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Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Assosa District, Western Ethiopia

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Abstract

This study identified farmers' choice of and factors determining adaptation strategies to climate change in Assosa district, western Ethiopia which is severely affected by climate change stresses. Both primary and secondary data were used for the study. Primary data were collected from a randomly selected 140 sample households through interview and focus group discussions. Relevant secondary data were also obtained from Assosa district office of agriculture, national metrology agency and different reports. Descriptive statistics were used to describe farmers' adaptation strategies to climate change. Multivariate probit model was estimated to identify the factors determining households' choice of adaptation strategies to climate change. The results of the model pointed out that the likelihood of households to adopt irrigation, improved varieties of crops, adjustment of planting date, crop diversification and soil conservation practices were 52.3%, 45.8%, 49.5%, 46.9% and 34.1%, respectively. The results also indicated that the joint likelihood of using all adaptation strategies was only 1.5% and the joint likelihood of failure to adopt all of the adaptation strategies was 3.5%. Moreover, Multivariate probit model confirmed that sex, literacy status, farming experience, family size, land holding, access to credit, access to media, extension contact, farmer to farmer extension, farm income, off/non-farm income, livestock ownership, market distance and access to training have a statistically significant impact on climate adaptation strategies. Therefore, policy makers should focus on the aforementioned factors to enhance farmers' adaptation to climate change in order to reduce their vulnerability to different shocks and seasonality as well as to improve their livelihood.

Keywords: Climate change, Adaptation strategies, Multivariate probit model, Assosa district, Western Ethiopia

1. Introduction

Climate change is a global concern as it severely affects the livelihoods of the world community in general and agricultural production and food security of the farming community in particular. Climate change affects agricultural production and productivity of the rural community both directly and indirectly. It directly affects agriculture by affecting the weather variables, which are important inputs for agricultural production, such as temperature, solar radiation, rainfall, wind speed and humidity (Sowunmi and Kintola, 2009) and indirectly through disease and pest outbreaks as well as favoring the development of climate related diseases like malaria that affect the work force (Ngigi, 2009). Newton *et al.* (2010) also indicated that climate change affects the complex interactions between crop and pathogens leading to increased outbreak of pests and diseases.

The impact of climate change on agricultural production is not uniform across regions of the world. Because of greater agricultural share in their economies and limited ability to adapt developing countries are expected to suffer more from global climate change. As depicted by Oxfam (2010), Ethiopia is especially vulnerable to climate variability and change because large portions of the population are poor and depend on agricultural income, which is highly sensitive to rainfall variability and change in temperature. Most of the farmers have low access to education, information, technology, and basic social and support services, and, as a result, have low adaptive capacity to deal with the consequences of climate change.

Particularly, the study area is highly affected by climate change and variability. As Temesgen *et al.* (2008) indicated most significant climate change impact in the western part of Ethiopia is due to drought and flood. The overall natural resources base of the region is highly degraded. This initial potential together with the current global climate change aggravates the vulnerability of the community to climate change impacts. Various reports agree that the region has been facing droughts that have occurred in the country indicating susceptibility of the region to climate change. Thus, people in the region are facing a variety of shocks and become vulnerable. However, farmers in the study area have been responding to climate change through various adaptation strategies. But, there was no empirical study that substantiates or supports the existing adaptation strategies practiced by the farmers in the area. To intervene the problem, which can motivate smallholder farmers adaptation to climate change, there needs to critically investigate the adaptation strategies used and determinants of the use of the adaptation strategies. Therefore, a thorough understanding of the adaptation strategies pursued and factors determining the use of adaptation strategies are important to improve the response mechanisms to climate change. Thus, these are the gaps of knowledge that this study intends to bridge. This study aimed at investigating the climate change adaptation strategies practiced by smallholder farmers' in response to its adverse effects and analyzing determinants of the use of adaptation strategies.

2. Methodology

Asosa district, the study area, is one of the 20 districts of Benishangul Gumuz region. The district is bordered by Banbasi and Menge districts in the east; Sudan and Kurmuk in the west; Komosha and Menge districts in the north; and Tongo and Bambasi districts in the south. Agro-ecologically, the district is mostly classified as lowland (kola) with an average rainfall of 1275 mm per annum and an altitude range of 1300-1570 meter above sea level. The total population of the district was 92,687, of whom about 73.98% live in rural set-ups while the remaining 26.01% were urban dwellers (BGRSDGA, 2010).

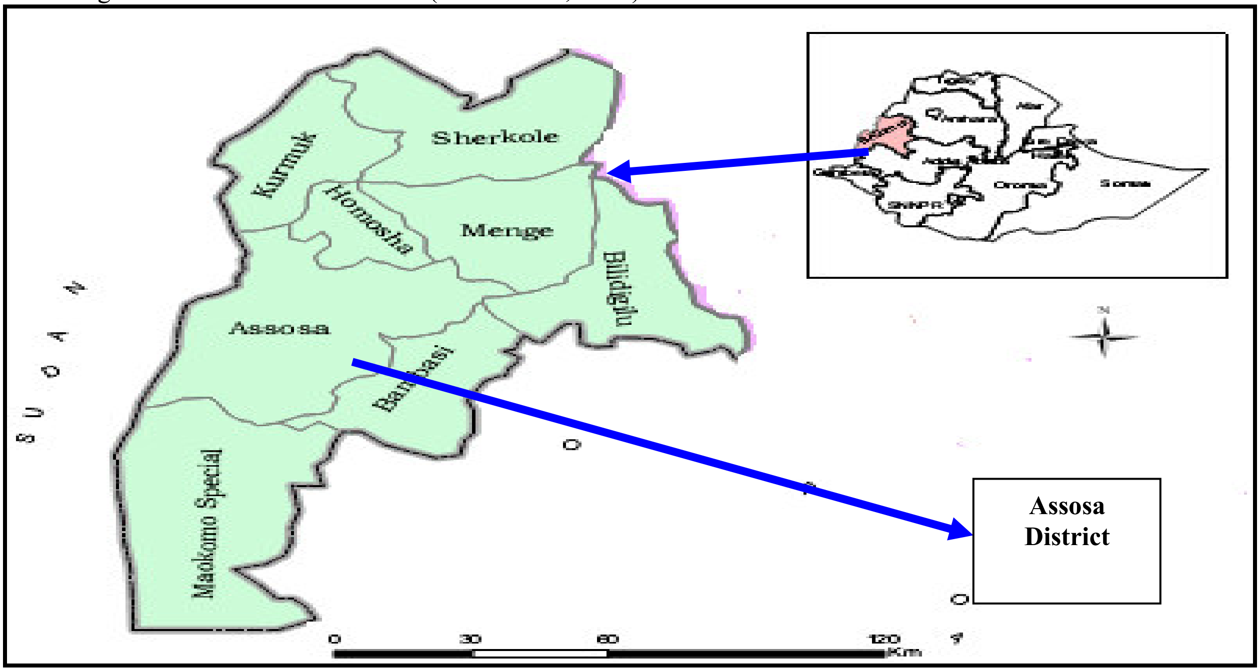

Figure 1. Location map of the study area

For this study, both primary and secondary data were used. Primary data were obtained from sample households in the district using interview schedule and FGD. Interviews were conducted between February and April 2014. Relevant secondary data were also collected from Assosa district office agriculture, national metrology agency and different reports.

A two-stage random sampling technique was applied to select sample households. In the first stage, ten peasant associations were randomly selected out of the total 74 Peasant associations in the district. In the second stage, a total of 140 household heads were selected randomly using probability proportional to size of households in the selected peasant associations.

As to the methods of data analysis both descriptive statistics and multivariate probit model were employed. Descriptive statistics such as percentages and frequency were used to describe the different adaptation strategies used by farmers in the study area.

Econometric model

Farmers are more likely to adopt a bundle of adaptation strategies to deal with a multitude of climate induced risks and constrains than adopting a single strategy. Based on this justification, Multivariate probit model was employed to analyze the data as it enables to analyze determinants of climate change adaptation strategies and the possible interrelationships between different adaptation strategies. The use of climate change adaptation strategies is modeled under the general framework of utility maximization (Nhemachena and Hassan, 2007).

The dependent variable in the empirical estimation for this study is the choice of a particular or different adaptation option(s) from the set of adaptation measures. Following Lin *et al*. (2005), the multivariate probit econometric approach for this study is characterized by a set of m binary dependent variables Y_{hpj} such that:

$$Y^*_{hpj} = X'_{hpj}\beta_j + U_{hpj} \quad j=1, 2, \ldots m \text{ and} \tag{1}$$

$$Y_{hpj} = \begin{cases} 1 \text{ if } Y^*_{hpj} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{2}$$

Where j=1, 2 …m denotes the climate change adaptation strategies available; X'_{hpj} is a vector of explanatory variables, β_j denotes the vector of parameter to be estimated, and U_{hpj} are random error terms distributed as multivariate normal distribution with mean value of zero and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, Y^*_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term. Given the latent nature of the variable Y^*_{hpj}, the estimation is based on the observable variable Y_{hpj} which indicates whether or not a household adopt a specific climate change adaptation strategy. Since adoption of several adaptation strategies is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with zero mean value and variance normalized to unity. The off-diagonal elements in the covariance matrix represent the unobserved correlation between the non-deterministic component of the j^{th} and m^{th} type of adaptation strategies. These assumptions mean that equation (2) gives a multivariate probit model that jointly represents decision to adopt a particular adaptation strategy.

Table 1: Operational definition of variables

Dependent variable	Measurement	Hypothesis
Climate change adaptation strategies		
Independent variables		
Sex of HH head	Dummy (0= female, 1= male)	+
Farming experience	Continuous (years)	+
Livestock holding	Continuous (TLU)	+
Land holding	Continuous (hectares)	+
Literacy status	Dummy (1= literate, 0= no formal education)	+
Farm income	Continuous (in Birr/year)	+
Off/non-farm income	Continuous (in Birr/year)	+/-
Access to training	Dummy(1= access to training, 0=otherwise)	+
Access to farmer to farmer extension	Dummy(1= if yes, 0=otherwise)	+
Access to mass media(Radio)	Dummy(1= if yes, 0=otherwise)	+
Family size	Continuous (number)	+/ -
Frequency of extension contact	Continuous (number of visit per year)	+
Access to credit	Dummy(1= if the HH get credit, 0=otherwise)	-
Distance to market	Continuous (km)	-

3. RESULTS AND DISCUSSION

3.1. Climate Change Adaptation Strategies

In the study district, farmers have adopted different strategies to reduce the consequences of climate change so far and to manage future patterns in climate change.

Table 2: Summary of adaptation strategies used by farmers

Adaptation strategies	Number of respondents	Percent (%)
Irrigation	77	55
Improved varieties	71	50.7
Adjusting planting date	69	49.3
Crop diversification	80	57.1
Soil conservation practices	51	36.4

Source: Survey result

Note that a farmer can have more than one adaptation strategy.

In the study area, about 55% of sampled respondents used irrigation as an adaptation strategy to reduce the adverse effects of climate change. It has become widely used substitute for inadequate or unreliable precipitation in the district since recent years. Because it provides large comparative advantage to farmers of the district to produce different horticultural crops such as tomato, onion, pepper, head cabbage, carrot, potatoes, sweet potato, *etc* to cope up the impact that climate change imposes on their livelihood. Moreover, about 50.7% of farmers used improved crop varieties (drought resistant and short maturing varieties) as an adaptation strategy to reduce the adverse effect of climate change.

In the study area, 49.3% of sample households used adjusting planting date, from early planting to late planting or vice versa, as an adaptation strategy to reduce the adverse effect of climate change. The descriptive statistics result also revealed that about 57% of sampled households used crop diversification (mixed cropping, intercropping and dividing farm lands into varying crops) as an adaptation strategy to reduce the adverse effect of climate change. This because crop diversification helps farmers to spread risks associated a single or few crop(s) (Lema and Majule, 2009).

A soil conservation practice is the other climate change adaptation strategy pursued by smallholder farmers in the study area. Accordingly, about 36.4% of sampled households used soil conservation techniques (Soil/stone bunds, tied ridging, ridging, *etc*.) as adaptation strategy to reduce the adverse effect of climate change on farm productivity. This is because land degradation as a result of climate change is declining production and productivity of smallholder farmers in the study area.

3.2. Determinants of Farmers' Choice of Adaptation Strategies

To respond to climate change and reduce its negative effects farmers in the study area used irrigation, improved varieties of crops, adjusting planting date, crop diversification and soil conservation practices as a major climate change adaptation strategies. But, choice of an adaptation option(s) determined by a number of factors. To analyze determinants of the choice of an adaptation option(s) the study employed Multivariate probit simulation model. The likelihood ratio test from Multivariate probit model showed the overall significance of the model at 1% probability level and supports that choice of climate change adaptation strategies are not mutually independent. The model results suggested that there was positive and significant interdependence between household decisions to adapt use of irrigation and using improved varieties of crops; use of irrigation and crop diversification; using improved varieties of crops and crop diversification; and crop diversification and soil conservation practices. It also suggested that there was negative and significant interdependence between household decisions to adapt use of irrigation and adjusting planting date, and using improved varieties of crops and adjusting planting date (See appendix table 1).

Furthermore, the result of MVP model shows that the probability of households to adopt irrigation, improved varieties of crops, adjust planting date, use crop diversification and soil conservation practices were 52.3%, 45.8%, 49.5%, 46.9% and 34.1%, respectively. The result also conveyed that the joint probability of using all adaptation strategies was only 1.5% and the joint probability of failure to adopt all of the adaptation strategies was 3.5%.

From the MVP model variables that are significant at less than or equal to 10% significance level are discussed as follows (See appendix table 1).

Literacy status of the household head: This variable significantly and positively affected use of crop diversification and soil conservation practices as adaptation strategies at 5% significance level. This implies that being literate household head increases the use of crop diversification and soil conservation practices as an adaptation strategy to climate change. This is because literate households can easily access information, capable to interpret the information, easily understand and analyze the information about consequence of climate change on productivity and benefit of crop diversification and soil conservation practices to reduce the impact of climate change relative to those farmers with no formal education. This finding is in line with the investigation of Temesgen *et al*. (2008).

Family size: It has positive and significant impact on the likelihood of using irrigation, use of improved crop varieties and crop diversification as an adaptation strategy to reduce the negative impact of climate change. The possible reason is that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks which are labour intensive such as diversifying farm products, using irrigation agriculture and using new varieties of different crops which require new farm operations. Temesgen *et al.* (2008) also found similar result. But, it has negative and significant impact on the likelihood of taking adjusting planting date and soil conservation practices as an adaptation strategy to reduce the negative impact of climate change. This could be because households with large families may be forced to divert part of the labor force to off/non-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family and this finding is in line with the finding of Belaineh *et al*. (2013).

Distance from the market center: It significantly and negatively affected use of adjusting planting date as adaptation strategy. This could be due to the fact that better access to markets enables farmers to obtain information on climate change and other important inputs they may need if they are to change their practices to cope with predicted changes in future climate (Temesgen, 2010).

Livestock ownership: The ownership of livestock of the households has positive and significant impact on use of soil conservation practices as adaptation strategy. The possible reason could be livestock plays a very important role by providing traction (especially oxen) and manure required for soil fertility maintenance. The other reason could be farmers with large herd size have better chance to earn more money to invest on tools required for soil conservation practices (Chilot, 2007). But, livestock ownership has negative and significant impact on use of crop diversification as adaptation strategy. The possible reason could be livestock rearing requires a grazing land which makes livestock competent with crop production.

Off/non-farm income: The result of the model indicated that off/non-farm income increases uptake of irrigation and improved crop varieties as adaptation strategies to climate change. The implication of the result was that availability of off /non-farm income improves farmers' financial position, which, in turn, enables them to purchase farm inputs such as seed, fertilizer and materials needed for irrigation. Aemro *et al*. (2012) reported similar result.

Farm income: It has a positive and significant impact on use of improved crop varieties as an adaptation strategy. The possible explanation is that when the main source of income in farming would increase, farmers tend to invest on purchase of improved seed varieties which increases productivity. This result is consistent with Temesgen *et al*. (2008).

Extension contact: The result of the model indicated that frequency of extension visit to the households has positive and significant impact on use of adjusting planting date to reduce the negative impact of climate change. This is because extension services serve as an important source of information on agronomic practices as well as on climate that enhance their awareness about the importance of adjusting planting date as an adaptation strategy. Aymone (2009) has found similar result.

Access to credit: The result indicated that having access to credit has a positive and significant impact on likelihood of using improved varieties of crops and soil conservation practices. Access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to take (Hassan and Nhemachena, 2008). Farmers with financial resources and access to markets farmers are able to buy new crop varieties and other important inputs they may need to change their practices to suit the forecasted and prevailing climatic conditions Temesgen *et al*. (2009).

Access to training: Participation in climate change related training programs is found to be positively and significantly associated with using irrigation and adjusting planting date as adaptation strategies. This is because farmers participated on training would have better awareness about climate change and possible adaptation strategies. This result is consistent with the finding of Isabirye *et al. (*2010).

Access to media: Access to media (radio) has significant and positive impact on the use of improved crop varieties to adapt to the negative effects of climate change. Media is used to access information and knowledge to strengthen local agriculture system. Raising awareness of changes in climatic conditions and on new seeds and crops variety, livestock breeds, irrigation applications, reminders about planting dates, pest and disease control and livestock vaccinations through radio and television would have greater impact in increasing adaptation to changes in climatic conditions.

Farmer to farmer extension: Access to farmer to farmer extension (information and input sharing) has a positive and significant impact on the likelihood of using adjusting planting date as adaptation strategy to climate change. Because, farm to farm extension and social network increases awareness about climate change impacts and its adaptation strategies and also farmers share useful information with each other about the appropriate time of planting date due to climate change. This finding is consistent with the finding of Temesgen *et al.* (2008).

Land holding: This variable significantly and negatively affected use of irrigation and improved crop varieties as climate change adaptation strategies. The possible reason could be if the farmers have more land holding they can benefit from the economic scale of it as compared with those who have small land holding. This result is consistent with the findings of Temesgen *et al*. (2008).

4. Conclusion and Recommendations

Farmers adopt different kinds of adaptation strategies to reduce the negative consequences of climate change so as to maintain and/or to improve their livelihood. Accordingly, this study pointed out that 55%, 50.7%, 49.3%, 57.1% and 36.1% of the farmers were using irrigation, improved varieties, changing/adjusting planting date, crop diversification and soil conservation practices, respectively.

Multivariate probit model was employed to determine the factors determining farm households choice of adaptation strategies related to climate change. The result of the model showed that farmers use irrigation and improved varieties; irrigation and crop diversification; improved varieties of crops and crop diversification; and crop diversification and soil conservation practices in a complementary fashion. But, farmers use irrigation and adjusting planting date, and use of improved varieties and adjusting planting date in a substitute fashion.

MVP result also confirms that land holding, family size, off/non-farm income and access to training have a significant impact on the use of irrigation as climate change adaptation strategy. It also showed that land holding, family size, access to credit, access to media, farm income and off/non-farm income significantly affect the use of improved crop varieties to adapt to climate change. Moreover, as obtained from the model result family size, extension contact, farmer to farmer extension and distance from the market center are significant in determining choice of adjusting planting dates as an adaptation strategy. Literacy status, family size, livestock ownership and access to training significantly determined farmers' use of crop diversification to adapt to climate change impacts. Finally, literacy status, family size, access to credit and livestock ownership significantly affect use of soil conservation practices to adapt to climate change.

Thus, Future policy should focus on awareness creation on climate change through different sources such as media, training and extension, facilitating the availability of credit especially to adaptation technologies, enhancing research on use of new crop varieties that are more suited to drier conditions, improving farmers farm and off-farm income earning opportunities, improving their literacy status, and improving their access to markets. Moreover, encouraging informal social net-works and environmental settings enhance the adaptive capacity of smallholder farmers. This is because improved adaptive capacity and adaptation contributes to reduce the adverse effects of climate change and generally help agricultural as well as economic development and poverty reduction.

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Appendix table 1: Multivariate probit simulation results for households' climate change adaptation decisions

Explanatory variables	**Use of irrigation**	**Use of improved crop varieties**	**Adjusting planting date**	**Crop diversification**	**Soil conservation practices**
	Coefficient (Std. error)	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**
Sex	-0.62(0.354)	0.27(0.34)	0.022(0.35)	0.063(0.33)	-0.103(0.368)
Farming experience	-0.001(0.015)	0.005(0.02)	0.019(0.015)	-0.007(0.015)	0.014(0.016)
Literacy status	0.105(0.286)	-0.07(0.28)	-0.168(0.28)	0.64**(0.279)	0.69**(0.32)
Family size	0.191***(0.054)	0.21***(0.056)	-0.2***(0.054)	0.15***(0.052)	-0.15**(0.06)
Distance to market	-0.048(0.0366)	-0.047(0.037)	-0.067*(0.035)	-0.021(0.037)	-0.039(0.039)
Livestock holding	-0.025(0.042)	0.013(0.043)	-0.043(0.041)	-0.07*(0.04)	0.11**(0.44)
Off/non-farm income	0.074**(0.033)	0.062*(0.034)	-	0.03(0.033)	-0.058(0.035)
Farm income	-0.063(0.154)	0.327**(0.156)	-	-0.169(0.162)	0.035(0.166)
Extension contact	-0.081(0.065)	-0.041(0.062)	0.13**(0.065)	-0.001(0.063)	0.047(0.063)
Access to credit	0.055(0.248)	0.493*(0.25)	-0.194(0.25)	-0.099(0.245)	0.77***(0.273)
Access to training	0.592**(0.272)	0.169(0.269)	-0.212(0.26)	0.51*(0.26)	0.38(0.279)
Access to media	0.293(0.299)	0.5*(0.296)	-0.152(0.288)	-0.194(0.287)	-0.24(0.299)
Farmer to farmer ext.	-0.197(0.311)	0.177(0.315)	0.882***(0.31)	-0.04(0.297)	0.26(0.33)
Land holding	-0.405***(0.126)	-0.503***(0.136)	0.077(0.118)	-0.11(0.12)	-0.026(0.127)
Constant	0.914(1.621)	-4.56***(1.69)	0.041(0.613)	1.14(1.67)	-0.47(1.75)
Rho2	0.236*				
Rho3	-0.4***	-0.44***			
Rho4	0.37***	0.25*	-0.19		
Rho5	0.12	-0.11	0.314**	-0.02	
Predicted probability	0.523	0.458	0.495	0.469	0.341
Joint probability(success)			0.015		
Joint probability(failure)			0.035		
Number of observations		140			
Number of simulations		5			
Log likelihood		-371.68			
Wald χ2(68)		137.13			
Likelihood ratio test of Rho*ij* = 0, P > χ2(10)		0.0003			