IMPLICATIONS OF FARMERS' ADAPTATION STRATAGIES ON MAIZE PRODUCTIVITY IN CENTRAL ETHIOPIA

By

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(Z50/69736/2011)

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Environmental Policy of the University of Nairobi

DECLARATION

This Thesis is my original work and has not been presented for a degree in any University.

Solomon Balew Deffersha Date----------------

This Thesis has been submitted with our approval as University

Supervisors

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Dr. Stephen O. Anyango Date-------------------

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DEDICATION

I dedicate this work to my brothers, friends and supervisors. My brother Dr Menale Kassie deserves special gratitude for his words of encouragement and push towards the success I have achieved so far. In fact, had it not been for his encouragement, material and financial support, it would have been difficult for me to study for my Master's degree. My brothers Abraham Balew and Daniel Balew also have never left my side and are very special, and thus deserve special and heartfelt thanks for what they have done for me to reach this level.

I also dedicate this Thesis to my friends who have supported me throughout the process. I will always appreciate all they have done, especially Goffery Morcho for helping me develop my statistical software skills, and for the many hours of proofreading. Peter Carol Negassa and Patrick Kituta also deserve my thanks for their good friendship throughout my stay in Nairobi.

This thesis is also dedicated to my supervisors Dr Jones F. Agwata and Dr Stephen O. Anyango who were with me starting from the conception to the end of the process of writing this Thesis. Particularly, Dr Jones Agwata deserves many thanks for his encouragements in addition to his very good supervision.

ACKNOWLEDGMENT

It would have been difficult to finalize this Thesis without the help of many people. First, I would like to thank my parents for bringing me to the stage where I am now. I would like to thank my supervisors Dr Jones F. Agwata and Dr Stephen O. Anyango for their guidance, intellectual feedback and for giving me the freedom to choose my topic and the methods applied in this work. The International Maize and Wheat Improvement Center (CIMMYT) also deserve my thanks for giving me access to the data used for this study and for allowing me to participate in the process of data collection.

My brother Dr Menale Kassie deserves special thanks for his encouragement and material support required to finalize the study. He helped me throughout my stay in Nairobi to finish my Masters work. Had it not been for his constant support, it would have definitely been difficult for me to study for my Masters. I would also like to thank my sister Jerusalem Tayelgne for the support and encouragement she gave me during my stay in Nairobi.

Finally, I am thankful to my friend Joffery Morcho for his advice and assistance during my stay in Nairobi. I thank him for the useful discussions we had while I was writing this Thesis and for reading various drafts of the Thesis and providing useful comments.

ACRONYMS

ATT: average treatment effect on the treated

ATU: average treatment effect on the untreated

BH: behavioral heterogeneity

(CIMMYT) : International Maize and Wheat improvement Center

ESR: Endogenous Switching regression

FAO: Food and Agricultural Organization

GDP: Gross domestic product

IPCC: Intergovernmental Panel on Climate Change

MNL: Multinomial Logt

N: Number of observations

OLS : Ordinary Least Square

PAs: Peasant Associations

SSA: Sub-Saharan Africa

SNNP: Southern Nations, Nationalities and Peoples

TLU: Tropical Livestock Unit

TT: Treatment of treated

TU: Treatment of untreated

TH: Treatment heterogeneity

US$: United States Dollars

TABLE OF CONTENTS

DECLARATION………………………………………………………………………………………………….. v

DEDECATION…………………………………………………………………………………………………v v

ACKNOWLEDGMENT ………………………………………………………………………………………vvv

ACRONYMS……………………………………………………………………………………………..iv

LIST OF TABLES…………………………………………………………………………………...vi

LIST OF FIGURES…………………………………………………………………………………...vii

ABSTRACT………………………………………………………………………………………. viii

CHAPTER ONE: INTRODUCTION ……………………………………………………………………..1-5

1.1 Background of the Study ……………………………………………………………………1
1.2 Statement of the Problem……………………………………………………………………3
1.3 Research Questions………………………………………………………………………….3
1.4 Objectives of the Study……………………………………………………………………...4
1.5 Justification and Significance of the Study……………………………………………….4
1.6 Limitations of the Study ……………………………….………………………………5

CHAPTER TWO: LITERATURE REVIEW …………………………………………………………………6-14

2.1 Introduction …………………………………………………………………………….6
2.2 Definition of Adaptation to Climate Change……………………………………………...6
2.3 Climate Change and Crop Adaptation Strategies………………………………………7
2.4 Empirical Studies and Methodologies in Ethiopia…………………………………...8
2.5 Theoretical Framework………………………………………………………………11
2.6 Conceptual Framework……………………………………………………...……12 .

CHAPTER THREE: STUDY DESIGN AND METHODOLOGY……………………………………….15-28

3.1 Introduction………………………………………………………………………………15
3.2 Study Sites…………………………………………………………………….………15
3.3 Data Types and Sources…………………………………………………………………16
3.4 Sampling Procedure and Data Collection……………………………………………..17
3.5 Data Entry and Cleaning………………………………………………………………18
3.6 Methods of Analysis……………………………………………………………………..18

CHAPTER FOUR: RESULTS AND DISCUSSIONS…………………………………………………….29-60

4.1 Introduction……………………………………………………………………………29
4.2 Results of the Descriptive Statistics ………………………………………………….29
4.3 Model Results and Discussions……………………………………………………….40
4.4 Summary on findings of the work …………………………………………………57

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS……………………………………..61-63

5.1 Introduction……………………………………………………………………………..61
5.2 Conclusions……………………………………………………………………………..61
5.3 Recommendations…………………………………………………………………...63

LIST OF TABLES

Page

Table 4.1: Climate change related risk factors faced--29

Table 4.2: Summary on the composition of risk factors ----------------------------- ---------------------31

Table 4.3: Risk factors and adaptation strategies (% responses)---33

Table 4.4: Description of variables estimated in the binary and multinomial logit models---35

Table 4.5: Description of dependent and explanatory variables estimated in ESR model---39

Table 4.6: The estimated coefficients of Binary logit model---40

Table 4.7: Parameter estimates and marginal effects of explanatory variables from multinomial logit model---45

Table 4.8: Parameters Estimates of Maize Adaptation and Maize Yield Productivity Equations---52

Table 4.9: Average Expected Production per Hectare; Treatment and Heterogeneity Effects---54

LIST OF FIGURES

Page

Figure 2.1: Summary of Variables Examined in the Study--12

Figure 3.1: A Map Showing the Location of the Study Sites--16

Figure 4.1: Percent of adaptation strategies used to cope with the risk factors-----------------32

ABSTRACT

In Sub-Saharan Africa, the capacity of smallholder farmers to adopt climate change adaptation strategies is limited. It is therefore imperative to identify and analyze factors that determine the adoption capacity of these farmers. Using household and plot level data from 898 smallholder farmer households in central Ethiopia, this study identified the major climate change related risk factors faced and the adaptation strategies used by those farmers to minimize the adverse effect of the risks on their crop yields. It also analyzed factors that determine the capacity of these farmers to adopt / choose from various climate change adaptation strategies and estimated the impact of the strategies on households´ maize productivity. Descriptive statistics and three econometric models namely binary logit, Multinomial logit (MNL) and Endogenous Switching regression (ESR) models were used to analyse the data. The findings from the descriptive statistics indicated that drought and flood were the major climate change related risk factors faced by the sampled households, and planting fitting seed varieties, soil and water conservation, crop choice, early or late planting and increasing seed rate were the major adaptation strategies used by those households to cope with the negative effects of the risk factors. The majority (about 52%) of the sampled households did not use climate change adaptation strategy in any of their crop farms. The results of the binary logit model indicated that farmers´ decisions to adopt any yield related climate change adaptation strategy was influenced by climate information, size of livestock, household heads' formal education level, soil fertility, experience to past drought and flood incidences, the type of risk factor faced, confidence on the skills of government extension workers, market and credit access, kinship, and membership to farmers groups found in the village. The MNL model showed that the direction and magnitude of determining factors varied across adaptation strategies, and farmers´ decision to choose from various climate change adaptation strategies was influenced by the type of risk factor they faced. Actual and counterfactual analysis built from the ESR model indicated that adoption of climate change adaptation strategies improved farmers´ maize productivity, and famers who did not adopt any strategy if they adopted would benefit more than those who actually adopted. Generally, while adoption of climate change strategies helps farmer households to enhance their maize productivity, various constraints that include lacks of education, climate change information, market and credit facility and social capital hindered the majority of farmers in central Ethiopia from adopting any climate change adaptation strategy in any of their maize farms. Therefore, policies should focus on improving access to education, information, market and credit facility, and should encourage informal social networks that can promote group discussions and better information flows and experience sharing.

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Available observational evidences indicate that global changes in climate, particularly global warming, have already affected the adverse sets of physical and biological systems in any parts of the world. It has been broadly accepted that mankind is causing global warming with the emission of greenhouse gases. The drastic increase in the emission of CO2 (carbon dioxide) within the last 30 years caused by burning fossil fuels has been identified as the major reason for the change of temperature in the atmosphere. In some parts of the world, climate changes are manifested through shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of mid to high latitude growing season, pole-word and altitudinal shifts of plant and animal ranges, declines of some plant and animal populations and earlier flowering of trees. In some other parts of the world the changes are observed through frequent drought and flood and emergence of insects (IPCC, 2001).

Global changes in climate have been found to impact various sectors of the global economy. Agriculture is one of the sectors largely affected by climate changes. The effect of climate change on the agricultural sector, however, differs from region to region, with benefits mostly for the developed world and strongly negative impacts for developing nations (Tol & Yohe, 2006). The negative impact is expected to be harsher on drought-prone areas of Sub-Saharan Africa (SSA). In this part of Africa climate change could reduce agriculturally suitable land area; some rain-fed crop yields as much as 50 percent by 2020 (IPCC, 2007).

In SSA, agriculture is practiced by millions of small scale and poor farmers that produce food crops for subsistence. Low land productivity and harsh weather conditions due to high average temperature, and scarce and erratic rainfall characterize the production environment. Consequently, low yields of food crops and food insecurity have been common in the region. Because of the low level of economic diversification and reliance on rain-fed agriculture, development prospects in this part of Africa are closely associated with climate. As a result, climate change is projected to further reduce food security (McCarthy *et al.*, 2001& Cline, 2007).

Ethiopia, a country in Sub-Saharan Africa, is highly exposed to the negative impacts of climate change. A recent mapping on vulnerability and poverty in Africa listed Ethiopia 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). The country has suffered from periodical extreme climate events, manifested in the form of frequent droughts and floods. The occurrences of droughts and floods have been found to significantly reduce Ethiopia's annual growth potential. For instance, the 1984-85 droughts 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).

Ethiopia has poor economy depending largely on agricultural production. The gross domestic product (GDP) is 43 billion billon US dollars. The population is estimated to be more than 90 million. In this country, agricultural production remains the main source of livelihoods for most rural communities. Agriculture provides employment for more than 80 % of the people. It contributes 46% of the country´s GDP and generates more than 85 percent of foreign exchange earnings (World Bank, 2013). Agriculture in Ethiopia is traditional. Small-scale, mixed crops and livestock farming dominate the agriculture sector. About eight million households use a small-scale farming method, which accounts for 95% of the total area under crops and for more than 90% of the total agricultural output. The largest proportion of food crops (94%) and coffee (98%) are produced by small-scale farmers. Traditional farm technologies, use of ox-drawn wooden ploughs with steel pikes and other time-honored farm equipments, minimal application of fertilizers and pesticides due to high input prices in the presence of credit constraints and weak extension services, and low use of improved seeds are common. The use of irrigation is very limited. The contribution of irrigation agriculture is only 1 % to the total cultivated land of the country (Deressa, 2006 & Molla, 2009).

In Ethiopia climate change is predicted to further continue as annual minimum temperature has been increasing by about 0.37 degrees Celsius every 10 years over the past 55 years (Di Falco and Veronese, 2012). 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). 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 farmer households, the potential adverse effects of climate change on crop agriculture and food security will be increasing through time.

1.2 **Statement of the Problem**

In Ethiopia the capacity of farmer households to adopt crop adaptation strategies is low. Evidence on how factors affect the adaptive capacity of farmers and their subsequent crop yields is scarce (Yusuf *et al*., 2008; Di Facalo *et al*., 2011; Di Falco and Veronese, 2012). Recent studies in Ethiopia focused on a single district in the Nile basin. Information based on findings of a specific district context might not be appropriate to design and promote policies applicable to other districts. Given the fact that different districts might have different socio-economic and environmental settings, studies need cover each district. Analysis of factors that affect the adaptive capacity of farmer households in specific district contexts is important to provide policy makers with information required to take appropriate decisions fitting to the district. This study, therefore, will give insight to policy makers on how factors affect the capacity of farmer households to adopt crop adaptation strategies in central Ethiopia's context. That would help them to design and promote adaptation policies well applicable to the district. Moreover, in analyzing the effect of adaptation strategies on crop yields, the existing studies in Ethiopia aggregated crops in one large group. Since adaptation strategies might affect yields of different crops differently, the impacts of adaptation strategies should be estimated to each crop type. That would help policy makers have more clear understanding about how crop adaptation affects crop productivity. The current research tried to fill this gap by analyzing the impact of adaptation strategies on maize yield, the major crop type produced in central Ethiopia.

1.3 **Research Questions**

This study was guided by the following research questions;-

a) What climate change related risk factors are occurring in central Ethiopia?

b) What climate change adaptation strategies are used by farmers to cope with the negative effects of climate change on crop production in the area?

c) How do various factors affect the decisions of farm households to adopt any climate change adaptation strategy in crop agriculture in the study sites?

d) How do factors affect the decision of farmers to choose among different crop adaptation strategies in study sites?

e) How does climate change adaptation affect maize yields of farm households in the study sites?

1.4 Objectives of the Study

The broad objective of this study was to analyze factors that affect households´ capacity to adopt crop adaptation strategies and examine the impacts of crop adaptation strategies on maize productivity. The specific objectives were to;-

a) Identify climate change related risk factors that affect crop yields in central Ethiopia;

b) Assess crop adaptation strategies used by the households to cope with climate change related risk factors in the area;

c) Determine factors that affect the decisions of farmer households to adopt climate change adaptation strategy in crop production;

d) Examine factors that affect the capacity of farm households to choose from various crop adaptation strategies; and

e) Assess the impacts of crop adaptation strategies on households' maize yields in the study sites.

1.5 Justification and Significance of the Study

This study is justified in several ways. First, while using crop adaptation strategies are believed to minimize the negative impact of climate change on crop yields, the adaptive capacity of Ethiopian farm households is low. In Ethiopia, there are few studies done to analyze factors that affect farmers´ adaptive capacity. Therefore, analyzing factors that affect the adaptive capacity of farm households in crop production is important to identify policy intervention areas in crop adaptation. Second, to our knowledge there are no recent studies done to analyze factors that affect crop adaptation strategies in central Ethiopia which is highly vulnerable to climate change and where the adaptive capacity of farm households is low. Third, most of the recent studies that analyze factors affecting crop adaptation strategies in Ethiopia aggregate crop adaptation in their analysis. Given that different factors may affect different crop adaptation strategies differently, studies need to be focused on analyzing the effects of factors on each crop adaptation strategy.

This study is important in several ways. First, it will estimate factors that limit the capacity of farm households to use or choose among crop adaptation strategies in central Ethiopia. The study will provide a meaningful insight to policy makers with policy intervention areas to design and promote effective adaptation policy that will help tackle constraints of crop adaptation in the district. Second, by analyzing factors that affect crop adaptation strategies and by estimating the impact of maize adaptation on maize yield in central Ethiopia, this study will contribute to the existing literatures.

1.6 Limitations of the Study

This study was limited in various ways. First, it is geographically limited to central Ethiopia, and hence the need for further studies to cover other geographical areas. Different geographical areas may have different socio-economic, demographic and climatic conditions. Thus, future studies need to encompass other geographical areas in their analysis. Second, in analyzing the effects of maize adaptation strategies on the subsequent maize output, the study aggregates maize adaptation strategies in two, adapting or not adapting. Different maize adaptation strategies may affect the subsequent maize outputs differently. Therefore, future studies should focus on comparing the effect of each adaptation strategy on the subsequent maize output. So that it will be possible to select the most efficient adaptation strategy in maize production. Moreover, such constraints as model uncertainties, lack of time and finances, and problems faced during data collection process due to illiteracy of the households are likely to limit the values of this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 **Introduction**

In this chapter key words were defined, crop adaptation strategies were identified, the role of climate change adaptation in crop production sub-sector were described, previous empirical studies done in Ethiopia were reviewed and gaps of the existing studies were identified.

2.2 **Definition of Adaptation to Climate Change**

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 and 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 (Deressa *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). 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 & Msangi, 2006)

2.3 **Climate Change and Crop Adaptation Strategies**

There exist substantial literatures on the impact of climate change on food production at country, regional, and global scale. Some of these literatures do not incorporate the roles of adaptation strategies in their analysis (for instance, McCarthy *et al.*, 2001; Parry *et al.*, 2004; Stern, 2007). These studies are crucial in providing information on the extent of the impacts of climate change on food productivity and giving insights about the importance of designing appropriate mitigation strategies at global or regional level. However, the aggregate nature of these studies makes it very difficult to provide insights about policy intervention areas in adaptation because the studies do not consider the actual constraints faced by farm households in adapting to different climate change risks (Veronesi *et al.*, 2011).

Other climate change impact assessment studies have incorporated the roles of adaptation strategies in minimizing the adverse effects of climate change on agricultural productivity. These studies explicitly or implicitly take the constraints of adaptation into consideration. For instances, Rosenzweig and Parry (1994) showed that there is great potential to increase food production under climate change in many regions of the world if adaptation is taken into consideration. Bradshaw *et al* (2004) also assessed the adoption of crop diversification in Canadian prairie agriculture for the period 1994-2002, reflecting upon its strengths and limitations for managing a variety of risks, including climatic ones. The study showed that individual farms have become more specialized in their cropping patterns since 1994 and this trend is unlikely to change in the immediate future, notwithstanding anticipated climate change and the known risk-reducing benefits of crop diversification. Similarly, Downing (1991) indicated that adaptation in African agriculture has the potential to reduce food deficits from 20 to 50 percent, if the adaptive capacity of African farmers is improved.

Some past studies in Ethiopia have shown the roles of adaptation strategies in minimizing the impacts of climate change on crop production. Molla (2009) showed that irrigated farms are more resistant to changes in climate in the Nile basins of Ethiopia. This implied that irrigation is an important adaptation option for reducing the negative impacts of climate change on crop yields. Di Falco *et al.* (2011) showed that households with climate change adaptation strategies tended to have an extra 10% in terms of net crop revenue in the Nile basins of Ethiopia.

According to this study, adoption of yield related adaptation strategies in the Nile basins of Ethiopia had a win-win outcome. It helped in coping with the adverse effects and risk of climate change while increasing agricultural productivities of poor farm households. Similarly, Veronesi *et al* (2011) and Di Falco and Veronese (2012) showed the role of crop adaptation strategies in minimizing the impact of climate change in the Nile basins of Ethiopia. The implication of all these findings is that even in adverse climatic conditions, it is possible to secure sustainable domestic food availability by improving the adaptive capacity of farm house holds.

2.4 Empirical Studies and Methodologies in Ethiopia

Recently, attention has been given to the importance of analyzing crop adaptation strategies at household level in Ethiopia. For instances, Deressa *et al* (2008) analyzed crop adaptation strategies in the Nile basins of Ethiopia within the framework of the general theory of profit/utility maximization. This study used a multi nominal logit model and applied a two stage Heckman probit selection method to estimate factors that limit the decisions of farm households to adapt and which strategy to use. It gave detailed analysis on how conditioning variables affect each crop adaptation strategy used by households in the Nile basins of Ethiopia. The findings of this study indicated that those who did not use any of the methods considered described lack of information on adaptation methods and lack of money as major constraints to adaptation. According to this study, variables that positively and significantly influenced adaptation to climate change in Nile basins of Ethiopia included education of the head of household, household size, and gender of the head of household, livestock ownership, extension on crop and livestock production, and availability of credit and temperature. A one-year increase in the education of the head of household raised the probability of adaptation to climate change by 1.9 percent. Similarly, increasing the size of the household by one person increased the probability of adaptation to climate change by 1.8 percent. The study also showed that farm size had a negative effect on adaptation. However; this study paid no attention to analyzing the effects of crop adaptation strategies on the subsequent level of crop yields.

Molla (2009) tried to analyze crop adaptation strategies in the Nile basins Ethiopia. This study also framed the analysis within the general theory of profit\ utility maximization and used descriptive statistics to indicate the major constraints faced in adaptation. It applied Recardian model to estimate the impacts of climatic variables and adaptation on crop net revenue of farm households in the Nile basins of Ethiopia. The findings showed that lack of information was the major constraint of adaptation. According to it, 43% of non-adapters did not adapt due to lack of information, whereas 22 %, 16%, 11 % and 8 % did not adapt due to lack money, shortage of labor, shortage of land and poor potential for irrigations, respectively. The study estimated crop net revenue of farm households with and without adaptation, and calculated the net effect of adaptation measures on the net crop revenue. The Recardian model estimates showed that the effect of climatic factors on net crop revenue per hectare of households can be significantly minimized if adaptation is used. This is complimented the previous study by Deressa *et al.* (2008) in terms of providing policy makers with insight about how adaptation can minimize the negative impact of climate change on crop production. However, in analyzing the impact of adaptation strategies on crop yields, the study aggregates crops in one large group and thus does not give insight about how crop adaptation strategies affect specific crop yields (net revenue) of households.

Another broader work done to analyze crop adaptation strategies in Ethiopia is by Yesuf *et al.* (2008). By framing the analysis within the standard theory of technology adoption, this study tried to analyze climate change adaptation strategies in crop agriculture in the Nile basins of Ethiopia. The study focused on the adaptation definition per se and employed a dummy variable for adaptation strategies to measure the effect of explanatory variables on the capacity (decision) of farm households to use adaptation in crop agriculture. It applied probit regression model to estimate factors that affect the decision of households to adapt\ not to adapt in their crop agriculture. By using a Ricardian model, this study estimated the effect of adaptation on the crop production (farm net revenue) of households. However, this study did not identify and estimate factors that affect the decisions of farm households to choose among different adaptation strategies. As a result, the study did not analyze how a unit change in an independent variable affected the change in probability of a particular choice (strategy) being made. It also did not estimate the effect of crop adaptation on specific crop yields (net revenue) of households and thus failed to insight about how crop adaptation strategies affected specific crop productivity.

Similarly, Veronesi *et al (*2011) analyzed factors that affect the decision of stallholder farmers to adapt (not to adapt) in their crop agriculture and the subsequent effect of their decision on their net crop revenue. The study focused on the adaptation definition per se and employed a dummy variable to measure whether farm households had adopted any measure in any of their plots in response to perceived climate changes. It applied a simultaneous endogenous switching regression model. In the first stage of regression, the effect of explanatory variables on the decision of farm households with a binomial probit model was estimated. To account for selection biases, it adopted an endogenous switching regression model of food productivity in the second stage of regression, where farmers face two regimes; to adapt and not to adapt. Just like Yesuf *et al.* (2008), this study also did not identify and estimate factors that affect the decisions of farm households to choose among different adaptation strategies and thus did not analyze how a unit change in an independent variable affected the change in probability of a particular choice (strategy) being made. It also failed to estimate the effect of adaptation on specific crop productivity. As the result, the study could not provide policy makers with specific information about factors that affect each crop adaptation strategy. It also failed to provide information about the effect of crop adaptation on specific crop yields.

Di Falco and Veronese (2012) established their framework within the theory of profit\ utility maximization and analyzed the effects of crop adaptation strategies on the subsequent level of households´ crop yields in the Nile basin of Ethiopia. By using a multi nominal logit endogenous switching regression model, the study estimated the effect of each adaptation strategy on the subsequent crop net revenue of farm households. It provided detailed information about how each adaptation strategy affected crop net revenues of households and thus gave insight about the most efficient crop adaptation strategies. This is important to policy makers in identifying and promoting crop adaptation strategies that can best help farm households obtain maximum benefit from their crop agriculture. However, it did not focus on analyzing factors that limit the capacity of farm households to adapt to climate change in their crop agriculture. It also did not estimate the effect of crop adaptation on specific crop net revenue of households.

From the above literature, two gaps can be identified for further research. First, the studies focused on a single district in the Nile basin. Second, in analyzing the effect of adaptation strategies on crop yields, they aggregated crops in one large group. The current research tried to fill these gaps identified in the literature by covering another district (central Ethiopia) and analyzing the impact of adaptation strategies on maize crop, the major crop type produced in central Ethiopia. It also estimated factors that limit the decisions of farm households to adapt and which strategy to use in maize crop production and gave detailed analysis on how conditioning variables affect each crop adaptation strategy used by households in the area.

2.5. **Theoretical framework of the study**

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 (Yusuf *et al*, 2008). In this study, the adaptation to climate change at all is binary case to adapt or not to adapt (0,1), while strategies (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 *et al*, 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* $k \neq j$ (Deressa *et al.*, 2008):

This can be indexed as;-

$$E\,[R\,(Y_j)] > E[R\,(Y_K)] \qquad (1)$$

where $k \neq j$, and:-

E is read as expected

R represents benefit to obtain from using an adaptation method and,

Y_j, and Y_K represent two different adaptation options compared. However, expected benefit (utility) is not directly observed, and thus the actions of economic agents (farmer households) are observed through the choices they make (Deressa *et al.*, 2008).

2.6 Conceptual framework

Different factors can affect the decision of stallholder farmers to adapt and which methods of adaptation to use. These factors can generally be classified as household characteristics, farm (plot) characteristics, infrastructure and institutional access, and social capital (Deressa *et al.*, 2008). Household characteristics can include age, education, experience, marital status, and gender of the household head and household income. Farm (plot) characteristics can include farm size, fertility, slope and location of the farm. Institutional and infrastructural factors can include access to extension and credit, distance to input and output markets and the availability of information services. Social capital can include number of peoples a household can rely for support in times of need (Figure 2.1).

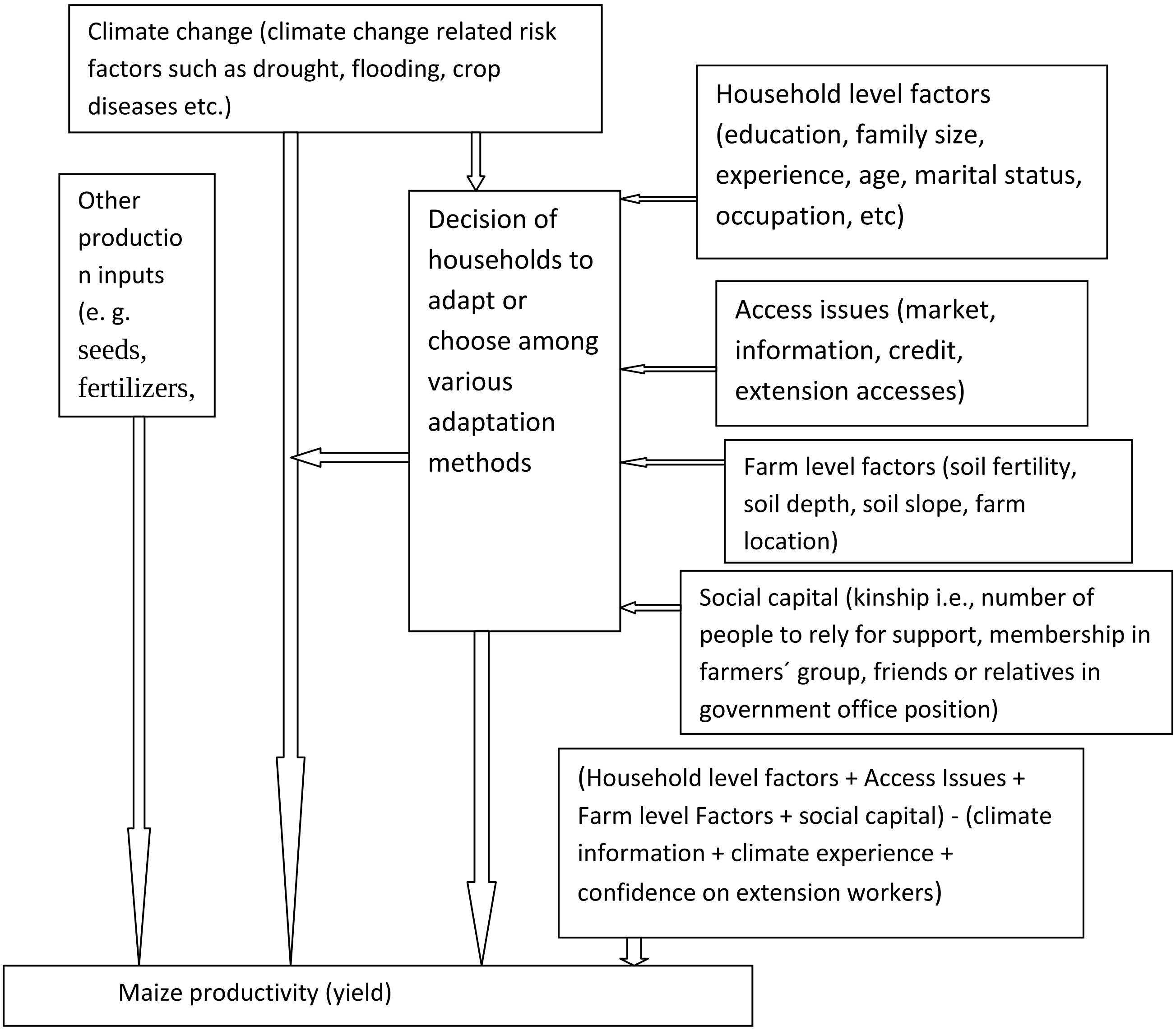


Figure 2.1: Summary of Variables Examined in the Study (adapted from Feenstra *et al.*, 1998)

There are constraints that can limit the capacity of households to respond to climate change in crop production. These include lack of information, lack of education, lack of money, shortage of labor, shortage of land, lack of irrigation capacity, lack of market access for inputs and out puts and health factors (Nhemachena and Hassan, 2007). Similarly, information concerning climate change forecasting, adaptation options and other agricultural production activities is an important factor affecting use of various adaptation measures for most farmers. Lack of this 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 (Jones, 2003; Nhemachena and Hassan, 2007). 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 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 (Deressa *et al* 2008). On the other hand, education is an important factor that can affect quality of labor. It is an important source of information for farm-level

Sources of education can be formal educational institutions such as agricultural colleges or informal education through extension services and learning from other progressive neighboring farmers and relatives (Nhemachena & Hassan, 2007; Deressa *et al,* 2008; Di Falco et al, 2011). 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 (Di Falco &Veronese, 2012). Personal behavior can affect the decisions of farm households to use adaptation strategies. For instance, farmhouse holds that are pessimistic may not have trust on extension services, and thus although extension services are available, those households may hesitate to use their services (Kassie *et al*., 2012).

Limited market access 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 cited in Nhemachena & Hassan, 2007). Similarly, lack of irrigation can also affect the decision of households to use irrigation as crop adaptation option. The location of a farm determines the availability of irrigation. Farm plots that are located near to water bodies like lakes and rivers can give the opportunity to use irrigation as adaptation option, whereas those that are located far from such water bodies may not be suitable to use irrigation as an adaptation option (Nhemachena & Hassan, 2007). Social capital can also affect the capacity of farmers to adapt and to choose among adaptation methods. It can directly affect farmers´ information access, credit source and financial capacity required to adapt to climate change (Deressa et *al*., 2008).

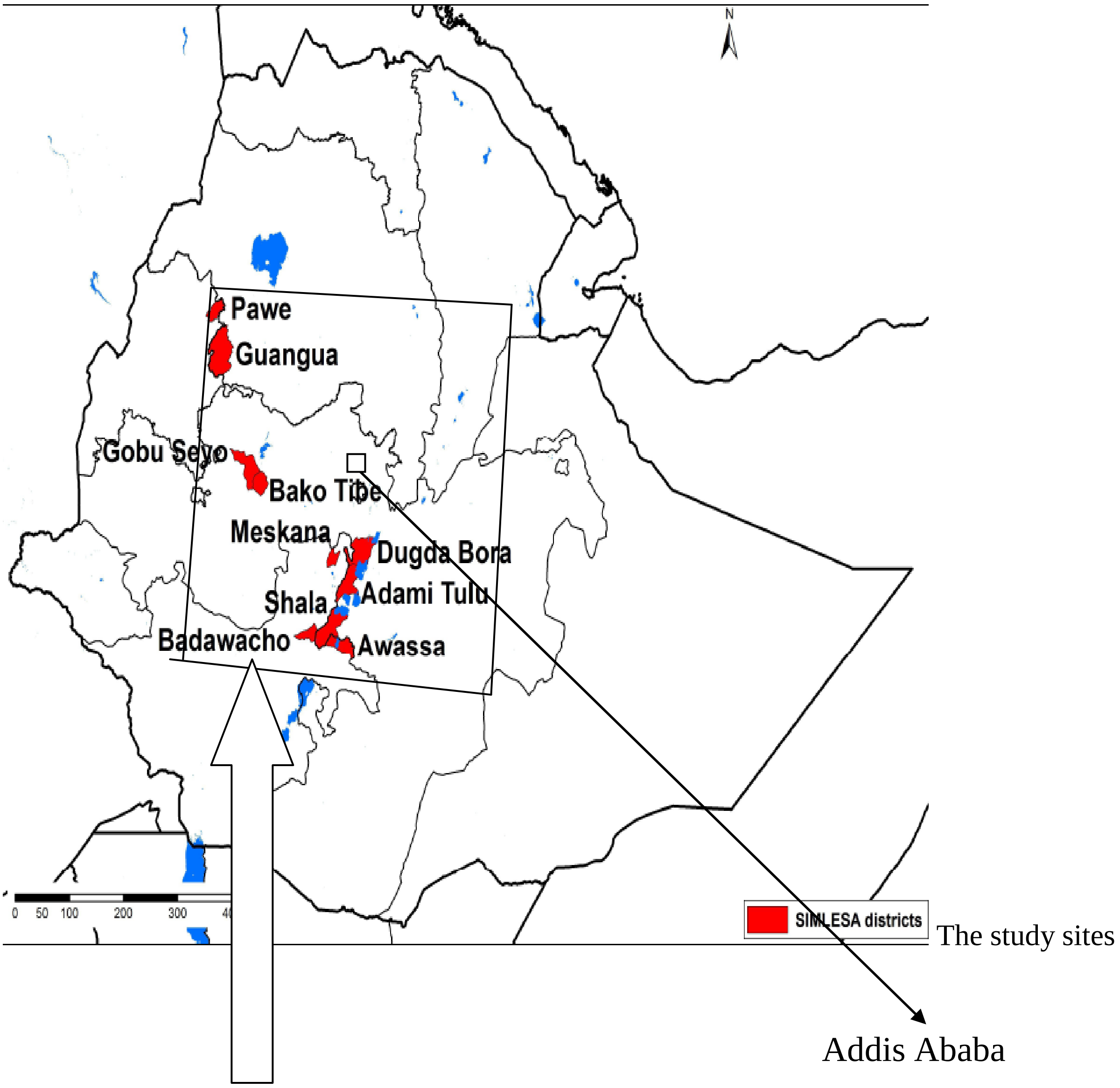
CHAPTER THREE
STUDY DESIGN AND METHODOLOGY

3.1 **Introduction**

This chapter describes the study sites, data types and sources. Methods and procedures of data collection, management and analysis are also presented. Finally, selected models and estimation procedures used are outlined.

3.2 **Study Sites**

The sites covered in this study are found in central Ethiopia which is one of the vulnerable areas to climate change. Central Ethiopia covers three regional states of Ethiopia: Benshangul Gomez, Oromya and the Southern Nations, Nationalities and Peoples (SNNP) regional states. In this part of Ethiopia, the major crop production is maize. Maize production in this area accounts for over 50% and 76% of the total cultivated land and consumption of own production, respectively (Kassie *et al.*, 2012). For this study, nine woredas (small districts) were selected from three regional states based on their maize production potential. The selected woredas are Pawe, Guangua, Gobu Seyo, Bako Tibe, Meskana, Dugda Bora, Adami Tulu, Badawacho and Awassa (see Figure3.1).



Central Ethiopia *(the study site*)

Figure 3.1: A Map Showing the Location of the Study Sites (Source: The International Maize and Wheat Improvement Center, 2010)

3.3 **Data Types and Sources**

Both secondary and primary data were used. Secondary data was used to prepare the background information of the study, establish the analytical framework and select and specify models and methods of estimations. Sources of secondary data included related literature which comprised of published journals papers, reports and practical hand books. On the other hand, primary data was used to estimate the models and analyze crop production adaptation strategies to climate change in the context of central Ethiopia.

The study utilized cross-sectional methodology to collect primary data from farm households that were sampled from the study sites. Data on household and plot characteristics, environmentally related risk factors, institutional and infrastructural factors as well as households´ maize yields and production inputs were derived from farm household survey using a semi-structured questionnaire. The data was used to identify and analyse factors that affected the capacity of farm households to use crop adaptation strategies, and to examine the impact of adaptation strategies on farm households´ maize productivity (yields). The rationale behind focusing on maze yield in this study is that maize is the largest cereal crop in terms of its share of total cultivated area, total production and role in direct human consumption in the study areas. Maize production accounts for over 50% and 76% of the total cultivated land and consumption of own production, respectively (Kassie *et al.*, 2012).

3.4 **Sampling Procedure and Data Collection**

A total of 898 farm households were sampled from nine districts in three regional states of Ethiopia. A multistage sampling procedure was employed to arrive at these households. First, based on their crop production potential, nine main maize producing districts were selected from the regional states. Secondly, based on proportionate random sampling, Peasant Associations (PAs) from each of the sampled districts and farm households from each PA were selected (see Appendix 1). Intending to provide the respondents with chances to bring new ideas, a semi-structured questionnaire was designed to capture all the necessary primary data that was sought (Appendix 2). A team of experienced enumerators were recruited and trained on how to use the designed questionnaire to capture the needed data. As part of the training and evaluation, the trained enumerators were used to pretest the questionnaire. The questionnaire was pretested in a non-sampled PA. After the pretesting, issues arising therein in were discussed and resolved before the enumerators were deployed for the actual data collection from the sampled households in the sampled PAs. The questionnaire sought to collect detailed data about households, farm plots, and village data including input and output market access, household composition, education, asset ownership, herd size, household income, participation in credit markets, membership of formal and informal organizations, participation and confidence in extension services, crop production, crop adaptation strategies and a wide range of plot-specific attributes.

3.5 **Data Entry and Cleaning**

The raw data from the field was entered directly into a STATA program using the STATA data editor. To minimize possible errors that might have occurred during the entry process, a double data entry strategy was applied. Before the data entry, the original questionnaires were reviewed to remove possible ambiguities in paper questionnaires. To avoid errors that might have occurred because of reasons other than data entry process, the soft copy of the data file was checked for implausible variables and variable combinations and the necessary corrections were taken. An econometric analysis was undertaken with precaution because cross sectional data is usually associated with problems of outliers, heteroscedasticity, multicollinerity and endogeneity of explanatory variables (Woodridge, 2002). Since these econometric issues were likely to affect the robustness of the results, the data was chalked for these problems and cleaned before estimation.

3.6 **Methods of Analysis**

Three econometric models were used to analyze the data. First, a binary logit model was used to analyze factors that affect the decision of farmers to adopt climate change adaptation strategy at all. Second, a multinomial logistic regression model was applied to model the adaptation strategies, and the parameters were estimated by using maximum likelihood method of estimation. Third, a two stage endogenous switching regression (ESR) model was applied to estimate the impacts of maize adaptation on maize yield of farmer households. Finally, the estimations from the endogenous switching regression model were used to build actual and counter factual analysis to compare the maize crop productivity under the actual and counterfactual cases that the farm household adapted or not to climate change. Treatment and heterogeneity were calculated to understand the differences in maize productivity between farm households that adapted and those that did not adapt. Details of these models are described in the following sections.

3.6.1 Binary Logit Model

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,

$$Y = Z_i\beta + \varepsilon_i \quad \text{..(1)}$$

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). 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(Nhemachena & Hassan, 2007; Deressa *et al.*, 2008; Di Falco *et al.*, 2011 & Di Falco &Veronese, 2012).

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.
The model is specified as shown in equation 2 (Woodridge, 2002):

$$p(Y = 1/Z) = \Lambda(z^{!}\beta) = \frac{e^{z^{!}\beta}}{\left(1 + e^{z^{i}\beta}\right)} \quad \text{..(2)}$$

, 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 (Woodridge, 2002). The derivation of the equation is given as:

$$\frac{\partial P(Y=1/Z)}{\partial z_k} = \frac{\partial \Phi(Y=1/Z)}{\partial z_k} = \Lambda(z!\beta)\left[1-\Lambda(z!\beta)\right]\beta_k \qquad (3)$$

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(Ibid). This is given by;

$$\frac{\partial P(Y=1/Z)}{\partial Z} = [\Lambda(z!\beta)][1-\Lambda(z!\beta)]z_K = 1 - [\Lambda(z!\beta)][1-\Lambda(z!\beta)]\beta_K]Z_K = 0 \qquad (4)$$

3.6.2 **Multinomial Logit Model**

Multinomial Logit (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 multinomial logit (MNL) model is that it allows the analysis of adoption options across more than two alternatives (Deressa *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 follows:-

$$Y^*_{ij} = Z_i\beta_j + \varepsilon_{ij} \qquad (5)$$

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

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

$$E\left(\varepsilon_{ij} \middle| z_i\right) = 0 \qquad (6)$$

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 (MNL) 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;-

$$\log\left(\frac{\pi_{ij}}{\pi_{iJ}}\right) = \log\left(\frac{\pi_{ij}}{1-\sum_{j=1}^{J-1}\pi_{ij}}\right) = \sum_{k=0}^{K} z_{ik}, where\, i = 1,2,\ldots N,\, and\, j = 1,2,..,J-1 \ldots\ldots\ldots\ldots\ldots(7)$$

Solving for π_{ij} we have;-

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

Like 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 (9) with respect to the explanatory variables provides marginal effects of the explanatory variables. The derivation of the equation is given as:

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

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. 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 i.e. $\beta_k = \frac{1}{\sum_{j=1}^{J-1}\beta_{jk}}$

(Koch, 2007).

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).

3.6.3 Modeling Impact of Adaptation Strategies on Maize Yield

When evaluating the impacts of climate change and adaptation on agricultural productivity, two approaches have become the most widely used methods: the agronomic (or crop) model and the Ricardian (or hedonic) model (Di Falco *et al*., 2011). Agronomic models are crop models that represent biophysical variables of crop production. They are used to simulate such relevant biophysical variables as soil, plant and climatic variables that determine plant growth and yield. These models attempt to estimate directly, through crop models, the impacts of climate change on crop yields. They rely on experimental findings that indicate changes in yield of staple food crops (i.e., maize) as a consequence of climate change related hazard. Then, the results from the model are fed into behavioral models that simulate the impact of different agronomic practices on farm income or welfare. They can be used to assess the impacts of climate change on agricultural productivity, as well as to investigate the potential effects of different adaptation options. However; this approach does not take into account other factors that affect the actual utilization of adaptation options by households (Molla, 2009; Di Falco *et al*., 2011).

On the other hand, Ricardian approach tries to isolate, through econometric analysis of cross-sectional data, the actual effects of climate change and adaptation on farm income and land value, after controlling for other relevant explanatory variables (e.g., factor endowment, proximity to markets, etc.). It implicitly takes into account other factors that affect the actual implementation of adaptation strategies. Thus, relatively, Ricardian approach is more advantageous in terms of minimizing huge costs required to conduct experiments and suitability incorporating farmers' efficient adaptations by including relevant variables that reflect adaptations made by farmers to alter their agricultural operations in accordance with a changing climate (Veronese *et al*., 2011; Di Falco & Veronese, 2012). However, the Ricardian approach fails to take into account the fact that adaptation is an endogenous decision governed by a host of factors, some observable and some not. Parameter estimates provided via Ricardian cross-sectional analysis can thus be affected because of unobservable heterogeneity of the error terms and endogeneity of observable variables (Mendelsohn *et al*., 1994).

To address these shortcomings, the climate change adaptation decision and its implications in terms of maize yield was modeled in a setting of a two-stage framework. In the first stage, a selection model for climate change adaptation where a representative risk adverse farm household chooses to implement climate change adaptation strategies was estimated. In the second stage, an endogenous switching regression model of maize productivity was estimated.

To specify the selection model, let S^* be the latent variable that represents maize climate change adaptation strategy choice with respect to and not to adapt. Thus, we will have latent equation for two possible maize adaptation options *j* defined as;-

$$S_{ij}^{*} = F_i \alpha_j + n_{ij} \quad \text{(10)}$$

With S_{ij}

$$\begin{cases} 1 \text{ iff a farm household decides to use maize climate change adaptation strategy} \\ 0 \text{ iff a farm household decides not to use maize climate change adaptation strategy} \end{cases}$$

In this study, maize climate change adaptation is defined when farmers use any of the maize adaptation strategy in any of their maize farms (plots). In the above equation, F represents all factors that affect the decision of households to use or not to use a given maize adaptation strategy. Those factors include household head and farm characteristics, institutional and infrastructural access, and social capital. On the other hand, n_{ij} captures all the variables that are relevant to the farm household's decision maker but are unknown to the researcher (e.g., farmers' skills and motivation). The output functions conditional on maize adaptation can be written as an endogenous switching regime model as follows:-

$$R_{ij}^{*} = X_i \delta_j + E_{ij} \text{...}(11)$$

$$with R_{ij} = \begin{pmatrix} \text{Re}\, gimea: R_{i1} = X_i \delta_1 + E_{i1}, if\, S_{ij} = 1 \text{..}(11a) \\ \text{Re}\, gimeb: R_{i0} = X_i \delta_0 + E_{i0} if\, S_{ij} = 0 \text{..}(11b) \end{pmatrix}$$

Where R_{ij} is the maize yield per hectare of farm household *i* in regime *j*, (*j* = *a*, *b*), and X_i represents a vector of inputs (e.g., seeds, fertilizers, manure, and labor), and farmer head's and farm household's characteristics, Institution and infrastructural access, and social capital included in F (in the selection model). E_{ij} represents the unobserved stochastic component, which verifies $E\ (E_{ij} \setminus X_i\ ) = 0$. For each sample observation only one among the *J* dependent variables of net yield is observed.

For the ESR model to be identified, it is important for the F variables in the maize adaptation model to contain a selection instrument in addition to those automatically generated by the non-linearity of the selection model of adoption (Kassie *et al*., 2013). Accordingly, access to climate information, confidence on the skills of government agricultural extension workers and climate change experience are instrumental variables used for identification of the impact of maize adaptation on maize yields. The behavior and capacity of farm households to respond to climate change can be influenced very much by access to certain source of information about climate change and the appropriate adaptation methods (Jones 2003; Nhemachena and Hassan, 2007). The confidence of farmers on the skills of government agriculture extension workers (who are the main sources of information and advices in Ethiopia) can also affect the decision of farm households to adapt to climate change using the information obtained from the extension workers(Kassie *et al*., 2013). Similarly, households past climate change experience can influence their decision to respond to climate change (Deressa *et al*., 2011).

However, instrumental variables used to identify the impact of climate change adaptation strategies on maize yield need to be correlated with the selection equation and at the same time they should not directly influence the outcome variables and the error terms of equations 11a and 11b (Wooldridge, 2002; Difacalo *et al*. 2011; Kassie *et al*., 2013). Accordingly, in this study these variables are considered to be likely correlated with the decision of farm households to use maize adaptation strategy but are unlikely to influence the outcome variable (maize yield) directly or correlated with the unobserved errors of equations 11a and 11b.

Access to different information sources has been used as instrument by various similar works done previously (e.g. Di Falco *et al*. 2011, Kassie *et al*., 2013).

To estimate the above yield equations, it could have been possible to apply ordinary lest square (OLS) method of estimation and the net yield equations could have been run separately, if the zero conditional mean assumption required running OLS holds true for the error terms of the yield equations. However, if the error terms n_{ij} of the selection model 11 are correlated with the error terms E_{ij} of the output functions, the zero conditional mean assumption for the error terms of the output equation will not hold true, the expected values of E_{ij} conditional on the sample selection will be nonzero, and the OLS estimates will be inconsistent (Di Falco *et al*. 2011, Kassie *et al*., 2013). To correct for such potential inconsistency, it is possible to estimate a system simultaneous equations of climate change adaptation and food productivity with endogenous switching by a two stage framework (Wooldridge, 2002,; Kassie *et al*., 2013). In such a model, the error terms in equations (11), (11*a*), and (11*b*) are assumed to have a tri-variate normal distribution, with zero mean and covariance matrix summation, i.e.,

$$\left(n, E_1, E_2 \right)' \sim N(0, \Sigma),$$

$$With, \begin{pmatrix} Q^2 & Cov\,n_1 & Cov\,n_2 \\ Cov\,n_1 & Q^2 E_1 & \cdot \\ Cov\,n_2 & \cdot & Q^2 E_2 \end{pmatrix}$$

where $Q^2 n$ is the variance of the error term in the selection equation (11), which can be assumed to be equal to 1, since the coefficients are estimable only up to a scale factor (Maddala, 1983 cited in Veronesi *et al* 2011 and Kassie *et al*., 2013), $Q^2 E_1$ and $Q^2 E_2$ are the variances of the error terms of regime a and b in the output model (11), and Covn_1 and Cov n_2 represent the covariance of n_i ,and E_{1i} and E_{2i} respectively. Since R_{1i} and R_{2i} are not observed simultaneously the covariance between E_{1i} and E_{2i} is not defined, that is the reason why it is reported as dots in the covariance matrix (Maddala, 1983 cited in Veronesi *et al*. 2011 and Kassie *et al*., 2013). The implication of the error structure is that since the error term of the selection equation (11) n_i may be correlated with the error terms of the output functions (11a) and (11b) (E_{1i} and E_{2i}), the expected values of E_{1i} and E_{2i} conditional on the sample selection (based on maize climate change adaptation) may not be zero, and thus estimating OLS will result in biased and inconsistent parameter estimates of the output equations (Veronese *et al*., 2011; Di Falco & Veronese, 2012; Kassie *et al*.,2013).

The expected value of the error term of the output equation (11a) conditional on maize adaptation for adapted maize farms can be expressed as;

$$E\left(E_{i1}\middle|S_i = 1\right) = \theta_{1E}\frac{\phi(F_i\alpha)}{\Phi(F_i\alpha)} \qquad (12)$$

$= \theta_{1E}\lambda_{i1}$, where $\lambda_{i1} = \frac{\phi(F_i\alpha)}{\Phi(F_i\alpha)}$ is the inverse mills ratio to be included in equation 11(a).

Similarly, the expected value of the error term of the output equation(11b) conditional on maize adaptation for non-adapted maize farms can be written as;-

$$E\left(E_{i0}\middle|S_i = 0\right) = -\theta_{0E}\frac{\phi(F_i\alpha)}{1-\Phi(F_i\alpha)} \qquad (13)$$

$= \theta_{0E}\lambda_{i0}$, where $\lambda_{i0} = \frac{\phi(F_i\alpha)}{1-\Phi(F_i\alpha)}$ is the inverse mills ratio to be included in equation 11(b)

The Inverse Mills Ratios (IMR) computed from the selection equation are included in 11a and 11b to correct for selection bias in a two-step estimation procedure i.e., endogenous switching regression (the same strategy was used in similar works (e.g. Veronese *et al.*, 2011; Kassie *et al.*, 2013). In the above equations $\phi(.)$ is the standard normal probability density function and $\Phi(.)$ is the standard normal cumulative distribution function.

3.6.4 **Average Treatment Effects**

The above framework can be used to estimate the average treatment effect on the treated (ATT) and average treatment effect on the untreated (ATU) maize farms by comparing the expected values of the outcomes of adopted and non-adopted farms in actual and counterfactual scenarios. Following Carter and Milon (2005), Di Falco *et al* (2011) and Kassie *et al* (2013) this study computes the ATT and ATU in the actual and counterfactual scenarios. The estimates from ESR allow for the computing of the expected values in the real and hypothetical scenario

Considering the real scenario, the expected maize yield in adapted maize farms (with maize climate change adaptation) observed in the sample can be expressed as follows;-

$$E\left(R_{i1} \middle| S=1; x\right) = x_{i1}Q_1 + \theta_{1E}\lambda_{i1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13a)$$

Similarly, expected maize yield in non-adapted maize farms (without climate change adaptation) observed in the sample can be written as follows;-

$$E\left(R_{i0} \middle| S=0; x\right) = x_{i0}Q_0 + \theta_{0E}\lambda_{i0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13b)$$

On the other hand, the hypothetical counterfactual scenario of mean maize yield in adapted maze farms if they had not been adapted is stated as follows;-

$$E\left(R_{i0} \middle| S=1; x\right) = x_{i1}Q_0 + \theta_{0E}\lambda_{i1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13c)$$

Similarly, the expected maize yield if the non-adapted maize farms had been adapted is expressed as follows:-

$$E\left(R_{i1} \middle| S=0; x\right) = x_{i0}Q_1 + \theta_{1E}\lambda_{i0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13d)$$

In the above equations, R_1 represents quantity of maize produced with maize climate change adaptation, while R_0 represents quantity of maize produced without maize climate change adaptation. Equations (13a) and (13b) represent the actual expectations observed from the sample, while equations (13c) and (13d) are the counterfactual expected outcomes. Using these conditional expectations the mean maize yield outcome difference can be computed. The expected change of maize yield in adapted maize farms, the effect of treatment on the treated (ATT) is computed as the difference between (13a) and (13d), which is written as follows;-

$$\text{ATT} = E\left(R_{i1} \middle| S=1; x\right) - E\left(R_{i0} \middle| S=1; x\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$= x_{i1}\left(Q_1 - Q_0\right) + \lambda_{1i}\left(\theta_{1E} - \theta_{0E}\right)$$

Similarly, the expected change in maize yields of non-adapted maize farms, the effect of the treatment on the untreated (ATU) is given as the difference between (13c) and (13b), which is expressed as follows;-

ATU= $E\left(R_{i1} \middle| S=0; x\right) - E\left(R_{i0} \middle| S=0; x\right)$...(15)

$= x_{i0}(Q_1 - Q_0) + \lambda_{0i}(\theta_{1E} - \theta_{0E})$

HAPTER FOUR
RESULTS AND DISCUSSION

4.1 **Introduction**

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

4.2 **Results of the descriptive statistics**

4.2.1 **Climate change related risk factors**

The climate change related risk factors in this study were based on asking farmers if they faced climate change related risk factors and which risk factors they faced in the last production season. Accordingly, in central Ethiopia farmers faced four types of climate change related risk factors in the last production season. The risk factors are drought, flood (too much rain), crop pest/daises and hail storm (Table 4.1).

Table 4.1: Climate change related risk factors faced

Risk factor faced	N=898	
	Number of households	**Percentage**
Drought	615	68.41
Flood(too much rain)	284	31.59
crop pest(diseases)	219	24.36
Hail storm	72	8.01
None	62	7.01

As can be seen in the above Table, about 93% of the sampled farmers faced at least one type of climate change related risk factor in the last production season. The majority (about 68%) of the sampled households faced at least drought, whereas the minority (about 8%) faced at least hail storm in the last production season. The second risk factor in terms of the number of households that faced it was flood. The results of the descriptive statistics (Table 4.2) indicate that the sampled farmers who experienced some climate change risk factors were also exposed to multiple risk factors. While there were those who faced just one risk factor, others reported multiple risk factors. For instance, there were farmers who only experienced drought, only experienced floods, only experienced crop pests/diseases or only experienced hail storms in the last production season. On the other hand, there were other farmers who reported multiple risks like drought and floods; floods and crop pests or even drought, floods and hail storms.

As presented in Table 4.2, out of the total households who faced climate change related risk factor, the majority (about 75 %) faced only one type of climate change related risk factor, while the rest (about 25%) faced more than one risk in the last production season. Out of those households who faced only one type of climate change risk factor the majority (about 73 %) faced only drought, while the minority (about 14%) faced only hail storm. Out of the total sampled farmers the majority (about 54%) faced only drought. Out of those households who faced more than one risk factor the majority faced drought, flood and crop pest together, while the minority faced drought, crop pest and hail storm together. Out of the total farm households who experienced crop pests/diseases in the last production season, only 25% experienced it without facing other risk factors. The rest of the households (75%) who experienced crop pest/diseases faced also one or more of other environmental risks. 126 households (which is about 15% of the sampled households) faced drought and too much rain (flood) together in one production season.

Table 4.2: Summary on the composition of risk factors

Risk factors faced	***Number of farmers who faced the risks***	***Percent of farmers***	***Cumulative %***
Only Drought	452	54.07	54.07
Only Flood	106	12.68	66.75
Only Crop Pest	50	5.98	72.73
Only Hail Storm	24	2.87	75.60
Drought and flood	35	4.19	79.31
Drought and crop pest	31	3.71	83.01
Flood and crop pest	41	4.9	88.4
Drought, flood and hail storm	7	0.84	96.05
Drought, flood and cpest	64	7.66	96.89
Drought, crop pest and hail storm	6	0.6	97.61
All risks togather	20	2.39	100
TOTAL	***836***	***100***	

Generally, the results indicate that drought and flood are the two major climate change related risk factors faced by farmers in central Ethiopia. In fact other studies also show that in Ethiopia drought and flood are the most serious climate change related risk factor faced by the majority of smallholder farms. For instance Bryan *et al*. (2011) showed that in Ethiopian Nile basin the majority of the sampled households faced frequent droughts and floods in five years.

4.2.2 Crop adaptation strategies used by farmers

Crop adaptation strategies were identified and used as dependent variables in the multinomial logistic regression model. Crop adaptation strategies in this study are based on asking farmers which crop adaptation strategy they used to counteract the negative impacts of climate change related risk factors on their crop yields. These were the most important strategies that the respondents adopted to counter the negative impacts of climate change related risk factors on their crop yields. If a farm household used a particular climate change adaptation strategy in at least one of the plots under crop(s), then that specific climate change adaptation strategy was assigned the value of 1. Similarly, if a farm household did not use a particular climate change adaptation strategy in plots under crop(s), then that particular adaptation strategy is assigned the value of 0.

To cope with the climate change risk factors, farmers used different crop adaptation strategies. The major strategies used by farm households were planting fitting seed varieties, early/late planting method, crop choice method, increasing seed rate and soil and water conservation methods (Figure 4.1). These are yield related strategies used by more than 96% sampled farmers who used adaptation strategies. However, farmers also used other strategies that are not related with yield including migration, transforming from crop to livestock agriculture and shifting to non-farm activities, which together accounted for less than 4% of households that used adaptation strategies. As the purpose of this study is to analyze factors that affected the decision of farmers to use yield related strategies and the impact of these strategies on households´ maize productivity, those farmers that used non-yield related strategies are considered as non-adapters in this study.

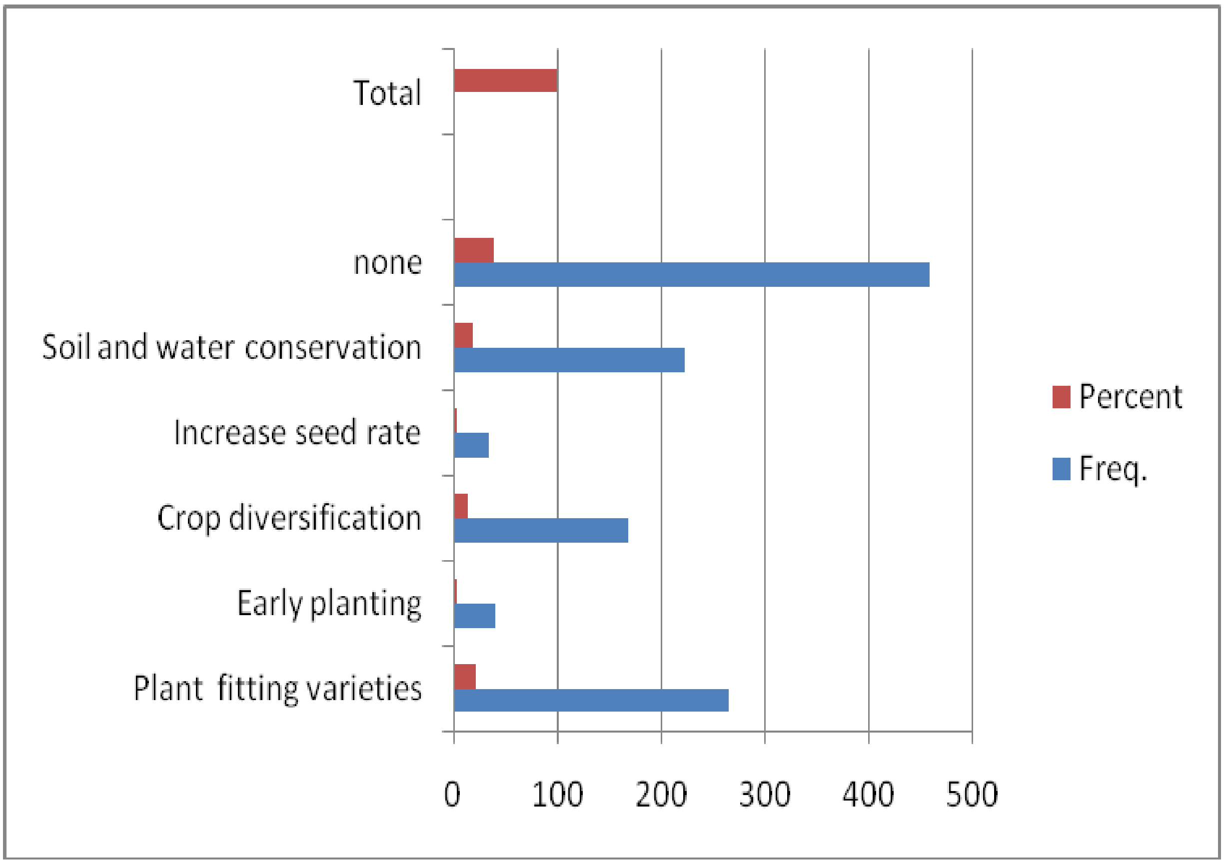


Figure 4.1: Adaptation strategies used to cope with the risk factors

Figure 4.1 shows that majority of farm households who faced environmental risk factors did not take any crop adaptation strategy in any of their cropped plot. Out of those households that reported they faced climate change related risk factors, about 52% reported that they did not use any crop adaptation strategy in any of their crop farms (Table 4.4). The most commonly practiced method of crop adaptation in the study areas was planting fitting seed varieties, whereas use of increasing seed rate was the adaptation method least practiced among the major adaptation methods (Figure 4.1). This could indicate that farm households had 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 maximizing 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 expectation that use of increased seed rate as a method of crop adaptation could result in less benefits in terms of maximizing crop yields.

Descriptive statistics results also indicated that a single type of crop adaptation strategy could be used to cope up with more than one environmental risk factor. All crop adaptation strategies (except increasing seed rate method) were used to cope with all types of identified climate change risks (Table 4.3).

Table 4.3: Risk factors and adaptation strategies (% responses)

Adaptation strategy	Drought (N=615)	Floods (N=284)	Crop pests or diseases (N=219)	Hail storms (N=72)
Plant fitting seed varieties	12.19	3.87	77.17	15.28
Plant fitting crop varieties (crop choice method)	19.67	4.58	9.13	20.83
Early planting	4.07	1.76	2.28	8.33
Increased seed rate	0	4.58	0	27.78
Soil & water conservation	2.93	70.1	0.91	5.56
None	61.14	15.14	10.5	22.22

However, the popularity of practicing a specific crop adaptation strategy to cope with the adverse effects of a given climate change risk factor varied based on the type of risk factor faced. The most widely used strategy to cope with the effect of drought was crop choice method (19.67%), followed by use of drought tolerant/resistant seed varieties (12.19%). Increased seed rate method was not used to deal with the problem of drought in crop production (Table 4.3). This may indicate that farmers had relatively better access to inputs required to practice crop choice and fitting seed varieties methods. It may also indicate that farmers had expected that these methods are relatively more effective in terms of minimizing the negative effect of drought on their crop yields.

Soil and water conservation was very popular in mitigating against the adverse effects of floods among the surveyed households. The strategy least practiced to cope with the negative effects of flood on crop yields was early\late planting. On the other hand, majority of the cases that experienced crops pests and diseases used tolerant or resistant seed varieties as an adaptation strategy to this problem. Finally increased seed rate was the most popular strategy to combat the hail storm problem among the surveyed households, followed closely by proper choice of crop types to be planted (Table 4. 3). Generally, there is limited use of increasing seed rate and early\late planting as adaptation strategies across all the climate change risks among the surveyed households. These results may imply that the type of risk factor faced could affect the decisions of farmers to choose from various crop adaptation strategies.

The response rates of farmer households to climate change related risk factors vary based on the type of risk factors faced. Despite the fact that drought was the most popular climate change risk factor, the results showed that it had the highest number of cases (over 60%) reporting that they had no crop adaptation strategy towards this risk. On the other hand, sampled farmers reported high rates of adaptation (over 70%) in crop pest/disease risk and floods compared to any other risk factor (Table 4.3). These results may imply that farmers are less interested to adapt drought. This may be because those farmers expect drought to result in lesser damages on their crop yields relative to flood and crop pest. It may be also due to lacks of necessary facilities and inputs required to adopt crop adaptation strategies used to minimize the negative effects of drought.

4.2.3 Description of variables used to estimate the binary and multinomial logit models

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 (Table 4.4). This study divides factors (independent variables) that affect the decision of farm households to adapt/ choose among crop adaptation strategies into five major types. These are climate change risk factors, household characteristics, farm/plot characteristics, institutional and infrastructural level factors and social capital (Table 4.4).

Table 4.4: Explanatory variables of the binary and multinomial logistic models

	Variable description	Adopter (48%) Mean (Stdev)	Non-adopter (52%) Mean (Stdev)	Total sample Mean (Stdev
Climate change risk factors (Environmental Variables)				
Flood	Faced in the last production season : 1 if yes and 0 otherwise	0.37 (0.48)	0.16 (0.37)	0.59 (0.49)
Drought	Faced in the last production season : 1 if yes and 0 otherwise	.23 (.42)	.12 (.33)	.34 (.48)
Frequency of Flood	Number of times faced in the last ten years	0.64 (1.6)	0.19 (0.82)	0.92 (1.9)
Frequency Drought	Number of times faced in the last ten years	2.1 (2.0)	2.33(1.62)	1.99 (2.2)
Household and household head characteristics				
Family size	Total family size (number)	6.6 (2.7)	6.7(2.74)	6.5 (2.8)
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)	0.80(0.40)	0.79 (0.40)
Risk experience	number of times a house exposed to the risks in 10 years	2.9(2.2)	2.8(2.0)	2.5 (1.6)
Age	Age of household head (years)	41.0(13.0)	41.4(13.12)	42.1 (13.1)
Gender	Dummy: 1 = male and 0 otherwise	0.89(0.31)	0.89(0.31)	0.89 (0.32)
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)	12,382(26,861))	10,808 (18,802)	14,219(33,853
Asset	Total asset of a household(in birr)	18,842(35,015)	18,245(38,108)	17,284(42,643)
Livestock ownership	Number of livestock a house hold has measured in TLU	2.6 (2.54)	2.5(5.52)	2.3(2.5)
Plot characteristics				
Soil/plot slope	Weighted average of all crop farms a household has	.097 (.071)	.098 (.076)	.1 (.08)
Soil fertility	Weighted average of all crop farms a household has	.12(.076)	0.12(0.84)	.12 (.096)
Soil depth	Weighted average of all crop farms a household has	.14 (.01)	0.15 (0.01)	0.17 (0.11)
Crop farm size	Total crop farm a household has(in hector)	9.2 (9.6)	9.3 (8.5)	9.5 (6.3)
Plot location	Distance from residence(measured in minutes)	16.3(21.4)	16.2 (20)	15.9 (17.5)
Institutional and Infrusturactural Variables				
Information	Dummy: 1 if a household had information and 0 otherwise	0.56 (0.5)	0.5 (0.5)	0.4(0.5)
Market access	Walking minute to input and output market	103.5 (72)	110 (76)	121 (80)
Extension access	Walking minute to the agricultural center	26 (23)	26 (26)	28 (30)
Confidence	Confidence on skills of government extension: 1 yes & 0 otherwise	0.77(0.4)	0.7 (0.4)	0.7 (0.5)
Cerdit constrain	Dummy 1= faced constrain and 0 otherwise	.06 (.2)	.06 (.24)	.07 (.25)
Social capital				
Friends/relatives in government offices	Dummy: 1= have and 0 otherwise	0.56 (0.5)	0.56 (0.5)	0.5 (0.5)
Kinship	Number of friends/ relatives to ask support in time of needs	6.2 (10.4)	5.4 (8)	4.4 (5.7)
Membership to any farmer groups in the village	Dummy: 1= member and 0 otherwise	0.5 (0.5)	0.4 (0.5)	0.3 (0.4)

As presented in Table 4.4, 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 drought in the last production season while 26 % reported they faced flood. The remaining 4 % reported that they faced both drought and flood in the last production season. The average occurrence (frequency) of drought in the last ten years for those households that used at least one adaptation strategy was about 2 and 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.

As presented in Table 4.4 , household and household head characteristics considered in this study include family size, household head´s formal education level, 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 14, 219 Ethiopian Birr which turns down to 10,808 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 18,842 Ethiopian birr, this was about 17,284 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 down 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.

Plot characteristics considered in this study were plot slope, soil fertility, soil depth, and 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.

Table 4.4 also presents institutional and infrastructural factors considered in this study including access to climate information, input and output market, agriculture extension and credit constraint. 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 time to the nearest agricultural extension center was about 28 minutes 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.

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 (see Table 4.4).

4.2.3 **Variables used to estimate the endogenous switching regression (ESR) model**

As indicated earlier, some households did not produce maize in the last production season. As a result those households that did not produce maize were excluded from the endogenous switching regression model. The ESR model was estimated at plot level. Therefore it was important to produce descriptive statistics for those households that produced maize. The description of variables and their descriptive statistics results for those households that produced maize are presented in Table 4.5 & Table 4.6.

Table 4.5: Description of Household level variables used in the ESR (Mena (standard deviation)

Variable name	Variable description	Adapters (N=327)	Non-adapters (N=380)	Full sample (N=707)
Family size	Family size (number)	6.6 (2.7)	6.5 (2.8)	6.6 (2.7)
Education	Education (years of schooling)	3.5 (3.3)	3.1 (3.4)	3.3 (3.4)
Experience	Climate experience (No of times household exposed to risk factors in last 10 years	2.8(2.0)	2.5(1.5)	2.6(1.8)
Age	Age of household head (years)	41.0(13.0)	42.0(13.0)	41.6 (13.3)
Gender	Gender (1 = Male; 0=Otherwise)	0.9 (0.3)	0.9 (0.3)	0.9 (0.3)
Marital	Marital status (1= Married; 0=Otherwise)	0.9(0.3)	0.90.3)	0.9(0.3)
Assets	Total household assets (ETB)	20384.0(33590)	16931.5(36533)	18528.4(35219.7)
Livestock	Livestock ownership (TLU)	2.6(2.7)	2.2(2.1)	2.4(2.4)
Information	Climate Information Access (1=Yes; 0-Otherwise)	0.5(0.5)	0.4(0.5)	0.5(0.5)
Market distance	Distance to input and output market (Walking minute)	99.6(73.0)	122.3(79.7)	111.8(77.6)
Credit	Credit constrain (1=Yes; 0=Otherwise)	0.1(0.2)	0.1(0.2)	0.1(0.2)
Extension distance	Distance to agriculture extension center (Walking minute)	27.0(25.0)	27.2(29.9)	27.2(27.7)
Confidence	Confidence on skills of government extension workers (1=Yes: 0=Otherwise)	0.76(0.4)	0.72(0.5)	0.74(0.4)
Kinship	Kinship (Number of dependable friends/relatives in village in times of needs)	6.0(11.9)	4.6(5.5)	5.0(9.0)
Relatives	Relatives\friends in government office position (1=Yes; 0=Otherwise)	0.6 (0.5)	0.5(0.5)	0.6(0.5)
Farmer group	Farmer group membership (1=Yes; 0=Otherwise)	0.4(0.5)	0.3(0.5)	0.4 (0.5)

As presented in Table 4.5, the majority (more than half) of the households who planted maize in the last production season did not use any crop adaptation strategies in any of their maize farms. This result is similar with the result for crop adaptation in general, where also the majority of households did not use any crop adaptation strategy in any of their crop farms (see Table 4.4). Just like it was for crop adaptation strategy in any of crop farms, the results of the descriptive statistics in Table 45, show that the average formal education, experience, income, asset and livestock holding was higher for those households that used crop adaptation strategy in any of their maize farms(compare Table 4.4 and Table 4.5).

Table 4.6: Description of plot level variables used in the regression (mean (standard Deviation))

Variable name	Variable description	Adapters (N=640)	Non-adapters (N=742)	Full sample (N=1382)
Adaptation	Adapted to climate change (1=Yes; 0=Otherwise)	1.0 (0.0)	0.0 (0.0)	0.46 (0.5)
Yield	Yield (kg/ha)	2,448.9 (1,625.9)	2,319.4 (1526.7)	2379.4 (1574.2)
Flood	Experienced flood/hailstorm (1=Yes; 0=Otherwise)	0.4 (0.5)	0.1 (0.3)	0.3 (0.4)
Drought	Experienced drought (1=Yes; 0=Otherwise)	0.3 (0.5)	0.8 (0.4)	0.6 (0.5)
Pest/diseases	Experienced crop pests/diseases (1=Yes; 0=Otherwise)	0.3 (0.5)	0.1 (0.2)	0.2 (0.4)
Soil fertility 1	Soil fertility 1(1=Good; 0=Otherwise) – Reference group	0.3 (0.5)	0.4 (0.5)	0.4 (0.5)
Soil fertility 2	Soil fertility 2 (1=Average; 0=Otherwise)	0.5 (0.5)	0.5 (0.5)	0.5 (0.5)
Soil fertility 3	Soil fertility 3 (1=Poor; 0=Otherwise)	0.1 (0.2)	0.1(0.2)	0.1 (0.2)
Soil slope 1	Soil slope 1 (1=Gentle; 0=Otherwise) – Reference group	0.6 (0.5)	0.6 (0.5)	0.6 (0.5)
Soil slope 2	Soil slope 2(1=Medium; 0=Otherwise)	0.3 (0.5)	0.3 (0.5)	0.3 (0.5)
Soil slope 3	Soil slope 3(1=Steep; 0=Otherwise)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Soil depth 1	Soil depth 1(1=Shallow; 0=Otherwise) – Reference group??	0.2 (0.4)	0.2 (0.4)	0.2(0.4)
Soil depth 2	Soil depth 2(1=Moderate; 0=Otherwise)	0.4 (0.5)	0.5 (0.5)	0.4 (0.5)
Soil depth 3	Soil depth 3(1=Deep; 0=Otherwise)	0.4 (0.5)	0.3 (0.5)	0.3 (0.5)
Plot dist	Plot distance from residence (walking minutes)	116.2(82.2)	101.3(69)	128(85)
Manure	Manure application (kg/ha)	110.2 (294.0)	112.5 (338.5)	111.4 (318.6)
Plough	Plow frequency (1=More than once; 0=Otherwise)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Fertilizer	Fertilizer application (kg/ha)	108.6 (194.3)	111.3 (143.8)	110.1 (169.1)
Chemical	Chemical application (kg/ha)	0.5 (2.6)	2.0 (20.1)	1.0 (14.8)
Weeding	Weeding frequency (number of times)	2.2 (1.0)	2.3 (0.9)	2.2 (0.9)
Seed	Maize seed rate (kg/ha)	16.2 (64.9)	22.8 (214.5)	19.8 (163.2)

As seen in Table 4.6, the ESR model used all the variables used for the binary and multinomial logit models. However, in the output model such production variables as yield amount, manure, plough frequency, fertilizer, chemical, weeding frequency and seed amounts were included. Table 4.6 shows that maize yield per hectare was higher in maize plots where at least one crop adaptation strategy was used. This may imply that using crop adaptation strategy helps households to minimize the negative effects of risk factors and enhance maize productivity.

4.3 **Model results and discussions**

In this section results obtained from the models are presented and discussed.

4.3.1 **Results and discussion of the Binary Logit Model**

A binary logit model was estimated to investigate the factors influencing adaptation to climate change in general. Table 4.7reports the results from the logit model estimating the probability of a typical farmer undertaking adaptation to climate change in Central Ethiopia.

Table 4.7: The Estimated Coefficients and Marginal effects of Binary logit 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	0.34*** (0.01)	.033*** (0.03)
gender	0.007(2.4)	.0006(.002)
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)
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(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

See notes of table 4.6:

*Dependent variable is Undertaking any adaptation l 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 (Table 4.7 column 2) 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, household heads' formal education level, 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 time required to arrive at the nearest input and output market, walking time 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 findings are similar with the findings of other studies done previously. For example, using household level data from Nile basins of Ethiopia, Deressa *et al(* 2008) showed that the probability of a smallholder farmer household to adapt to climate change in crop production increases with climate information, livestock ownership, credit facility, number of relatives and household head's formal education level. Deressa *et al (2008*) also indicated that distance to output market, distance to input market and farm size decreases the probability of a farmer to take crop adaptation strategy in the Ethiopian Nile basins. Similarly, Bryan *et al* (2011) showed that farmers' decisions to adopt yield-enhancing adaptation strategies in the Ethiopian Nile basin are influenced by informal and formal institutional support, the availability of information on climate changes and household specific characteristics like formal education levels of household head. Using data from Tanzanian crop production system, Komba and Muchapondwa (2012) also showed that the probability of a specific Tanzanian smallholder farmer to adapt on climate change increases with household heads formal education level and past experience to drought incidences .The study also showed that distance to input market and farm size had negative effects on the probability of Tanzanian farmers to adapt to climate change.

As indicated earlier, 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 4.7(Column 3) 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 drought. 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 likely to respond to flood than drought. This result; however, seem to contradict with the work of Deressa *et al* (2008) that showed in precipitation level decreases the probability of adapting to climate change while increasing temperature increases the probability of adaptation, in Ethiopian Nile basins increase. Unlike Deressa *et al* (2008) that used continuous variables of precipitation and temperature, the current study used dummy variables for drought and flood to represent climate change variables. Therefore, the source of that contradiction between the two studies regarding the effect of climate change variables on the decisions of farmers to adapt to climate change may be due to the differences in taking climate change variables.

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. Household heads' formal education level also principally increases the probability of undertaking adaptation strategy. A one year increase in the formal education level of household heads increases the probability of adapting to climate change by 3.3 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 1 percent more probability to adapt to climate change. Similarly, having friends or relatives in government office decreases the probability of adapting by 1 percent. Farmers who have friends or relatives in government offices 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 drought 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. This may imply that rather than using technologies to improve productivity, farmers intend to enhance production by expanding cultivated land areas. 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. The implication of these results is that proximity to input and output market and crop plots determine the decision of farmer households to adopt climate change adaptation strategies.

4.3.2 **Results and discussion of the multinomial logit model**

Undertaking some adaptation to climate change is a step in the right direction by farmers in Ethiopia given that climate change occurs in that 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 risk factors. 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 (Komba and Muchapondwa, 2012).

Table 4.8 presents 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. Other previous studies (for instance,Deressa *et al* (2008) and Komba and Muchapondwa (2012) showed that the direction and magnitude of the effect of different factors on farmer's adaptation options vary across the adaptation methods.

Table 4.8: Marginal effects of explanatory variables from multinomial logit model (base category=no-adaptation)

Dependent variables (Adaptation Strategies)\	Methods 1; Planting fitting seed varieties	Method 2; Soil and water conservation method	Method 3: Crop choice method	Method 4; Early\late planting method	Method 5; Increasing seed rate method
Explanatory variables					
Climate variables;					
past draught 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***(.4) ***
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** (.033)***	1.0* (.01)*
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)	-0.6*** (-.9)***	0.3 (.01)	-0.14 (-.0007)
membership	0.54*** (.04)*	1.3*** (.073)***	0.70*** (.06)**	0.8* (.011)*	-0.33 (-.0101)
constant	-1.31**	-4.0***	-0.46	-5.5***	-3.6*
Number of plot (household) observations	836(940)				

, **, * , implies significance level at 10%, 5%, and 1%, respectively*

a) Fitting seed varieties method

The results for Method 1(Table 4.8) 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. The implication is that experience could help farmers know the importance of using fitting seed varieties method to minimize the negative impacts of climate change related risk factors on their crop productivity. However, relative to current drought, current occurrence of flood decreases the probability of using fitting 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 drought in the last production season. This may be due to that farmers know that fitting seed varieties method is relatively more effective to minimize the negative effects of drought than the effects of flood. 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. This may imply that having climate information could help farmers to make preparation required to adopt fitting seed varieties method.

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. This impels social capital is important to respond to climate change related risk factors by using fitting seed varieties method. Households that have larger social capital could obtain more information and help required to use this method.

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. This probably indicates that farmers who have confidence on the skills of government extension workers are more willing to use the information and advices those workers provide them about climate change and the appropriate adaptation strategies. 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 using fitting seed varieties method by 84 percent. This may be due to that fitting seed variety method may be inappropriate to be used in plots with deep soil. Credit constraint decreases the probability of using fitting seed varieties method by 9 percent. Farmers who faced constraint to obtain credit had a 9 % decrease in probability of using this method compared to those farmers who did not face credit constraint. This may imply that using seed varieties method could require more financial resources.

On average a 1 hectare increase of households´ crop farm size decreases the probability of using fitting seed varieties method by 0.5 percent. As indicated earlier, households with larger plot size may intend to improve production by expanding cultivated land areas, rather than using technologies. Similarly a 1 minute increase required arriving 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.

b) Soil and water conservation

The results for Method 2(Table 4.8) 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 drought 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. This may be due to that soil and water conservation method is relatively more effective to minimize the negative effects of flood than minimizing the negative effects of drought. 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. This may imply that those social groups could be sources of information and helps required to use soil and water conservation method. 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. As indicated earlier, farmers with confidence on the skills of government extension workers could be more willing to invest their resources on adopting climate change strategies. In other words, farmers who do not have confidence on the skills of extension workers could not be willing to take the risks of investing on adaptation strategies.

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 drought 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 drought 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. This may be due to that from experience farmers could know that soil and water conservation method is relatively more effective to cope with the negative effects of flood than effects of drought.

c) Crop choice method

The results from Method 3(Table 4.8) show that the likelihood of using crop choice method relative to “no adaptation’ increases with past experience to drought 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 (relative to current drought 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 crop choice method, experiencing one more incident of floods results in a 1 percent higher probability of using this method. However, relative to current drought incidence, current flood incidence decreases the probability of using crop choice method by 15 percent. Farmers who have an extra exposure to drought 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 drought 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. This may imply that farmers could believe that crop choice method is relatively more important to minimize the negative effects of drought than effects of flood.

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. 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 using 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. This may be due to that farmers believe that crop choice method is inappropriate to be used in plots with deeper soil. 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. This may be due to that farmers could have lack of human resources required to bring crop varieties from far markets.

d) Early\late planting method

The results from Method 4(Table 4.8) 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 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.

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. This probably implies that those farmer groups could be sources of information and other inputs required to adopt early\late planting method.

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.

e) Increasing seed rate method

The results from Method 5(Table4.8) 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. This could imply that having climate information is decisive in helping households to take the necessary preparations required to use this method of adaptation. 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.

4.3.3 **Results and discussion of the endogenous switching regression model**

Finally, Endogenous switching regression model was used to examine the impact climate change adaptation strategy adoption. Parameter estimates of climate change adaptation strategies and maize yield equations are presented in Table 4 9. Climate information, household heads' climate change experience and confidence on the skills of government extension workers are variables used to represent determinates of households´ decision to adopt some strategies in response to climate change related risk factors

The simplest method to examine the impact of adaptation on crop productivity is estimating a one stage ordinary least square (OLS) model of crop productivity that includes a dummy variable equal to 1 if the farm household adapted and 0 if otherwise. Estimates from the one stage OLS model however are likely to be inconsistent and biased. The inconsistent and biased results of a one stage OLS model emanates from the fact that this approach assumes that adaptation to climate change is exogenously determined while it is a potentially endogenous variable. That is, it does not explicitly account for potential structural differences between the productivity function of farm households that adapted to climate change and the productivity function of farm households that did not adapt (Di Facalo *et al*., 2011).

To compare the results of the model, an estimate of one stage ordinary least square model was done. The estimates of both models are presented in Table 4.9. The estimates from the one stage OLS model are likely to be misleading in making a wrong conclusion that adaptation would lead to a maize yield advantage of 193.5 kg\ha above non adapting households (see Table 4.9 Column 1, raw 3). The estimates presented in column 3 and 4 of Table 4.9 account for the endogenous switching in the maize yield function. Both the estimated coefficients of the correlation terms (mills ratios) are not significantly different from zero (Table 4.9, bottom row). Although it could not have been known initially, this may imply that the hypothesis of absence of sample selectivity bias may be rejected. However, the differences in the coefficients of the maize yield equation between the farm households that adapted and those that did not adapt can indicate the existence of heterogeneity in the sample (Table 4.9, columns (3) and (4)). Those differences in coefficients of the two functions indicate the existence of structural differences between two functions (Di Facalo *et al*., 2011).

Table 4.9: Parameters Estimates of Maize Adaptation and Maize Yield Productivity Equations

Estimation at plot leve, Sample size: 1616 plots. *, **, and *** significance level at 10, 5, and 1% level.

			ENDOGENOUS SWITCHING	
	1	2	3	4
Dependent Variables	OLS	Maize Adaptation (1/0)	Adapters	Non-adapters
Adaptation(1\0)	193.5(0.078*)			
Explanatory variables				
Confidence		0.1(0.32)		
Climate Information		0.21(0.02)**		
Climate experience		0.2(0.1)*		
Flood & hailstorm	-263.6(0.047)**	1.4(0.000)***	-1089 (0.076)*	29(0.9)
Crop pest (daises)	32.7(0.82)	1.6(0.000)***	-862 (0.1)*	512(0.6)
Famly size	21.4(0.24)	0.013(0.44)	-7.6(0.78)	43.7(0.056)*
education	17.1(0.24)	0.03(0.01)**	31.8(0.2)	1.5(0.9)
age	-5.5(0.1)*	0.003(0.5)	-7.7(0.2)	-5.86(0.32)
Gender	172.6(0.33)	-0.024(0.9)	130(0.54)	29.2(0.90)
Asset	0.001(0.4)	9.34E-07(0.42)	-0.0003(0.89)	0.00098(0.69)
Total livstok	0.31(1.0)	0.024(0.316)	-18(0.64)	16.0(0.7)
Distance to market	-0.5(0.4)	- 0.00149(0.008)***	0.68(0.55)	-0.79(0.30)
Credit constrains	-245.6(0.2)	-0.1(0.6)	-318(0.32)	-249.0(0.27)
Kinship	36.8(0.7)	0.12(0.1)*	75.20.62)	-51.8(0.71)
Friends\relatives in government office	2.4(0.7)	0.009(0.07)*	-5.58(0.42)	13.4(0.32)
Paricipation in farmers group	-228(0.02)*	0.34(0.000)***	-607.3(0.003)***	98.8(0.65)
Distance to extension center	2.2(0.19)	0.0003(0.87)	-0.5(0.85)	3.0(0.17)
Soil fertility 2	-16.7(0.86)	0.2(0.03)**	-77.0(0.6)	-10.4(0.9)
Soil fertility 3	-347(0.08))	-0.001(1.0)	-360.2(0.1)*	-257.8(0.35)
Soil slope 2	-31.7(0.82)	0.15(0.12)	-46(0.79)	250.6(0.10)*
Soil slope 3	-295.6(0.047)**	0.12(0.6)	-97(0.76)	868.7(0.04)**
Soil depth 2	158(0.1)	-0.06(0.6)	-423(0.065)*	-287.1(0.10)*
Soil depth 3	508(0.03)**	0.13(0.31)	-691(0.003)**	-173(0.40)
Plot distane	-379(0.004)***	0.002076(0.19)	-2.27(0.35)	-1.4(0.46)
Fertilizer intensity	-462(0.001)***		5.0(000)***	6.12624(0.000)***
Seed amount	-3.3(0.2)		8.3(0.2)	13.2(0.035)**
Chemical intensity	6.2(0.000)***		161(0.01)**	0.37(0.83)
Wedding frequency	9.5(0.02)**		218(0.000)***	47.5(0.52)
Plow frequency	-46.1(0.8)		318(0.37)	-399.6(0.27)
Manure quantity	290(0.006)***		298(0.08)*	247.2(0.09)*
Mills Ratio	-		-934(0.19)	439.4(0.6)
constant	1784(0.000)***	0.013(0.9)	2566.6(0.001)***	2023(0.06)*

In accordance with economic theory assumptions, inputs such as fertilizer, chemicals (herbicide& pesticide), manure and labor (invested on weeding) had strong association with the productivity of the farm households that adapted to climate change. On the other hand, seed amount and fertilizer significantly impacted on crop productivity of the farm households that did not adapt to climate change. It was also found that floods, compared to drought, had more negative impact on the productivity of households (Table 4.9, column 1). However, the relative adverse effects of floods were particularly associated with the yields of those that adapted to climate change (Table 4.9 column 3 & 4). That is households that faced drought and used adaptation methods were able to obtain more maize per hectare than those households that faced flood and used adaptation methods. The implication is that climate change adaptation strategies were more effective in minimizing the negative effects of drought than flood. The relative effects of the risk factors for those households that did not adapt were statistically insignificant (see column 3 and 4 of table 4.9).

4.3.4 **Results and discussions of actual and counterfactual comparisons**

To disentangle the impact of maize crop climate change adaptation strategies on maize yield from the impacts of unobserved heterogeneities between households who adapted and those who did not, a counterfactual analysis was built from the endogenous switching regression estimates. The estimates of maize yields for adapters and non-adapters in both actual and hypothetical cases were as presented in the Table 4.10.

Table 4.10: Average Expected Production per Hectare; Treatment and Heterogeneity Effects

Sub -Sample	Adoption decision		Treatement effect
	To adapt	Not to adapt	
Farm households that adapted	(a)2450(32)	(c)2248(27)	TT= 202***(42)
Farm households that did not adapt	(d)2767(117)	(b)2339(24)	TU= 428***(120)
Heterogeneity effects	BH_1= - 317	BH_2= -108	TH= -226***

See table 4.10 note; Standard errors are presented in parenthesis, * ** represents significance level at 1%

Cells (a) and (b) in Table 4.10 represent the expected maize quantity produced per hectare as observed in the sample. The expected quantity produced per hectare by farm households that adapted is about 2,450 kg, while it is 2,339 kg for the group of farm households that did not adapt. In the observed sample, the difference between the expected maize yield of those who adapted and those who did not was about 111 kg/ha. This simple comparison, however, can mislead the researcher to wrongly arrive at a conclusion that adaptation helped the farm households that adapted to produce about 111 kg more on average than the farm households that did not adapt. Such comparison can erroneously underestimate the impact of adaptation on households´ maize productivity. As seen in the last column of Table 4.10 that presents the treatment effects of adaptation on maize productivity, in the counterfactual case (c), farm households who actually adapted would have produced about 202 kg/ha less than they actually produced if they had not adapted. In the counterfactual case (d) farm households that did not adapt had they adapted would have produced about 428 kg/ha more. These results imply that adaptation to climate change significantly increases maize productivity. However, the transitional heterogeneity (TH) effect is negative, that is, the impact of adaptation on the productivity of households that actually did adapt relative to those that did not adapt was significantly smaller. Moreover, the last raw of column 3 in Table 4.9 implies that farm households who actually adapted would have produced less than the farm households that did not adapt in the counterfactual case (c). This implies that farm households that did not adapt have some characteristics (e.g., unobserved skills and other unobserved farm characteristics) that make them more productive regardless of climate change and adaptation. Yet the farm households who did not adapt would have been much better off adapting than not adapting. Finally, none -adapters had they adapted in the counterfactual case (d) would have produced the same as the farm household that actually adapted.

The results of the actual and counterfactual comparisons built from the endogenous switching regression model are more or less similar with the results of previous studies done in Ethiopia. For instance, Di Facalo *et al.* (2011) showed that in Ethiopia's Nile basin farmer households that did not adopt climate change adaptation strategies would have obtained more crop yields per hector had they adapted, and households that actually adopted would have obtained lesser crop yields per hector than they actually obtained had they not adapted. Di Facalo *et al.* (2011) also showed households that did not adapt if they had adopted would have obtained more production per hector than households that actually adopted. However, results in this study are different from Di Facalo *et al.* (2011) in that for the counterfactual case(d), if households that actually adapted had not adapted would have obtained smaller production per hectare than those who did not adapt. Regarding this particular counterfactual case Di Facalo *et al.* (2011) found that households that actually adapted would have still obtained more than those that did not adapt, if the former had not adapted. The findings generally imply that adopting climate change adaptation strategies can improve maize productivity, even in adverse climatic conditions.

4.4 **Summary on findings of the work**

This study had five interrelated objectives: (1) to identify climate change related risk factors faced by smallholder farmers in central Ethiopia, (2) to identify the major climate change adaptation strategies used by these farmers to minimize the negative effects of climate change in their crop production, (3) to analyze factors that limit the decision of smallholder farmers to adapt at all to climate change in their crop agriculture activities, (4) to investigate factors influencing their choice of particular adaptation methods to climate change, and(5) to examine the impact of climate change adaptation strategy adoption on households maize productivity .

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 representative districts selected based on their crop production potential. Farmers were asked if they had faced any climate change related risk factor in the last production season, and they were asked which risk factor they had faced. Accordingly, the study showed that farmer households in central Ethiopia had faced four types of climate change related risk factors: Drought, flood (too much rain), crop pest (daises) and hail storm. About 93 % of the sampled farmer households indicated that they had faced at least one type of climate change related risk factor in the last production season, while the remaining 7 % answered that they had not faced any. Out of those sampled farmers the majority (about 68%) faced at least drought, while about 32%, 24 %, and 8 % faced at least flood, crop pest and hail storm respectively. The study also showed that some farmer households had faced more than one type of climate change related risk factors, while some others faced only one type of risk factor. Out of those farmers who faced only one type of climate change related risk factor the majority (about 73%) faced drought, while the minority(about 14%) faced hail storm. The findings of this study also showed that out of the total sampled households more than half (54%) had faced only drought. The implication of these all findings is that drought is the most serious climate change related risk factor faced by farmers in central Ethiopia.

Those 836 farmer households who indicated that they had faced climate change related risk factors were asked if they had taken any climate change adaptation strategy in any of their crop farms to minimize the negative effect of climate change on their crop production. Accordingly, the majority (about 52 %) of those households responded that they had not taken any yield related adaptation strategy in any of their crop farms in the last production season. The remaining 48 % indicated that they had used at least one crop adaptation strategy in at least one of their crop farms. 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 most commonly method was planting fitting seed varieties , whereas increasing seed rate method was the least practiced one among those households who used crop adaptation methods. The study also showed that a single type of adaptation strategy was used to cope with different risk factors. However, the popularity of practicing a specific crop adaptation strategy to cope with the adverse effects of a given climate change risk factor varied based on the type of risk factor faced. The most widely used strategy to cope with the effect of drought was crop choice method, whereas soil and water conservation and planting fitting seed varieties were mostly used to cope with the negative effects of flood and crop pest respectively. Early\ late planting and increasing seed rate methods were mostly used to cope with hail storm.

The findings of the descriptive statistics also showed that the response rates of farmer households to climate change related risk factors vary based on the type of risk factors faced. Despite the fact that drought was the most popular climate change risk factor, the results showed that it had the highest number of cases reporting that they had no crop adaptation strategy towards this risk i.e. over 60%. Therefore, analyzing factors that affect the decision households to adopt climate change adaptation strategies and the impact households' decision on their maize productivity was very important.

To analyze the data, three models: binary logit, multinomial logit regression and a two stage endogenous switching regression models were estimated. 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, household heads' formal education level, 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.

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 time 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.

Regarding, the impacts of climate change adaptation strategies on maize yield, the findings can be summarized with four main points. First, the group of farm households that did not adapt to climate change risk factors had systematically different characteristics than the group of farm households that adapted. Estimating OLS model including a dummy variable for adapting or not adapting to climate change cannot help to take these sources of variations into consideration. Second, adaptation to climate change was found to increase maize productivity.

A critical look at this result for the two different groups of farm households (those that adapted and those that did not) shows interesting patterns. Farm households who actually adapted would have produced less than farm households that did not adapt in the counterfactual case than if they had not adapted. This implies that farm households that did not adapt have some characteristics (e.g., unobserved skills and other unobserved farm characteristics) that make them more productive regardless of climate change and adaptation. Third, the impact of adaptation on maize productivity is equal in both groups because if the farm households that did not adapt had adapted, they would have obtained the same maize productivity as the farm households that actually adapted. Fourth, the impact of unobserved heterogeneities on maize productivity of households who did not adapt if they had adapted is still more than those who adapted. That is farm households who did not adapt have some unobserved characteristics that would have helped them produce more than those who actually adapted in the counterfactual case if they had adapted. Generally, the implication is that farm households that adapted have relatively weaker production capacity than those that did not adapt. Therefore, adaptation strategies seem to be important for both groups of households.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents conclusions and recommendations of this study. In section two, conclusions are presented based on the objectives and findings of this study. The third section was devoted to provide recommendations for policy makers and further studies.

5.2 Conclusions

From the findings of descriptive statistics and econometric models, the following conclusions can be made.

1. Farmer households in central Ethiopia were facing various climate change related risk factors in their crop farms. The two major climate change related risk factors were drought and flood.

2. The majority of farmer households in central Ethiopia did not use any crop adaptation strategy in any of their crop farms. It was only less than half of the sampled households that used climate change adaptation strategies in their crop farms. The two major climate change adaptation strategies used by farmer households in their crop farms were planting fitting seed varieties and soil and water conservation methods. Farmer households proffered fitting seed varieties method mostly to cope with the negative effects of drought on their crop yields. Soil and water conservation method was most preferred to cope with the negative effects of flood.

3. Various factors were found to affect the capacity of farmer households to take crop adaptation strategy in their crop farms. The most important policy variables that affected the decision of farmer households to take any climate change adaptation strategy at all were household head education, climate information, confidence on the skills of government extension workers, access to input and output market, access to credit and social capital.

4. Various factors were found to affect the decision of farmer households to choose from various crop adaptation strategies. Such factors as climate information, access to input

and output market, confidence on the skills of government extension workers and social capital were found to be important policy variables affecting about 80 % of crop adaptation strategies used by households in central Ethiopia.

5. Crop adaptation strategies were found to enhance maize yields of farmer households. They were helping farmers to minimize the negative effects of climate change related risk factors of their maize yields.

5.3. Recommendations

The findings of this study imply that government policy makers and development practitioners need to improve the adaptation capacity of smallholder farmers. The task of improving the capacity of smallholder farmers to adopt climate change adaptation strategies in crop production can be done in the follwong ways.

1. To improve the capacity of the farmers to adapt to climate change at all, government policy makers and development practitioners should focus on improving information flow, formal education level, access to input and output market and credit facility.

2. In addition, policy interventions should focus on encouraging informal social networks that can promote group discussions and better information flows and experience sharing. That could help improve the capacity of smallholder farmers to use any one of the adaptation strategies identified in this study.

3. Government policy makers and development practitioners can identify the most appropriate climate change adaptation strategy and tackle determinant factors that affect the decision of farmers to use that strategy. This can be done based on environmental context of districts. For instance, in areas that are mostly prone to drought, policy makers and development practitioners can work on tackling determinant factors that affect the capacity of smallholder farmers to use crop choice (diversification) method which based on this study was mostly chosen by farmers to cope with the negative effect of drought on their crop yields. Similarly in areas that are mostly exposed to flood, they can work on tackling determinant factors that affect the decision of farmers to use soil and water conservation method which based on this study was mostly chosen by farmers to cope with the negative effects of flood on their crop yields.

4. Finally, future studies should focus on estimating the effect of each of the adaptation strategies on crop yields of farmer households. That would help compare the impacts of crop adaptation strategies on farmers' productivity and thus could help identify the most effective adaptation option in terms of crop productivity. They should also focus on estimating the impact of crop adaptation strategies on households' net crop income. That would help choose and promote the most efficient method of crop adaptation strategy.

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APPENDIX-1

Appendix 1: Study Sites location and number of Peasant Associations (PAs) and farmers sampled

No	Name of districts	Location	Number of Peasant Associations (PAs)	Number of farmers sampled
1.	Pawe	Benshangul Gomez regional state	24	128
2.	Guangua	Benshangul Gomez regional state	26	139
3.	Gobu Seyo	Oromyia Regional State	14	75
4.	Bako Tibe	Oromyia Regional State	12	64
5.	Meskana	Oromyia Regional State	23	124
6.	Dugda Bora	Oromyia Regional State	20	107
7.	Adami Tulu	Oromyia Regional State	15	80
8.	Badawacho	Southern Nations Nationalities and Peoples regional state	18	96
9.	Awasa	Southern Nations Nationalities and Peoples regional state	16	85
	Total		**168**	**898**

Appendix 2: Questionnaire

Survey Questionnaire-2013
Ethiopian Agricultural Research Institute (EARI)
in partnership with
International Maize and Wheat Improvement Center (CIMMYIT)

Part 0: Interview Background

1. Respondent's name (household head)…………………………..
2. Gender of the respondent……0)Female 1) Male
3. Mobile number……………………
4. Date of interview ……………………………..
5. Interviewed by……………………………………….
6. Checked by …………………………………………….
7. Regional State……………………………………..
8. Zone………………………………………………….
9. District ………………………………………………..
10. Village……………………………………………..

Part 1: Farmers Identification and village Characteristics

1. Number of Years respondent has been living in the village………….
2. Major Family language (code A)………………………………
3. Religion of the respondent (household head)……………………..
4. Does the main residential house have the following inbuilt? (Code C) 1. Kitchen…… 2. Grain Store…………………………..3. Livestock pen…………………….
5. Type of toilet used…………………………1. Flash toilet private 2. Flash Toilet shared 3. Pit Latrine Private 4. Pit Latrine shared 5. Bucket latrine 6. No toilet
6. Walling Material of main residential house……………………………….(Code D)
7. Roofing Material of main residential house ……………………(code E)
8. Experience in growing maize (years)………………………………………
9. Experience in growing legume (years)………………………………………
10. Distance to the nearest input and output market (km)………….walking minutes………
11. Distance to the nearest source of seed (km)…………….waling minutes………….
12. Distance to the nearest source of fertilizer (km)…………….waling minutes………….
13. Distance to the nearest source of herbicides and pesticide (km)…………….waling minutes………….
14. Distance to the nearest farmer cooperative (km)…………….waling minutes………….
15. Distance to the nearest agricultural extension center (km)…………….waling minutes………….
16. Distance to financial services (walking minutes)……………………………………

Code A: 1…………………2……………………3………………………..4. Other, specify……………………………….

Code B: 0. No religion/atheist: 1 Orthodox Christian 2. Catholic 3. Protestant 4. Christian 5. Muslim 6. Other, specify…………………………..

Code C: 1. Yeas 0. No

Code D: 1. Burned bricks 2. Unburned bricks 3. Stone 4. Wooden 6. Other specify ………………

Code E: 1. Grass thatch 2. Iron sheet 3. Tiles 4. Other, specify………………….

Household identification number ………………

Part 2: Current Household composition and Characteristics

Family code	Name of household member	Sex/Code A	Marital status /code B	Age	Education /years /Code C	Relation to HH/code D	Occupation/code E main	Occupation/code E Secondary	Own farm labor contribution/code F

Code A	Code B	Code C	Code D	Code E	Code F
0. Female 1. Male	1.married 2.unmarried 3.divorced	0. Non literate 1. Adult education 2. Give other education in years	1. household head 2. suppose 3. child 4. grand child 5. hired worker 6. other , specify	1.Farming 2. non farming	1.100% 2. 75% 3. 50% 4. 25% 5.10% 6. Other Specify……

Part 3: Social Capital and Networking

Section A: Membership in formal and informal institutions in the last 3 years (husband and wife only)

Family code	Membership/Code A	Type of group you are a member of /code B	Year joined………….	Role in the group/code C	Still a member now?/code D

Code A	Code B	Code C	Code D
0. Not Member 1. .Member	1.Formal 2.Informal	1.Group Leader 2.Ordinary Member 3. Other, specify…………	0. No 1. Yes

Section B: Social networks

1. Number of people that you can rely in times of need within this village ……………….
2. Number of people you can rely on outside of this village ………………..
3. Are any of your friends or relatives in leadership position in government offices….? Codes: 1 yes 0. No
4. Are you confident on the skills of government extension workers……..?
   Codes: 1. Yes 0. no

Part 4: household assets

Asset	Number	Purchase price	Current price to sell	Total value
1.hourse, mule cart				
2.donkey car				
3.mourse/mule saddle				
4.push cart				
5.tie ridger				
6.plow metal point(marehsa)				
7.plow yoke				
8.plow beam				
9.plow lever				
10.pair of plow blade				
11.plow metal support				
12.stickle				
13. pick axe				
14. axe				
15. hoe				
16.Knapsack sprayer				
17. Water carrier made of canvass /skin/inner tire tube				
18. Stone grain mill				
19. Motorized grain mill				
20. Water mill				
21. Mechanical water pump				
22. Motorized water pump				
23. Spade or shovel				
24. Radio, cassette or CD player				
25. Cell phone				
26. Improved charcoal wood stove				
27. Kerosene stove				
28. Bicycle				
29. Motorbike				
30. Motor cars, picks –ups, trucks				
31. Jewelry				
32. Wooden box				
33. Leather bed				
34. Wooden bed				
35. Metal bed				
36. TV				
37. Chairs/ sofa				
38. Table				

39, gun				
39. Grass roofed house				
40. Corrugated iron sheet house				

Part 5: Livestock Holding

Animal Type	**Number**	**Current price to sell**
Cattle		
1.Indogenous milking caws		
2. Crossbred milking cows		
3. Non milking indigenous cows		
4. Non milking crossbred cows		
5. Trained oxen for plowing		
6. Indigenous bulls		
7. Indigenous heifers		
8. Crossbred heifers		
9. Indigenous calves		
Goats		
1.Mature milking goats		
2. Other mature female goats		
3. Mature male goats		
4. Young female goats		
5. Young male goats		
Sheep		
1. Mature female sheep		
2. Mature male sheep		
3. Young female sheep		
4. Young male sheep		
Other Livestock		
1. Mature trained donkeys		
2. Young male donkeys		
3. Young female donkeys		
4. Hoarse		
5. Mule		
6. Mature Chicken		
7. Local beehives		
8. Modern beehives		

Part 6: household income from other (non -crop) activities

Do you have other means of income?	Specify sources of income if any …………….	Specify Amount in a year …………….
Codes 1. Yes 0.no		

Part 7: Access to credit and climate information

Section A: Access to credit

Reason to loan	**Needed credit? Codes A**	**If yes in column 2, did you get it? Codes A**	**If yes in column 3, then source? Codes B**	**If no in column 3, then why? Codes C**	**If yes in column 3, how much did you get?**	**Did you get the amount you requested? Codes A**
1. Buying seed						
2. Buying fertilizer						
3. Buy herbicides and pesticide						
4. Buy farm equipment						
5. Buy oxen for traction						
6. Buy other livestock						
7. Invest in irrigation						
8. Invest in water and soil conservation						
9. Other specify……….…						

Codes A	**Codes B**	**Codes C**
0. No 1. Yes	1.Money lender 2. farmer group 3. merry go round 4. micro finance 5. bank 6. relative 7. other specify……..	1.borrowing is risky 2. interest rate is high 3. too much paper work 4. expected to be rejected and thus did not ask 5. no asset for collateral 6. other, specify

Section B: Access to climate information

Did you get information or training about climate change during 2012/2013?(codes A	Did you get information or training about climate change before 2012/2013?(codes A	If yes in column 1 from whom did you get it? Codes B	If yes in column 2 from who did you get it? Codes B

Codes A	Codes B
0. No 1. Yes	1.Government 2. Non-government organizations 3. Niebuhr 4. friends 5. relatives 6. Others specify …………..

Part 8: Crop farm characteristics

Serial number	Plot code	Plot location name	Plot size (hector)	Plot distance from residence(km)	Walking minute to crop plot	Soil fertility(Code A)	Soil slope(codes B)	Soil depth (codes C)

Codes A	Codes B	Codes C
1.Poor 2. Medium 3. Good 4. Very good	1.Gently slope(flat) 2. medium slope 3. steep slope	1.Shallow 2.Medium 3.Deep

Part 9: Maize production

Section A: Maize farm characteristics

Serial number	Plot code	Plot location name	Plot size (hector)	Plot distance from residence(km)	Walking minute to Maize farm	Soil fertility(Code A)	Soil slope(codes B)	Soil depth (codes C)

Codes A	Codes B	Codes C
1.Poor 2.Medium 3Good 4Very good	1.Gently slope(flat) 2. medium slope 3. steep slope	1.Shallow 2.Medium 3.Deep

Section B: Input use 1

(Column 1 and 2 in this section should exactly be similar with column 1and 2 in section A)

Serial number	Plot code	Fertilizer in kg		Seed amount in kg	Manure(dray equivalent) in kg	Herbicide in kg	Pesticide in kg
		dap	Urea				

Section C: Input use 2 and maize harvested

Serial number	Plot no	Oxen days		Total labor(labor days)									Total harvested(kg)	
		Plowing frequency	Plowing days	Land preparation and planting		Weed control			Harvesting		Threshing or shelling		Fresh or green	Dray
				No of Male	No female	Weeding frequency	Number of male	Number of female	Number of male	Number of female	Number of male	Number of female		

Part 10: climate change related risk factors and copping strategies

Did you face climate change related risk factor during the last production season? (Codes A)	Which Risk factor did you face?	How many time occurred in the past 10 years ?	Rank importance of shocks in affecting crop yields(1= most important)				Did you take any adaptation strategy to minimize the negative effect of the risk on your crop yields in any of your crop farm?(Codes A)	Important adaptation strategies taken in any of crop farms(1=most important)(Codes B)		
	1. Drought		1st	2nd	3rd	4th		1st	2nd	3rd
	2. Too much rain(flood)									
	3. Crop pest /daisies									
	4. Hail storm									
	5. Other, specify									

Codes A	**Codes B**
0. No	1.Planting Drought Tolerant Crops
1. Yes	2. Planting drought tolerant seed varieties
	3. early planting
	4. late planting\
	5. plant disease or pest tolerant crops
	6. crop diversification
	7. increasing seed rate
	8. soil and water conservation
	9. more on non-farm work
	10. others, specify