.024(0.012)* | 0.004(0.011) | 0.022(0.010)* | -0.047(0.011)*** | -0.022(0.010)** |
| Extension | 0.206(0.164) | -0.046(0.140) | 0.072(0.039)* | 0.101(0.036)*** | 0.265(0.134)** | -0.07(0.038)* |
| information | 0.259(0.273) | 0.477(0.286)* | 0.161(0.258) | 0.452(0.27)* | 0.479(0.264)* | -0.4600.252)* |
| On-farm income | 0.117(0.006)** | 0.151((0.059)** | 0.469(0.260)* | 0.080(0.528) | 0.429(0.220)** | 0.476(0.542) |
| Off/farm income | 0.166(0.042)*** | -0.646(0.276)** | -.098(0.031)*** | 0.075(0.249) | 0.228(0.238) | -0.148(0.245) |
| Age of hh | -0.058(0.023)** | -0.032(0.016)** | -0.009(0.019) | 0.009(0.016) | -0.025(0.017) | -0.013(0.016) |
| Rho2 | -0.346** | | | | | |
| Rho3 | 0.111 | 0.306** | | | | |
| Rho4 | 0.091 | -0.297** | -0.333** | | | |
| Rho5 | -0.065 | 0.359*** | 0.241* | -0.061 | | |
| Rho6 | 0.314** | 0.165 | -0.164 | 0.318** | 0.111 | |
| Predict probability to adapt | 0.442 | 0.565 | 0.461 | 0.487 | 0.513 | 0.474 |

Joint probability (success) =0.0219 Joint probability (failure )= 0.0274

Likelihood ratio test of Rhoij=0, chi2 (15)= 37.24, prob>chi2= 0.001

Draw number= 100 No of observation = 155 Wald chi2(78)= 506.48 Log likelihood= -497.86

*, **, and *** show levels of significance at 10%, 5% and 1%, respectively.

Source: model output based on survey result, 2016

**Determinants of adaptation strategies of climate change in of the study area**

Results of the model indicated that there are different factors that affect the probability of selecting adaptation strategies to climate change.

The results conveyed that all explanatory variables which are included in the study except access to credit significantly affect the adaptation strategies against Climate change stresses in the study area. (Table2). The significant factors are discussed as follows:

**Agro ecological zone (AGREC)**

Agro- ecology is one of the main factors that determine opting strategies to climate change in the study. The model outputs revealed that agro-ecology was negatively and significantly affectsmallholder farmers' decision to use small-scale irrigation as coping option. Farmers in woinadega agro- ecological zone were less likely than farmers who were living in kola in using small scale irrigation as option to cope up with climate change This might be relate to differences in natural of resources, evapotranspiration and soil type. Farmers in kola agro ecological setting are expected to invest more on small scaled irrigation in order to minimize the moisture stress and shortage of rainfall. In line with this finding, Gebre*et al.* (2015) reported that as compared to Kola, farming communities in "Woinadega" deceases to use irrigation, and soil and water conservation, but increase in using different crop type s and/or varieties in Tigray, Northern Ethiopia.

**Sex of the household head (SEXHH)**

The sex of the household head is significantly and positively affectsadaptation of agro- forestry, soil and water conservation and small- scaleirrigation. Male headed sample households are more likely to use more strategies as compared to female headed households.This might be due to the fact that women may have limited access to information, land, and other resources due to traditional social barriers or due to the large involvement of the female in housing activities. This result in line with that of Ajibefun and Fatuase (2010), and Temesgen et al. (2010). Furthermore, Belaineh*et al*. (2013) reportedthat male headed sample households are more likely to select and use diversified crop and soil and water conservation as adaptation strategy to lessen the holistic effect of climate change as compared to female headed households in the face of an ever increasing pressure on grazing resources and prevalence of severe shortage of animal feed.

**Educationallevel of the household head (EDUHH)**

This variable significantly and directly affected use of soil and water conservation practices.Thus, education increases the use of soil and water conservation practices as adaptation mechanism to the change in climate. This might be education distinct individual’s with the necessary knowledge on how to access information in climate change. Because higher level of education isdirectly related with access to information on improved technologies and higher productivity (Norris and Batie, 1987). The model output is also in line with the result of Aschalew (2014),Gebre*et al. (*2015), and Dirriba and Jema(2015) who explained that farmers with higher level of education were more likely to adapt with different adaptation options to the change in climate. Seid*et al*. (2016) also suggested that literacy status of farm households’ increases awareness about the consequences of climate change on productivity and benefit of crop production and soil and water conservation practices to reduce impacted of climate change.

**Livestock ownership size in TLU (LISTOW)**

The model results indicated that the size of livestock holding in TLU is found to affect positively and significantly the use of soil and water conservation practice, adjusting planting date and improved varieties. Farmers with large herd size have better chances to invest on tools required for conservation practice (Seid*et al.*, 2016). This result is also similar with Temesgen(2010),Belaineh*et al* (2013), Aschalew (2014) and Kide (2014). But livestock size has a negative and significant impact on use of temporary migration as adaptation strategy. This might be due to that livestock size play a great role in increasing food security by serving as source of food, income and traction andas assetsin order to stay stabled the households in their local area.Wassie and Fekadu (2015) explained that household’s mobility from one location to other location is significantly determined by livestock ownership as option choice in pastoralists of southern part of Ethiopia.

**Family size (FSIZE)**

Family sizehas positive and significant impact on the likelihood of using soil and water conservation practice as an adaptation strategy. The reason might be that families with higher number of members may have the probability of work division between them in order to handle soil and water conservation as an adaptation mechanism. This finding is consistent with Temesgen*et al*. (2008). Furthermore, Seid*et al*. (2016) stated that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks which are labor intensive such as diversifying farm products, using irrigation agriculture and using new varieties of different crops which require new farm operations.Similarly, family size has shown positive and significant association with temporary migration as coping option. This means that unit increase in family size will aggravate the migration to urban and Arab countries. The reason might be households with higher family size are forced to migrate to fulfill the household basic necessities as compared to families with lower household size.

**Land holding size (LAHSIZ)**

This variable significantly and positively affected use of agro forestry as an adaptation strategy. Farm size is always associated with greater wealth, more capital and resources and those families with such large land holding have an opportunity to formal and non-formal credit service accesses, and the ability to take risk regarding to climate change decisions (Lemmi, 2013; Aschalew, 2014). However, land holding size has shown negatively and significantly association with soil and water conservation practice. The reason might to due to fact that farmers with more land holding can benefit from the economics of scale of it as compared to those who had small land holding size. This result is consistent withLemmi (2013) and Aschalew (2014).

**Distance of market from home stead (MARKD)**

This variable significantly and negatively affected use of improved varieties (crop and livestock) and temporary migration as opting mechanism.The possible reason is households nearer to the market use improved varieties as opting strategy because they may access information on improved varieties to use it as an adaptation strategy against climate change stresses. This finding is similar with that of Temesgen (2010) and Aschalew (2014). Moreover, Seid*et al*. (2016) explained that when farmers are far from market center, the transaction cost for acquiring input and output will be high and this will, inturn, reduces the relative advantage of adopting new technologies

**Frequency of extension contact (FREX)**

The output of the model revealed that number of extension contact was significantly and positively affected use of small scale irrigation practice and improved crop and livestock varieties as coping mechanism.The reason might be that farmers with higher extension contact have more information on climate change in order to takemechanisms by using improved crop and livestock varieties (early mature, drought tolerant, and pests and diseases tolerant) and irrigation to supplement the low precipitation. This finding was found to be consistent with Temesgen*et al*. (2010). Moreover,Aymone (2009) had indicated that access to extension service increases the probability of perceiving the climate change and increase the likelihood of uptake of adaptation techniques. Similarly Nhemachena*et al*. (2014) reported that farmers who have higher extension contacts have better chances to be aware of change in climatic conditions and also have various management practices that they can use to adapt to climatic conditions. On the other hand extension contact was inversely and significantly related with adjusting planting date and temporary migration. Farmers with higher extension services are lesser likely to migrate from their homeland to other areas. This might be helped them to participated in other adapting strategies such as non-farm and off-farmactivities, small scale irrigation (to reduce moisture stress effect) and soil and water conserving practice to enhance their farm productivity. Similarly,those households with better extension service have less probability to adopt adjusting planting/sowing date in the study.

**Access to climate change information (ACINF)**

This variable has shown positive and significant association with soil and water conservation, adjusting planting/sowing date and improved varieties as coping options. This might be due to the fact that access to extension contact, access to media, networks and climate change forums. In agreement with this finding, Madison (2006) had indicated that access to climate information increases the probability adjusting planting date and harvesting time, decision on choice of variety and time of fertilizer application, practicing soil and water conservation and planting more trees at plot level. Madison also expressed that access to climate information on climate change through extension agents or other sources creates awareness and favorable condition for adoption of farming practices that are suitable under climate change also it is an important precondition for farmers to take up adaptation measures.

Further, access to climate change information has inversely and significantly influence on temporary migration. The possible reason might be during amusingfuture climatic condition, farmers with more access to climate information of their local area areless likely to migrate temporarily to other locations.

**On-farm income (lnFARIN)**

As expected, the model result revealed that on-farm income had positive and significant impact on use of agro forestry, soil and water conservation, small- scale irrigation and improved varieties (crop and livestock) as adapting strategies. This has shown that farmers with higher on-farm income are more likely to adapt agro-forestry, soil and water conservation practice, small scale irrigation and improved varieties in study area. The reason might be due that farmers with higher on-farm income may have the ability to invest on agriculture inputs (irrigation materials, improved seeds) and human power (employing daily laborer in conserving soil and water, and irrigation actives). This finding is also similar with Kide (2014), Seid et al. (2016) and Gebre*et al*. (2015)

**Non/off- farm income (lnOFFAR)**

This variable negatively and significantly impacted the soil and water conservation, and small- scale irrigation as adaptation strategies in study area. Farmers with lower non/off-farm income have higher probability to adapt soil and water conservation practice, and small- scale irrigation. The possible clarification could be farmers with less non/off-farm activities may have higher possibility to invest more time on agricultural activities in order to reduce the impact of the change and variability in climate. In line with this result, Aschalew (2014) stated that the farmers' income from non-farm activities increased they devote less and less time for farming activities hence it could negatively affect the farmers' climate change adaptation decision. However, non/off-farm income has shown positively and consistently relationship with agro forestry as an adaptation strategy. The reason might be farmers with higher off/non-farm income may have additional financial power in order invest on planting trees to maintain and enhance their farm productivity. In line with result, Aymone (2009) and Seid et *al*. (2016) reported that availability of off /non-farm income improves farmers' financial position, which, in turn, enables them to purchase farm inputs such as, seed and fertilizer.

**Age of household head (AGEHH)**

Age matters in any occupation and rural households mostly devote their live time or base their livelihoods on agriculture and it is believed that the older the household head, the more experience he has in farming and climate change forecasting. Opposite to the expectation, the model output showed that this variable negatively and significantly associated with agro forestry at p<5% probability level. Moreover, this variable inversely and significantly related to soil and water conservation activity to reduce the adverse effects of climate change in the study area. The possible reason might be, farmers are expected to make stone bunds, ridging, mulching, conservation agriculture and manure application as soil and water conserving mechanisms which are labor intensive.Therefore, aged farmers may lack to perform such activities due to being aged. This finding is in agreement with Mulwa*et al*. (2015). Furthermore, CCAFS (2015) reported that developing countries such as Ethiopia are highly vulnerable to climate change impacts due to underdevelopment and widespread poverty, thus limiting their capacity to adapt; elder, women, and disable communities in arid and semi-arid areas lack to adapt different strategies to lessen the negative effects of climate change.

## Conclusionand Recommendations

In the study area, climate change adaptation options used by the sampled households are agro forestry, soil and water conservation practice, small scale irrigation, adjusting planting/sowing date, improved varieties (crop and livestock) and temporary migration (urban and Arab countries).

The result of Mvprobit model has shown that the probability to adopt agro forestry, soil and water conservation, small- scale irrigation, adjust planting/sowing date, improved varieties (crop and livestock) and temporary were 44.2%, 56.5%, 46.1%, 48.7%, 51.3% and 47.4%respectively. The result also indicated that the joint probability of success and failure to adopt all of the adaptation strategies were only 2.19% and 2.74% respectively.

The model results also confirmed that agro-ecology, sex, education, livestock size, family size, land holding size, market distance, extension contact, accesses to climate information, on-farm income, off/non-farm income and age are the significant determinants of adaptation strategies against climate change anxieties in the study area.

Therefore, policies and programs should focus on level of literacy status of the families(to improve their awareness of the climate change), formulate different information opportunities such as local climate forums, networks, accessing to media centers and strengthen the farmers training centers. Furthermore, policies should give better attention to family planningin order to optimize the number of individuals per households and to enhance the food security of each individual household by adapting other climate opting mechanisms. Moreover, climate change adapting options should involve opportunities to diversify livelihoods to include less climate sensitive strategies. For instance, off-farm and non- farm activities. Programs must therefore give different strategies and focus efforts on opening up the options available to farm households to enable adaptive management of livelihoods.

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