SCHOOL OF GRADUATE STUDIES
SCHOOL OF ECONOMICS

THE EFFECT OF CLIMATE CHANGE ADAPTATION STRATEGY ON FARM HOUSEHOLD'S WELFARE IN NILE BASIN OF ETHIOPIA: IS THERE SYNERGY OR TRADEOFF?

BY

FISSHA ASMARE MARYE

ADDIS ABABA, ETHIOPIA
JUNE, 2016

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF ECONOMICS

The Effect of Climate Change Adaptation Strategy on Farm Household's Welfare in Nile Basin of Ethiopia: Is There Synergy or Tradeoff?

A Thesis Submitted To the School Of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree Of Master of Science in Economics (Resource and Environmental Economics Stream)

By

Fissha Asmare Marye

Addis Ababa, Ethiopia

June, 2016

Addis Ababa University

School of Graduate Studies

This is to certify that the thesis prepared by Fissha Asmare, entitled: the effect of climate change adaptation strategy on farm household's welfare in Nile basin of Ethiopia: is there synergy or trade off?; and submitted in partial fulfillment of the requirement for the degree of Masters of Science in Economics (Resource and Environmental Economics) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by the examining committee:

Chairman: Kebede Bekele signature_______________

Date: _____________________________

External Examiner: Abebe Damte (PhD) signature_____________

Date: _____________________________

Internal Examiner: Adane Tuffa (PhD) signature______________

Date: _____________________________

Advisor: Hailemariam Teklewold (PhD) signature______________

Date: _____________________________

Graduate programs coordinator, Department of Economics Kebede Bekele: signature ____

Date: _____________________________

ACKNOWLEDGEMENTS

First I would like to thank God Almighty; it is not exaggeration to say that without insisting the Almighty God would not have been in a place to complete successfully this thesis paper.

I would like to offer my heartfelt thanks to my supervisor Dr. Hailemariam Teklewold for his guidance, patience, and constructive criticisms throughout the accomplishment of this thesis. Doctor, no words can explain my gratitude to your friendly supervision and without your guidance, it would have been impossible for me to overcome all the difficulties I faced for a year. I was not expected to meet such like personality. Besides, I am grateful to Dr. Alemu Mekonnen, for initiating my interest towards such striking subject and the support for getting resources from IDRC through EDRI.

My special thanks also go to ECRC (Environment and climate research Centre) for its invaluable contribution to get farm household data used in this work and financial support through EDRI(Ethiopian development research institute) and IDRC(International development research Centre of Canada). And also I am grateful to ECRC staffs particularly Smueal Abera, Sahile sillassie and Zelalem G/medihn for their welcoming approach when I was in need of their assistance. I am also indebted to my friends, Workisha, Yechalle, Tsegish, for their constructive comments

I also wish to thank my supporting friends especially Denekew and Tewodros for their advice and encouragement with any aspect.

Last but not least my immense gratitude and appreciation goes to my family and Selamye for everything what they do in my critical time.

Table of content

Contents Page

ABSTRACT

Climate change is affecting different dimensions of human life. The effect is significant for rural farm households in Ethiopia. In response to this farmers use different adaptation strategies. However, there is a gap in knowledge on the effect of different adaptation strategies on farm household's welfare. This study examines the effect of Crop Diversification (CD), as a climate change adaptation strategy, on farm household's welfare in terms of farm income and demand for labor in Nile Basin of Ethiopia. The study also identified the main determinants of adopting CD. The study explore whether there is synergy or tradeoff between the effect of CD on household income and labor demand. The relationship between Farm household's income and family labor demand are modeled by using Endogenous Switching Regression model (ESRM) containing household and farm characteristics including a set of geo referenced climate variables such as, temperature and growing season rain fall. The analysis is based on farm household data collected in 2015. The result indicates that, climate variables such as, the amount and variability of growing season rain fall and temperature are the most important factors affecting both household's income, demand for labour and adoption of CD. The study also shows that adopting CD is more likely in areas characterized by low rain fall and high temperature. In addition to this the study indicates synergy on the effect of adoption of CD, a positive and significant effect in enhancing farm household's income and reducing family labor demand. Adopters benefited more in terms of reduction in labor demand than their non adopter counter parts. The findings of this study confirms that using crop diversification is a win-win climate change adaptation strategy that provides double benefit both in terms of productivity improvement and labor reduction. Thus, the result suggests the adoption of CD in the Nile Basin of Ethiopia to improve the wellbeing of farm household's and to build a resilient agricultural system for the catastrophic effect of climate change.

ACRONYMS

AE- Adult Equivalent

ATA- Agricultural Transformation Agency

BOP- Balance of Payment

CD- Crop Diversification

CSA- Central Statistics Authority

ECRC- Environment and Climate Research Center
EDRI- Ethiopian Development Research Institute
ESR- Endogenous Switching Regression

FIML- Full Information Maximum Likelihood

GDP- Gross Domestic Product

IPCC – International panel for climate change

MOWR- Ministry of Water Resource

OLS- Ordinary Least square

PCI – Per Capita Income

SNNP- Southern Nations Nationalities and Peoples

SSA- Sub Saharan Africa

TH- Transitional Heterogeneity

TLU-Tropical Livestock Unit

TT- Treatment effect on Treated

TU- Treatment effect on non Treated

UN- United Nation

VPFA- Value of Productive Farm Asset

WB- World Bank

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Climate change is among the top serious problems facing the world, and that is why every nation in the world put it as its top economic and development agenda. It is considered to be a critical global challenge and recent events have demonstrated the world's growing vulnerability to climate change. The impacts of climate change range from affecting agriculture to further endangering food security, to rising sea-levels and the accelerated erosion of coastal zones, increasing intensity of natural disasters, species extinction and the spread of vector-borne diseases (UN, 2007).

Developing countries are severely affected by climate change because many of these are heavily dependent on agriculture as their source of income which is highly vulnerable for climate change effects. They are also least equipped financially and technically to adapt to changing conditions (John et al, 2014). In Africa, many countries are hit hard by severe climate change scenarios. The continent is also highly lagging behind in the adoption of improved technologies like irrigation, capital and high yield varieties (WB, 2013). Studies in the continent revealed that by 2100, every nation in Africa will experience the negative climate change impacts. In addition to this, the damage from climate change to African agriculture expected to range from 0.13% to 2% of GDP by the same year (Mendelson, 2000).

The impact is more devastating in a country in which the economy people depend up on natural resources like agriculture and forestry for their livelihoods (WB, 2003). The agricultural sector is the most vulnerable to climate change effects. Dry land crop and livestock farmers are vulnerable for the impact of climate change with temperature elasticity's of -1.9 and -5.4 respectively while those with irrigated crop land benefits from marginal warming because irrigation will reduce the impact of climate change to some extent (IPCC, 2014).

Like other countries, Ethiopia is also suspected of future and current climate change impacts. The mean temperature is projected to increase by 1.7-2.7^{o}c in the year 2050, which is very damaging and dangerous. Besides, the GDP of the nation will be 10% lower compared to the no climate change scenario. In a uniform climate change scenario, increase in temperature and reduction in precipitation found both damaging to Ethiopian agriculture; but comparatively decrease in precipitation appeared to be more damaging than increasing temperature (Yibeltal. *et al*, 2013;Sherman *et al*, 2012; and Deressa, 2007)

The Agriculture sector is the mainstay of Ethiopian economy. It accounts for nearly 46% of GDP, 73% of employment, and nearly 80% of foreign export earnings (ATA, 2014). Despite its immense contribution to the overall economy, this sector is challenged by many factors, of which climate-related disasters like drought and floods (often causing famine), are the major ones (Deressa,2007; Elias *et al*, 2014). On the contrary, taking adaptation measures will provide a relief for climate related shocks. According to the definition of IPCC(2001) adaptation to climate change refers to – adjustment in natural and human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunity (IPCC, 2001). Many adaptation practices are mentioned in literatures. Adaptive water management techniques including scenario planning, learning based approaches, and flexible and low regret solutions can help to create resilience to uncertain hydrological changes and impacts due to climate change (IPCC, 2014). Changing crop varieties, crop diversification, adoption of soil and water conservation measures, tree planting, water harvesting, migration, chemical fertilizer, shifting farming practices from crop production to livestock herding, and changing dates of planting are the commonly used practices by farmers (Maddison, 2007; Salvator et al, 2012;Ferede *et al*, 2014; and Bewket *et al*, 2015).

However, the practice of taking climate change adaptation measures is very low in Ethiopia. In Nile basin of Ethiopia, the agricultural practice is very much traditional which is highly dependent on plough and yolk (animal draught power). Labor is the major means of production during land preparation, planting and post harvesting processes. Agriculture is highly rain-fed for many households with only 0.6% using irrigation water to grow their crops. 58% of farm households are not practicing adaptation measures for climate related shocks. The major constraints are lack of information, shortage of labor, land and money (Salvator *et al*, 2012).

Even though the impact of climate change in the area is very devastating and characterized by low response rate for this impact, studies to identify the appropriate adaptation strategy specific to the socio-economic and agro-ecological context of the farmers in the area are scanty.

This highly necessitates the researcher conducting a deep investigation on the effect of adaptation strategy on household's welfare.

1.2. Statement of the Problem

Sub-Saharan African countries (SSA) have been affected by many problems that share similar features. The government of the nations tried to alleviate the problems by following different policies and strategies. However, low per capita income (PCI), debt servicing and negative BOP at the national level have limited the ability of the governments to invest in basic infrastructure needed for markets and the private sectors to improve operation. Apart from this, there is high variability of rainfall and continual increase in temperature which makes the return on production uncertain. Due to increase in uncertainties on return and outcomes of production from year to year, both the farming communities and agricultural stakeholders become reluctant enough to invest in potentially more sustainable, productive and economically rewarding practices (Cooper *et al*, 2008).

The only panacea for this overwhelming impact of rainfall variability and increase in temperature on production is to take effective and efficient adaptation measures. Theoretically, the rationale behind the implementation of adaptation measures is to improve the living standard of the poor households by reducing the impact of climate change. Practicing different adaptation strategies like, crop diversification would expect to increase agricultural productivity and farm income by improving the resilience of the crops as well as the fertility of the soil (Ferede *et al*, 2014; Bola *et al;* 2012; Rockstrom *et al*, 2008). Nonetheless, many adaptation strategies are failed to bring the expected benefits after implementation. Most of the time adaptation strategies are implemented following a blue print approach which assumes that they are equally suitable for all parts of the targeted areas. Yet, there is a big difference in the areas where the adaptation measures are taken. Primarily, there is variation in land and labor resources available at the farmers' disposal as well as soil suitability (Sukallya *et al*, 2010).

Luke *et al*, (2014) stated that farmer's adaptive capacities are highly constrained by many factors like education level, availability of extension services about climate change, credit access, availability of enough family labour, family size and framing experience. On top of others, availability of labour is a great epidemic. This is because there are some adaptation strategies that require an extra labour than the usual one. Therefore, farmers that are affluent enough to employ labor or that have self owned surplus labor are more likely to consciously use climate change adaptation strategies (Luke *et al* ,2014). For instance, the adoption of crop diversification in Thailand increases labor requirement of framers. In many cases famers has to deploy additional labor to carry out all sorts of farming activities ranging from land preparation to crop cultivation until the period of harvesting the crops (Sukallya *et al*, 2010). Similarly studies in Ethiopia indicate that the adoption of sustainable agricultural practices needs an extra labor than the convectional one. Especially, female's labor is compromised substantially when a given household adopt sustainable agricultural intensification practices. This will divert their time from critical activities such as, household food preparation, nutrition and child care (Teklewold et al, 2013). Salvatore also showed that the role of household labor availability in the adoption decision of farmers in Nile Basins of Ethiopia is very critical (Salvatore, 2012). The promotion of practicing different climate change adaptation strategies is mainly aimed at increasing the productivity of poor rural farmers. This helps to attain food security and alleviating poverty. However, a great caution should be given for the appropriateness of the strategies for the existing socio economic context of the adopters. Some strategies require complementary inputs that can compromise the benefits generated from the yield enhancing capacity of the adaptation strategy, while others boost farm productivity without bearing additional input costs. In addition to the costs incurred for improved seeds, fertilizer, pesticide and herbicide use the expenditure for labor is substantial. This would be exacerbated for poor farmers that have large opportunity cost of labour and high credit constraint. This is because poor farmers will work on others farm by employing as a daily laborer to finance their daily consumption expenses during the period of cash deficiencies. Furthermore, when they adopt these labor intensive strategies they are not only losing their daily employment but also incur an additional labor cost to finance the additional labor requirement in their own farm. This implies that, a great attention is needed to identify the role of adaptation strategies in increasing agricultural productivity visa-vis their labor requirement (Chistire *et al*, 2002).

All these indicated that, in one or another way farm household's welfare will be affected by adopting these agricultural technologies. Though they increase farm income and enhance production but they are reducing the time available for leisure and other activities. Time saving is one of the important indicators of welfare improvement albeit not considered most of the time (Kohlin *et al, 2005*). For instance, in Ethiopia adoption of sustainable agricultural practices increase the amount of female labor for farming activity. This reduces the time available for women's for taking rest and other activities. Thus, though farm income increases, since welfare is the total some of both income and leisure the total household welfare is decreasing (Ibid).

In general, while countries continue to promote different adaptation strategies, but utmost attention is not given for their implication on welfare by considering different dimensions of it. This is due to the fact that some strategies have a potential to increase productivity without adding extra labor (they are characterized by synergy) while others will be effective only by deploying a huge labour in combination with the practice

(Tradeoffs). Thus, in areas where farmers are confronted with a higher labor shortage practicing adaptation strategies that require more labor would be futile (Sukallya *et al*, 2010).

Crop diversification provides many ecosystem services, including N fixation and C sequestration; breaking the life cycle of pests; improving weed suppression; and smoothing out the impacts of price fluctuations (Altieri, 1999; Di Falco et al., 2010; Jhamtani 2011; Liebman and Dyck, 1993; Snapp et al., 2010; Tilman et al., 2002; Woodfine, 2009). This can save farmers the cost of fertilizer and pesticides. Minimizing the use of these inputs also contributes to the mitigation of climate change. System diversification enables farmers to grow products that can be harvested at different times and places and that have different weather or environmental stress-response characteristics. These varied outputs and degrees of resilience are a hedge against the risk of drought, extreme or unseasonal temperatures, rainfall variations and price fluctuations, all of which affect the productivity and income of smallholder systems.

In any cases Crop Diversification have a direct or in direct implication on farm income and family labor demand however not empirically testified as to my knowledge. In order to have an effective intervention that takes in to account all these tradeoffs and win-win opportunities between adaptation strategies with respect to different indicators of household welfare, a rigorous investigation on the issue are fundamental. Therefore, this study tried to address the impact of climate change adaptation strategy (Crop Diversification) on household welfare. A modest attempt is also given to identify the synergy and tradeoffs between the effect of crop diversification on the two dimensions of welfare; farm income and family labor.

Generally, the study will try to answer the following basic research questions.

- What factors determine the household's decision of adopting crop diversification and farm income?
- How the adoption of crop diversification can influence rural farm income?
- How the adoption of crop diversification can influence family labor demand?
- Is there a win-win opportunity or tradeoffs between the joint effects of crop diversification on household welfare (family labor and farm income)?

1.3. Objectives of the Study

The main objective of this study is to investigate the impact of adaptation strategy for climate change on household's welfare in Nile Basin of Ethiopia.

Specifically, it tries to address the following objectives.

- To examine the effect of climatic variables and other socioeconomic factors on the decision of Adopting Crop Diversification.
- To examine the differential effect of climate variables and other socio economic factors on farm income and household labor demand among adopter and non adopters of CD
- To explore the farm income and labor demand implications of Crop Diversification
- To show whether there is synergies and tradeoff between the joint effects of crop diversification on the two dimensions of household welfare (family labor and farm income).

1.4. Significance of the Study

The huge investments made by farmers in their farm are highly weakened by climate related shocks which implies that climate change has an important implication to agriculture. In countries like Ethiopia where the share of agriculture in terms of GDP, employment and export is very high, rain fall and temperature variability in this sector would adversely affect the level of farm income in particular and the country's economy in general. Therefore, delivering information on the role of climate adaptation strategies in line with their complementary input requirements like labor is vital. The identification of effective determinants of agricultural productivity practices and farmers decision for adoption will inform decision makers and instruct policy on successful implementation of welfare enhancement practices. Moreover, knowledge of the factors that determine farmers' decision to practice adaptation strategies can augment their ability to capability of climate change adaptation measures to evade them from agricultural production failure in general.

1.5. Scope and Limitation of study

The scope of this study is confined to the Nile Basin of Ethiopia, selected because it is part of the country where agriculture is the most important economic activity. It identified the variables that determine farm household's welfare, factors that influence farmers' adoption of crop diversification, welfare differences among the adopters and non-adopters and specifically focused on the effect of Crop diversification on rural farm household's welfare. Also the study is limited to a cross sectional data collected by ECRC in March 2015 on a total sample of 929 households and future studies can consider the dynamic aspect by taking data from the same sample on repeated time.

1.6. Organization of the Study

The remaining part of the thesis is organized as follows. Chapter two which presents a literature review provides the reader with an overview on the main previously published papers related to adaptation to climate change, climate change adaptation strategies, and household welfare. The third chapter presents the methodology. It describes the methodological choices made in this work and it also examines its validity and reliability. Chapter four analyzes the empirical data which are collected by the means of questionnaire. This study ends with chapter five in which the main findings of the study are concluded and some important policy implications are discussed.

CHAPTER TWO: REVIEW OF RELATED LITERATURES

2.1. Theoretical review

2.1.1. Agriculture, Climate Change and Farm Household Welfare

According to IPCC (2007) "*climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer*". It is the variation and variability of climatic factors like temperature, rain fall and precipitation over time which might be caused by natural or manmade factors.

Climate change is about the growth of green house gas emissions due to the burning of fossil fuels, resulting mainly from industrial activities and motor transportation. Hence, there is a buildup of the carbon dioxide levels in the atmosphere. The carbon dioxide build up is made worse by the increasing loss of forests which act as "carbon sinks" that absorb gases and prevent its release into the atmosphere. Furthermore, the increase of carbon dioxide and other gases in the atmosphere also enhances the "Greenhouse Effect" (in which more heat is generated), thus leading to temperatures rising. A significant rise in temperature can trigger several events, such as melting of the ice sheets, the death of some significant marine life and other biodiversity, and effects on agriculture and human health (UN, 2007).

Africa, horn of Africa in particular, is one of the region's most vulnerable to climate change because of multiple stress and low adaptive capacity. Though the continent contributes less for the current anthropogenic climate change, it is hit hard as its major economic sectors are vulnerable to climate sensitivity. Since their economy is dependent on agriculture climate change poses a highly complex challenge. In special case African agriculture is predicted to be vulnerable to climate change as the region is faced with high heat and low precipitation. Besides, large fraction of the economy is covered by agriculture and farmers rely on traditional technology (Peter *et al*, 2010; Declan *et al*, 2010; Arndt *et al*, 2012)

The economies of many African nations are dependent on sectors such as agriculture, fisheries, forestry, and tourism that are vulnerable to climate conditions. Agriculture and natural resources provide the livelihood for 70% to 80% of the population, and account for 30% of GDP and 40% of export revenue in Sub-Saharan Africa (Toulmin and Huq, 2006).

Ethiopia, where agriculture is the pillar of its economic development and around 85% of the population is dependent on agriculture as a means of livelihood, has been challenged by the problem of climate change. The country's far reaching problem is that almost 100% of its agricultural production is rained. From the country's total cultivated land the irrigation agriculture accounts only less than 1%. This makes the amount and temporal distribution of rainfall and other climatic factors during a growing season to be crucial for agricultural productivity (Difalco *et al*, 2011; Peter *et al*, 2010). Though agriculture is the main base of the national economy, it is dominated by small scale farmers who are dependent on low output low input rain fed mixed farming with traditional technologies. Farming is done by much without tools, using traditional seeds and oxen (Temesgen, 2007; Mintwab *et al*, 2014). Given the rain fed nature of agriculture in Ethiopia, agricultural productivity is highly affected by recurrent climate change. The lives and wellbeing of many rural Ethiopians are ruled by rain. It determines whether they have enough to eat and whether they will be able to provide basic necessities and earn a living. Indeed, the dependence on rainfall and its erratic pattern has largely contributed to the food shortages and crop crises that farmers are constantly faced with (Mintwab *et al*, 2014).

There are many indicators for the devastating impact of climate change on agriculture and farm household's welfare. For instance the country is one of the world's food insecure countries, with problems along with all the key dimensions of food security. In recent decades, the horn of Africa in general and Ethiopia in particular have become a symbol for hunger and starvation. The scope and intensity of famines regularly hit this region have shocked the world. Their repetitive occurrence in Ethiopia is awful (1972-1975, 1983-1985, 1989-1990 and 2002-2003) (Peter *et al*, 2010). In one or another way, the entire above are the results of climate change. The absence of enough rainfall, its erratic nature, unexpected rain, flood and large increase in temperature leads to high agricultural production loss and intern messed up the overall welfare of agricultural farm households. Thus, this calls a deep rotted investigation on the issue and needs to develop an effective adaptation mechanism for this overwhelming impact of climate change.

In this study, household welfare is proxy by the two main dimensions of welfare. First the study considered net farm income as one measure. Second, total family labor demand is also taken as an indicator, so as to account the effect of the considered strategy on the household time.

It is also possible to proxy welfare by agricultural productivity which can be measured by the farmer's net farm revenue (Ferede *et al*, 2014). All of the above indicated that there is no one unique measure of household welfare and it varies based on the methodological, data and related contexts that we are faced.

Above all, welfare can be also measured in terms of time (labor) saving for leisure and other activities. However most of the time this dimension of welfare is not gets attention yet (Kohlin, *et al, 2005*). As far as we are concerned about the total wellbeing of a given household it is mandatory to consider its time saving. A given farm household might not only maximize its utility by having higher farm income alone. Rather he/she may be highly satisfied by having a discussion or other social activities with its soul mate, family, or the local community.

Kohlin *et al*, (2005) has used opportunity cost of time as a welfare measure. Because if we look at the household's decision to maximize welfare, they will maximize welfare subject to budget constraint which takes in to account the price of outputs and purchased inputs, the time endowment of each household member, net accumulation of wealth, and the wage rate that each member can obtain in the market.

2.1.2. The idea of climate change adaptation and adaptation strategies

This is the reality; climate change is here and is a difficult problem that affects human life for several decades. The eco-system is damaged irreversibly by human activity and further will appear most likely. Therefore, it is imperative to think how we will adjust not only to these specific changes but also to future uncertainties about our climate. This is especially important for developing countries in which the challenge of climate change is very difficult and needs to address many institutions and capacity issues in order to ensure sustainable adaptation to climate change (MRC, 2010).

According to the definition of IPCC, (2001), adaptation to climate change refers to *adjustment in natural and human systems in response to actual or expected climate stimuli or their effects which moderates harm or exploits beneficial opportunity*.

Large number of farmers perceived the existence of climate change over time. They noticed that temperatures have increased and precipitation has declined. To curb the impact of this change, they have used different adaptation mechanisms.

Adaptation to climate change can be geared at altering circumstantial conditions or at reducing damage to farm produce. Environmental and socio-economic impacts of climate change can be confronted through adaptation. Two main types of climate change adaptations are autonomous and planned adaptation. Autonomous climate change adaptation is the reaction of a farmer to changing precipitation patterns, in that he/she changes crops or uses different harvest and planting dates; whereas planned climate change adaptation measures are conscious policy options or response strategies, often multi-sectoral in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptation (Arimi, 2014).

Two main scales of adaptation can exist in agriculture. These are at macro-level and micro-level. Macro-level analysis is concerned all about adaptation for agricultural production at the national and regional scales and it's interlinked with the internal as well as external policy (Bradshaw *et al,* 2004 and Nhemachena and Hassan, 2007). The common types of macro-level or national level adaptation includes crop adaptation measures and reuse of water and combinations of both. However, some measures such as rain water harvesting can be practiced at the individual level or may require collective actions. Investments at national or government level may include building dams and releasing new cultivars that are more water efficient (Jawahar and Msangi, (2006).

On the other hand, micro-level adaptations are those which can be practiced at household level by farmers with strategic actions in response to agriculture focuses on tactical decisions that farmers make in response to cyclical differences of climatic conditions. Adaptation options such as changing planting and harvesting dates, mixed crop- livestock farming mechanisms, new crop varieties and agricultural water management such as (irrigation, river diversion, micro-dams, terracing.) are examples of household level adaptation mechanisms (Temesegen *et al*, 2008).

In the literature, many adaptation strategies are identified. For instance, Maddision, (2007) categorized adaptation strategies based on the precise perception of climate change. When temperature increases, farmers' plant different varieties; move from farming to non-farming activities, practiced and increased water conservation. While varying, the planting date appears to be an important response for changes in precipitation and particularly in the timing of the rain (Ibid). Besides, irrigation water and related inputs are taken as a successful adaptation practices in Africa. However, the region is moving very slowly in technology adoption (KUrukulasuriya *et al*, 2006). A study conducted in Egypt revealed that, in order to cope up with the adverse effects of climate change on agriculture, the adaptation practice should focus on 3 areas: namely, crop management, water management and land management practices. In the country, the most common adaptation practice when there is increase in temperature is irrigation. It might be practiced either by increasing frequency of irrigation or by increasing the quantity. In addition to this, changing crop panting dates, using heat tolerant varieties, pesticide and fertilizer applications, planting trees as fences around the farm, using intercropping and fruit mulching are also the most commonly practiced types of adaptation strategies (Helmy *et al*, 2007).

A study done by Kabubo *et al,* (2007) tried to classify adaptation strategies in Kenya as ; adaptations to short term climate variation and adaptations to long term climate variation, albeit they are not mutually exclusive. In the former case, crop diversification, or mixed cropping and tree planting are identified as effective adaptation strategies. For long term temperature changes, improved water management, which includes, increased water conservation, crop diversification, increased use of irrigation, shading or sheltering, crop diversification are common.

Similarly, in Ethiopia different adaptation strategies are identified. For instance, Temesgen (2007) showed that investment in technologies such as irrigation, planting drought tolerant and early maturing crop varieties, strengthening institutional setups working in research, and educating farmers and encouraging ownership of livestock as an adaptation practice for climate change. Nile basin of Ethiopia is one part of the country which is highly vulnerable to shocks resulted from long term climate variability. In response to this, farmers have used different adaptation strategies. Difalco et al, (2011) classified these strategies as yield related and non- yield related. The yield related measures account more than 95% of the measures; while the non- yield related measures account only 5%. From the yield related measures, adaptation strategies like, changing crop varieties, adoption of soil and water conservation measures, water harvesting tree planting, and changing planting and harvesting dates are common. Migration and a shift in farming practices from crop production to livestock herding and other sectors are the dominant non-yield related strategies.

Crop diversification is among the climate change adaptation strategies which cover an increasingly wide range of technologies and practices available for improving productivity and achieving food security. Crop diversification is usually viewed as a shift from traditionally grown, less profitable crops to newer, more profitable crops. It is also a strategy that is used to maximize the use of land, water, and other resources for the overall agricultural development in a country. It provides farmers with feasible options to grow different crops on their land. Diversification is seen as having two main properties. First, it expands the production possibility set or area allocation frontier for a farmer, thereby increasing opportunities for income generation and employment creation. Second, it reduces the risk of having all of one's eggs in a basket with one crop only or a few crops with potentially high covariance risk (Sichoongwe *et al,* 2014).

There are some key factors that derive farmers “demand” for crop diversity: i) managing risk, ii) adapting to heterogeneous agro-ecological production conditions and iii) meeting market demands and food security

(Rehima *et al, 2013*). Crop diversification can provide many advantages. According to the study by Lin *et al (2011),* Pest suppression is a perennial challenge to farmers, and it is a very important ecosystem service. In agricultural systems, as in natural ecosystems, herbivorous insects can have significant impacts on plant productivity. The challenges of pest suppression may intensify in the future as changes in climate affect pest ranges and potentially bring new pests into agricultural systems. It is expected that insect pests will generally become more abundant as temperatures rise as a result of range extensions and phonological changes. However, a diversified crop plays an important role in pest reduction. It can be also considered as Climate variability buffering and mitigation. Diversified agro ecosystems have become more important for agriculture as climate fluctuations have increased. Research has shown that crop yields are quite sensitive to changes in temperature and precipitation, especially during flower and fruit development stages. Temperature maximums and minimums, as well as seasonal shifts, can have large effects on crop growth and production. Disease suppression is also indicated the other benefit of crop diversification.

It is also thought that, crop rotation provide different services that are essential for the ecosystem service such as, Nitrogen fixation, Carbon sequestration, breaking the lifecycle of pests, improving weed suppression, and smoothing out the impact of price fluctuation. Diversification creates an opportunity for farmers to grow crops that can be harvested in different times and places. At the same time, farmers can able to grow crops that have different weather or environmental stress response characteristics (Jhamtani, 2011; Difalco *et al*, *2010*).

2.2. Empirical Literature Review

2.2.1. Determinants of practicing climate change adaptation strategies

A wide and detail empirical literature is available on the factors that affect the behavior of farmers to practice different adaptation strategies. As mentioned by Difalco *et al* (2011), socio-economic and demographic factors (including sex, age, education, family size, marital status), institutional factors (information, extension service and credit access) affect the decision of farm households to use/choose among climate change adaptation strategies which would have an impact on agricultural productivity.

In the literature, there is no unanimity in the magnitude and relevance of some factors in affecting the likelihood of farmers to take adaptation measures to climate change. The first disagreement arises on the effect of gender. According to the studies made by Nabikolo *et al*, (2012), Nhemachena and Hassan (2008), Hiley *et al*, (2010), female-headed households are more likely to take up adaptation options than male-headed households. In most rural smallholder farming communities, women do much of the agricultural work; men in most cases based in urban areas. Therefore, they tend to have more farming experience and information on various management practices. Farming experience increases the probability of uptake of all adaptation options. However, another study by Oyekale and Oladel, (2012) confirmed that the probability of taking adaptation measures to climate change is lower for female headed households when we compare with their male counterparts. Similarly, the study in Nile Basin of Ethiopia by Deressa *et al* (2010) showed that the propensity to practice adaptation measures is higher for male headed households than that of the female one. It is argued that women are less able to diversify income sources and adapt to climate change because of other domestic responsibilities and less control of financial resources. Pycroft (2008) have also found the same result.

The other determining factor for adaptation is age of the household head. Like that of gender, there is also a disparity in the effect of age on the propensity of adaptation. The studies done by Pycroft (2008), Oyekale and Oladel, (2012) indicated that as the age of the household head increases the likelihood of taking adaptation measures to climate change tends to decline. The results of these studies showed that aged household heads were fragile and unable to explore many coping alternatives. In addition to this, it can also be explained by the young are more likely to embrace new ideas and having less aversion to risk.

However, Shongwe, *et al*, (2014); Hiley, *et al*, (2010) and Deressa, *et al*, (2008) were come up with results that contradict with the aforementioned one. Age of the household head, which represents experience, affected adaptation to climate change positively. For instance, a unit increases in age of the household head results in a 9% increase in the probability of soil conservation, a 12% increase in changing of crop varieties, and a 10% increase in tree planting.

Education is also another important factor for practicing adaptation strategies. Kassie, *et al*, (2011) has conducted a study in Uganda to investigate the effect of agricultural technology on crop income and poverty alleviation. The study has used cross sectional data of 927 households. It has used propensity score matching for analysis purpose. The Logit estimates of the adoption propensity indicated that farm size, occupation, participation inland rental market, and plot number determine adoption positively and significantly. Indeed, years of education and membership to farmers' group have similar effect. According to the study, education and membership to farmers' group can be considered as proxies to access to information. Membership in farmers' group will create an opportunity to share experiences and information about new agricultural technologies. Similarly, educated farmers tend to have a potential to practically implement new information and analyze the importance of new technologies. On the other hand, lack of access to seeds and market distance are negatively related with adoption (Kassie, *et al*, 2011). Moreover, another study by Abid *et al* (2014) supports this argument. In this study, the highly significant coefficient of education of the household head shows that the probability of adapting to changes in climate increases with an increase in the years of schooling. A 1% increase in the years of schooling of household head would lead to an increase in the probability of changing crop type (0.08 %), changing crop variety (0.09 %), changing planting dates (0.17 %), planting shade trees (0.08 %), soil conservation (0.08 %), changing fertilizer (0.15 %) and irrigation (0.09 %) as adaptation measures to climate variability.

In a similar vein in Ethiopia, Education of the head of household increases the probability of adapting to climate change. A unit increase in number of years of schooling would result in a 1 percent increase in the probability of soil conservation and a 0.6 percent increase in change in planting dates to adapt to climate change. Moreover, almost all of the marginal values of education are positive across all adaptation options indicating the positive relationship between education and adaptation to climate change (Deressa, *et al*, 2008).

There are also other studies that tried to show how different socio-economic and institutional factors affect the likelihood of practicing adaptation strategies in response to climate change. For instance, by using Logit model Nbikolo, *et al*, (2012) tried to estimate the determinants of climate change adaptation strategies among male and female headed households in eastern Uganda. The Logit regression result over the entire sample showed that land ownership, uses of purchased input, gender of the household head, total land size, access to credit and possession of bicycle significantly influenced the decision to adapt to climate change. On the other hand, household size, level of education of the head, and possession of animals were mainly insignificant. The probability to adapt is negatively influenced by land ownership and gender of the household head. On the other hand, land size, uses of inputs, access to credit and possession of bicycle determined positively the decision to adapt.

Menberu, *et al*, (2014) conducted a study on the determinants of climate change adaptation in North West Ethiopia by taking land management practices. The binary Logit model result indicated that age and education level of the head are not a significant determinants of adaptation. However, family size, agro ecological zone, livestock ownership and access to climate information affect the probability to adapt positively and significantly.

The study made by Hilery, *et al*, (2013), similarly had also drawn a profound result. By using Heckman selection model, age, gender, education, family size, farm experience, market distance, irrigation, local agro-ecology, on and off farm income, access to information on climate change, credit access, changes in temperature and precipitation were found to have a significant effect to household's likelihood of taking adaptation measures; while age, education, farm experience, irrigation, local agro ecology, on and off farm income, access to information on climate change, and changes in precipitation were factors that affect positively the propensity to adapt. However, gender, household size, distance to the nearest market, credit access and changes in precipitation were found to have negative effect on the likelihood of taking adaptation. According to the study, the justifications for the negative relationship between household size, market distance and likelihood of adaptation were as follows: household size is the proxy for labour availability. Thus, large households are likely to have a lower probability to new agricultural practices since households with many family members are likely to divert labor force to off farm activities in an attempt to earn more income to ease the consumption pressure imposed by the large family size. Due to the fact that, markets provide an important platform to farmers to gather and share information large market distance reduces the probability of adapting to climate change. Credit access also has negative effect on adaptation behavior and the possible reason as per the study is weak borrowing capacity of farmers.

Moreover, another study conducted by Pycroft (2008) in West Gojam zone was aimed at investigating the factors that determine the adoption and productivity of modern agricultural technologies like, improved seed. By using a censored Tobit and Probit model, it has showed that gender, education and land size determined adoption positively and significantly.

In the study area, Nile Basin of Ethiopia, many factors were identified as a key determinant for adaptation. Difalco, *et al,* (2010) conducted a research to examine the driving forces behind farmers' decision to adapt to climate change. As per the results of the study, information access about climate change, access to formal and informal institutions, and extension service off farm income were found to increase the likelihood of implementing adaptation. Furthermore, climate variables play a very important role in determining the probability of adaptation. Rainfall in '*Belg'* and '*Meher'* rainy season displays an inverted U **–** shape behavior. However, in the former case, the coefficient while positive not significant. Similarly, another study by Difalco, *et al,* (2011) revealed that education, household size, '*Belg'* and '*Meher'* rainfall, extension advice, and average temperature are the determining factors for adaptation. The study also added that availability of information on climate change is the other important factor. This is because information about climate change may raise farmers' awareness of the threats posed by the changing climatic conditions. In line with this, extension services provide an important source of information and education on choosing the best combination of strategies that can deliver the highest benefit.

Deressa, *et al,* (2010) conducted a study to analyze the two step process of adaptation to climate change in Nile Basin of Ethiopia. A cross sectional data collected from a total of 1000 was analyzed by using the Heck man sample selection model. According to the study, education, family size, gender, credit access, livestock ownership, and temperature were variables that influence positively and significantly adaptation to climate change. However, large farm size and average precipitation were negatively related to climate change.

Moreover another study by Maddison (2007) also showed that farmers who have worked for a long period of time are more likely to perceive climate change. However, it is educated farmers who are more likely to respond by making at least one adaptation. By using the Heck Man selectivity model, the study identified that farmers with free extension advice and who are suited close to the market where they sell their produce are more likely to adapt to climate change .

2.2.2. The Effect of Climate Change Adaptation Strategies on Household's Welfare

There are many studies that tried to address the effect of different climate change adaptation strategies on household's welfare. Elias, *et al,* (2014) conducted a study in Zambia to investigate the effect of minimum tillage and crop rotation on household's welfare. The study used cross sectional data collected in 2012/13 from 1231 households across six districts of Zambia and applied propensity score matching techniques and Heckman's selection estimators. The results showed that the strategies improved on-farm maize productivity by about 26% to 38% for minimum tillage and 21% to 24% for crop rotation. Minimum tillage also improved total household maize production. However, crop rotation did not significantly improve total maize production and gross income from the crop. This could reflect the small proportions of areas allocated to legumes versus the areas subsequently allocated to the maize crop during crop rotation.

Similarly, the study from Canada also confirmed the above result. According to the study, farmers are bountifully beneficial when they implement minimum tillage accompanied with diversified crop rotations than the usual monoculture cereal rotations. Based on 12 (1987- 1998) years of experimental data, it had showed that, there is 7% - 13% yield increment resulted from practicing the stated strategies (Zentner, *et al*, (2002)).

Another study by Kassie, *et al,* (2014) had also supported the above result. The analysis was based on a total of 1,925 households operating on 2,937 maize plots in Malawi. The results of the Multinomial Endogenous Regression model indicated that the adoption of Minimum tillage and Crop rotation are associated with significant maize yield improvements. Indeed, the study also showed that joint adoption of strategies could provide a higher yield than the effect of each practice independently. A highest yield of 850 kg/ha is obtained when farmers jointly implement minimum tillage and crop rotation.

Similarly, Kassie, *et al,* (2012) had investigated the impact of adopting improved ground net varieties on crop income and poverty in rural Uganda. By using Propensity Score matching Estimation method (PSM), the adoption of improved ground net varieties was found to have a positive significant impact on crop income and poverty alleviation. The increase in ground net crop income was ranged from US$ 159 to us$ 180 per hectare. At the same time, due to the adoption of improved ground net varieties, poverty was reduced by 6 percentage (%) points.

Another study by Madiana (2014) in Uganda has also agreed with the results of Kassie, *et al*, (2012). By using a two stage least square (2SLS) estimation technique, the study showed that strategies taken during flood have positive and significant impact on welfare (44.6% welfare gain); while strategies taken for crop pest attack leads to a welfare gain of 34.4%, the coping strategies employing during drought are bad for welfare of a household (51.7% welfare loss).

The study by Asfaw (2010) has also provided an important inference on the impact of improved technology adoption on household's welfare. The study evaluated the potential impact of adoption of modern agricultural technologies on rural household welfare measured by crop income and consumption expenditure in rural Ethiopia and Tanzania. It has used cross-sectional farm household level data collected in 2007 from a randomly selected sample of 1313 households (700 in Ethiopia and 613 in Tanzania). By utilizing endogenous switching regression and propensity score matching methods, it tried to estimate the causal impact of technology adoption. The model result revealed that adoption of improved agricultural technologies has a significant positive impact on crop income although the impact on consumption expenditure was mixed. It was clearly showed that pigeon pea adopters mean consumption expenditure per adult equivalent is 72% higher. When non-adopters had adopted improved pigeon pea, their consumption per adult-equivalent would have been increased by 70%. Results for the casual impact of adoption of improved agricultural technologies on consumption expenditure are mixed. For Ethiopia, the overall average gain of adopting improved chickpea technologies in consumption expenditure per adult equivalent was 0.07. For Tanzania, adoption of improved pigeon pea technologies had no significance impact on consumption expenditure per adult equivalent.

The other important adaptation strategy is using improved varieties. In Nigeria, the impact of improved varieties on rice productivity and household's welfare (measured by consumption expenditure) was positive and significant. Using a cross sectional data of 481 rice farmers, the instrumental variable method was showed a significant positive impact on rice productivity (358.89kg/ha) and total households' expenditure (N32890.82) (Awotide *et al*, 2012).

In addition to this, investment in soil and water conservation strategies was also proved to have a paramount impact on household's welfare (Mariara *et al*, 2006).

In Tanzania, maize-pigeon pea intensification has increased both income and consumption expenditure of households. According to the study by Mulubrhan *et al*, (2011), by using propensity score matching and endogenous switching regression model, maize – pigeon pea adopters mean consumption per- capita was found to be 120% and 95%.

By using the same methods of analysis like Mulubrhan *et al* (2011), and El-Shater *et al* (2015) have got the following result. The study investigated the impact of Zero tillage on farm income and wheat consumption of 621 wheat farmers in Syria. According to the results of the study, adoption of the ZT technology leads to a US$ 189/ha (33%) increase in net crop income and a 26 kg (34%) gain in per capita wheat consumption per year (adult equivalent).

The only study that attempts to estimate the impact of adaptation strategies on farmer's net revenue was the work of Difalco *et al,* (2012). Difalco *et al* (2012) investigated the welfare impact of adaptation strategies by considering -3 adaptation strategies like, changing crop varieties, implementing water strategies, and implementing soil conservation. By including 1000 households a plot level analysis was undertaken by Multinomial Endogenous Switching Regression Model. The results of the study indicated that, though practicing strategies individually don't have a significant effect, the joint adoption of strategies will increase farmer's net revenue by 1552.9 ETB/ hectare. In similar vein Teklewold *et al* (2013) have also found the effectiveness of adaptation strategies when they implement in group than individually.

Though, Difalco, *et al*, (2012) try to address the impact of different adaptation strategies on farm net revenue, it considered adaptation strategies in a very general way. But this approach fails to indicate the specific importance of different adaptation strategies which needs further study to identify specific relevance of adaptation strategies that can be appropriate with the agro-ecological and socio economic contexts.

From the brief review of previous theoretical and empirical literatures, this study identifies important research gaps. First, empirical works addressing the direct impact of climate change adaptation strategies, like crop diversification, on household welfare is scanty. The existed ones are concentrated their analysis by considering a single product like wheat and maize except Difalco *et al* (2012).

Second, no study was attempted to investigate the tradeoff and synergies between crop diversification effect on household welfare and labor demand. Third, empirical studies investigating the effectiveness of micro-level adaptation strategies to climate change by considering growing season rainfall along with its variability are almost non-existent. Therefore, the current study attempts to fill each of the above research gaps.

CHAPTER THREE: METHODOLOGY

3.1. Description of the study area

The study is conducted in the Nile basin of Ethiopia. Nile basin of Ethiopia is a very large area that covers about 34% of the total geographical region and almost 40% of the population of the entire country (Deressa et al, 2009). This area is equivalent with 358,889 km^2, on which 40% of the country's populations lives in. The basin covers six different regional states of Ethiopia with different proportions which is 38%, 24%, 15%, 11%, 7% and, 5% of the total land areas of Amhara, Oromiya, Benishangul-Gumz, Tigray, Gambella and Southern Nations Nationalities and Peoples respectively (MOWR 1998). Moreover, three major rivers specifically: the Abay River, originating from the central highlands; the Tekeze River, originating from the north-western parts of the country and the Baro-Akobo River, which originates from the southwestern part of the country are included in the basin.

Farming in the study area is characterized by small- holder subsistence farmers. The size of farm per household which is less than one hectare on average is quite small. Farmers use plough and animals' draught power which makes production very traditional. The major input in the production process (land preparation, planting, and post-harvest) is labor and the use of other inputs is very limited (Deressa et al 2009).

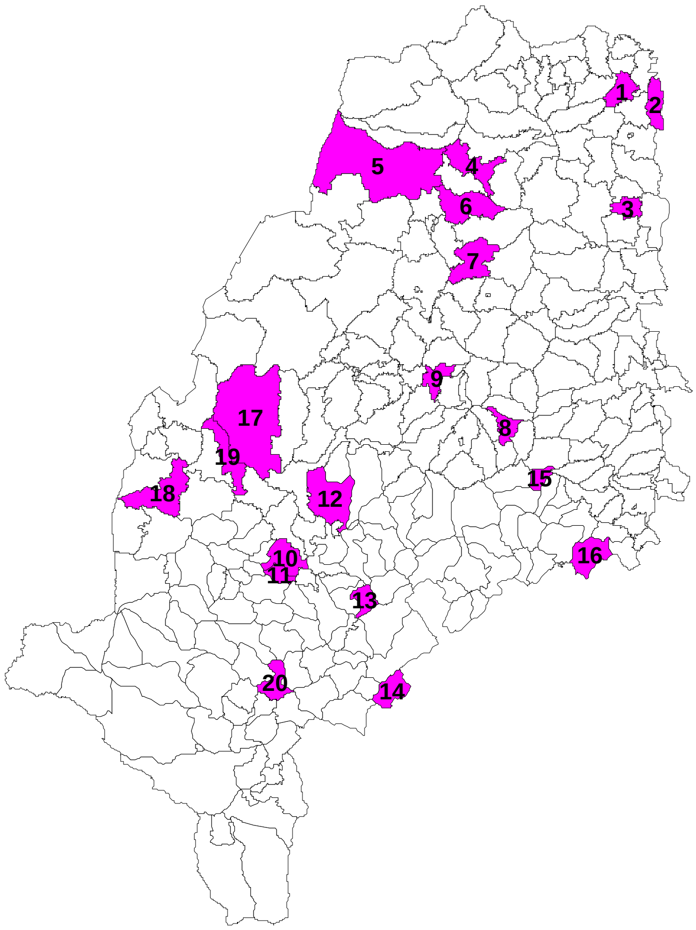

Figure 1. Map of woredas selected for sample in Nile Basin of Ethiopia .

S/N	Woreda
1	Hawzien
2	Atsbi Wonberta
3	Endamehoni
4	Debark
5	Chilga
6	Wogera
7	Libo Kemkem
8	Bichena
9	Quarit
10	Gimbi
11	Haru
12	Limu
13	Nunu Kumba
14	Bereh Aleltu
15	Hidabu Abote
16	Wonbera
17	Bambasi
18	Sirba Abay
19	Kersa
20	Gesha Daka

3.2. Nature and Sources of data

The study have used primary data which has been collected using structured questionnaire on 929 farm households within the Nile basin of Ethiopia in 2014/15. The collected data comprises household characteristics, land characteristics, credit, social capital, and perceptions on climate change.

3.3. Sampling Frame and Techniques

The sampling frame considered traditional typology of agro-ecological zones in the country (namely, Dega,Woina-Dega, Kolla and Berha). Percent of cultivated land, degree of irrigation activity, average annual rainfall, rainfall variability, and vulnerability (number of food aid dependent population) were the set of characteristics by which the frame was developed to select sample districts purposely. The sampling frame selected woredas[2] in such a way that each class in the sample matched to the proportions for each class in the entire Nile basin of Ethiopia. Having these, twenty woredas were selected purposely and simple random sampling was then used in selecting one village from each woreda and fifty households from each village. . One of the survey instruments was in particular designed to capture farmers' perceptions and understanding on climate change, and their approaches for adaptation

3.4. Model Specification and Statistical Analysis

3.4.1. Conceptual Framework

The conceptual frame work of this study is dated back to the study of Roy (1951). In his study, Roy tries to show how individual's self selects themselves between two different occupations, hunting and fishing based on their comparative advantage. The decision to participate in either of the two occupations is conditional on the benefit that will be generated from the occupations (Maddala, 1986).

Similarly farm households will practice a given adaptation strategy by their own will. Households will self select in their decision to adopt a given strategy. However, the decision to practice a given adaptation strategy will depend on the expected utility of adoption. The farmer will practice a given adaptation strategy if the utility from that strategy is greater than the remaining strategies. Thus, the decision for taking adaptation strategies can be modeled in a random utility framework (Difalco, 2011; Solomon, 2010; Kassie et al, 2011).

Let difference in utility from adoption (u_h,A) and non adoption (u_h,N) is denoted by T*. But the utilities are unobservable. To do so let we represent by the following latent variable model (observable function).

$T_h^* = \beta_{Zh} + \mu_h , T_h = 1 \quad if \;\; \text{Th} * > 0 -------------- (1)$

Where $T_h^* = U_{hA} - U_{hN}$

T= 1 if a farmer practice at least one of the given adaptation strategies

T= o otherwise

β = vector of parameters

Z = vector of explanatory variables

μ = is the error term

Now if we assume the relationship between agricultural productivity and adaptation strategies is linear,

$Y_h = \gamma X_h + \delta T_h + \varepsilon_h ------------------------(2)$

Where,

T- The indicator of the adoption decision

γ & δ **-** are vectors of parameters to be estimated and ε is the error term.

If we run the above regression the coefficient of adoption isδ, which measures the impact of practicing a given adaptation strategy/ies on the outcome variable. Yet, this measurement is not accurate. To be taken as an appropriate measure the decision to practice adaptation strategies should be random. In other words, the groups of adopters and non adopters should be randomly assigned. But in the case of practicing climate change adaptation measures farmers will decide to practice each adaptation strategy by their own consent. There is the problem of self selection which leads to selection bias. The decision for taking a given adaptation measure is likely to be affected by unobservable characteristics like, managerial skill, average land fertility, motivation etc that may be correlated with the outcome of interest.

When we look from the regression perspective it is similar with saying that ε is correlated with T orμ. If this is the case, the specified equation above failed to account self selection, ending up with a biased result.

Therefore, the appropriate approach is to follow a model that takes in to account selection bias correction. In the literature of selection model different bias correction methods had been flourished. Mainly the works of Lee (1983), Dubin and Mc Fadden (1984), and semi parametric alternatives proposed by Dahl (2002) are noticeable. However, the method given by Dubin and Mc Fadden are highly preferable to other methods as shown by Borguignon et al (2007).

In this study an Endogenous Switching Regression Model (ESR) with the Dubin and Mc Fadden method, which is improved by Borguignon et al (2007)[1] is implemented. This is to be in line with recent advances in the area and to lend the outcomes of this study for comparison with previous studies. Recently the approach is used by many researchers (Difalco 2011; Kassie et al, 2014; Teklwold et al, 2013; Difalco et al 2010).

3.4.2. The empirical model

In this section we specify a model of climate change adaptation strategy (Considering crop diversification) and household welfare. Different approaches can be used to estimate the impact of adaptation strategy on household welfare. The first simple method is to include dummy variable by classifying farm households as adopters and non adopters and using OLS to estimate the parameters. However, this will yield a biased result. Because it assumes that the decision to adopt is exogenously determined. But adaptation decisions are different based on the characteristics of farm household's. Therefore, using this technique will leads to inconsistent result. As adoption decision is potentially endogenous. Endogineity of such nature can be addressed by explicitly modeling the simultaneity nature of the equations (Heckman, 1977). Yet , pooled data estimation of both participants and non-participants assumes that the list of explanatory variables have the same impact on both groups of farmers and implies that adaptation has an average effect on the whole sample which may not be necessarily true due to selection problems as the effect of adaptation strategies on household's welfare is not similar for the two groups (Heckman, 1979). Based on this fact, we used simultaneous model to account endogienety and sample selection problem. To account for the differential impact of covariates on the welfare outcome of different groups, a separate welfare outcome function is specified and estimated simultaneously through an endogenous switching regression (ESR) model

[1] See Bourguignon et al (2007) for detail derivations of the specifications and the comparisons between different selection bias correction methods

(Maddala and Nelson, 1983). The model is specified following recent works by using ESR in order to account for endogeneity, sample selection and interaction between adaptation and other covariates that affect outcome equation.(Solomon,2010; Martha,2012; Difalco et al, 2011; Salvatore et al,2012 ;Teklewold et al,2014). This model is highly preferable in many aspects. First, it has an advantage of estimating both the selection and outcome equations at a time simultaneously. It also allows to construct the counterfactual expected outcome of the treatment effect under different regimes (i.e. adopt or not adopt). The functional form of the model is specified following Difalco *et al* (2011) and Teklewold *et al* (2013).

3.4.2.1. Endogenous switching regression model (ESRM)

A representative farm household will chooses to adopt CD if the expected utility from adopting is greater than the expected utility of not adopting. Now let $A*$ be the latent variable that captures the expected benefits from CD practice choice with respect to not practicing. Finally the criterion (selection) equation is described as follows:

$$A_i^* = X_i\beta + \varepsilon_i, \text{with } A_i = \begin{cases} 1 \text{ if } A_i^* > 0 \\ 0 \text{ other wise} \end{cases} ---------------- (3)$$

Farm household *i,* will choose to practice CD (A_i=1) in response to long term changes in mean temperature and rainfall if$A_i^* > 0$, and will not practice otherwise. The vector **X** represents variables that affect the likelihood to practice such as the characteristics of the operating farm; farm head and farm household's characteristics; the presence of assets; past climatic factors; the experience of previous extreme events; whether farmers received information on CD; government and farmer-to-farmer extensions, which can be used as measures of access to information about adaptation strategies and other institutional factors such as credit and land tenure.

In overcoming the standard econometric method of using a pooled sample of CD adopters and non-adopters, endogenous switching regression model framework for household net farm income which is peroxied by the net revenue per hectare is employed. Accounting for endogienety and selection biases this measure can then be elicited in to two estimable functions where farmers face two regimes. (1) To practice CD, (2) not to practice and is defined as follows;

$$\begin{cases} \text{Regime 1}: Y_{1i} = Q_{1i}\alpha_{1i} + \mu_{1i} \quad \text{if } A = 1 -------------(4) \\ \text{Regime 2}: Y_{2i} = Q_{2i}\alpha_{2i} + \mu_{2i} \quad \text{if } A = 2 -------------(5) \end{cases}$$

Where Y_i is the outcome variable which is farm household's net farm income in the two regimes and Q_{1i} and Q_{2i} represents a vector of exogenous variables such as the past climatic factors, inputs, assets, farm households and plot characteristics included in **X**. α_{1i} and α_{2i} are vectors of population parameters that will be estimated in the model using the survey data. Further our model relies on the assumption that the error terms in equations (3), (4) and (5) have a trivariate normal distribution, with zero mean and covariance matrix of: $\begin{pmatrix} \delta_1^2 & \delta_{1\varepsilon} & \delta_{2\varepsilon} \\ \delta_{1\varepsilon} & \delta_2^2 & * \\ \delta_{2\epsilon} & * & \delta_\varepsilon^2 \end{pmatrix}$

Whereδ_1^2 and δ_2^2 are variances of the stochastic disturbance terms in the regime functions in equation (4) and (5). δ_ε^2 Is the variance of the stochastic disturbance term in the selection equation shown as equation (3). $*$ represents the covariance of the stochastic disturbance terms in equation (4) and (5) while it is not determined as Y_{1i} and Y_{2i}cannot be observed simultaneously. $\delta_{1\varepsilon}$ is the covariance of the error term of selection equation (ε_i) and the outcome equation of regime one(μ_{1i}). Likewise, $\delta_{2\epsilon}$ represent the covariance of the stochastic disturbance terms in the selection equation and the outcome equation of regime two (μ_{2i}). The variance for the error term in the selection equation (δ_ε^2) is assumed to be 1, since the coefficients are estimable only up to a scale factor (Maddala, 1983).

An important implication of the error structure is that, because the error term of the selection equation (4) ε_i is correlated with the error terms of the regime equations (5) and (6) which are μ_{1i}And μ_{2i} the expected values of these two error terms conditional on the sample selection are nonzero.

Mathematically; $[\mu_{1i}|Ai=1]= \delta_{1\varepsilon}\frac{\phi(X_{i\beta})}{\Phi(X_{i\beta})} =\delta_{1\varepsilon}\lambda_{1i}$ and

$[\mu_{2i}|Ai=0] = -\delta_{2\varepsilon}\frac{\phi(X_{i\beta})}{1-\Phi(X_{i\beta})} = \delta_{2\varepsilon}\lambda_{2i}$where ϕ (.) Is the standard normal probability density function, Φ(.) the standard normal cumulative function, $\lambda_{1i} = \frac{\phi(X_{i\beta})}{\Phi(X_{i\beta})}$ and $\lambda_{2i} = -\frac{\phi(X_{i\beta})}{1-\Phi(X_{i\beta})}$ If $\delta'_{1\varepsilon}$and $\delta'_{2\varepsilon}$ (estimated co variances) are statistically significant the decision to practice CD and household's welfare are correlated which becomes an evidence for endogenous switching and in turn indicates the existence of sample selection bias. The above model described by equations (3) through (5) is known as a "switching regression model with endogenous switching" (Maddala and Nelson, 1975).

The commonly used approach to estimate models that involves self selection is by following the two stage procedure. However, this method is in appropriate and highly criticized. Because it requires some adjustment to derive consistent standard errors and it shows poor performance when there is high multicollienarity between the covariates of the election equation and the covariates of the outcome equation (Maddala, 1983). The appropriate and efficient method to estimate endogenous switching regression models is **full information maximum likelihood (FIML)** estimation. This method is very preferable to other approaches in many instances. First it is feasible with available software, it provides efficient estimate, in addition it allow restrictions to be applied and permit construction of likelihood ratio tests on the restriction (Lee and Trost, 1978; Winship et al., 1988). When similar variables affect the adoption decision (X) and the subsequent outcome equations (Q), lack of identification of the model will be a problem. Because, even though non linear correction terms are included, this may not be enough and resulting in to the problem of multicollienarity (Khanna, 2001; Wu and Babcock, 1998). To overcome this problem finding an instrumental variable is very tedious and impossible (if not). Therefore, in order to assure the admissibility of the model, we have used exclusion restrictions. These variables are hypothesized to affect directly the selection variable but not the outcome variable. Variables related to information sources like, government extension, farmer to farmer extension, and information from radio, and input market distances are used in the welfare function. The admissibility of these instruments is be established by performing a simple falsification test. i.e., if a variable is valid selection instrument then it will affect the decision of choosing an adaptation strategy but it will not affect the net revenue per hectare among farm households that did not adopt. The logarithmic likelihood function given the previous assumptions regarding the distribution of the error terms is:

$$lnL_i = \sum_{i=1}^{N} A_i \left[\ln \phi \left(\frac{\varepsilon_{1i}}{\delta 1}\right)\right] - ln\delta_1 + ln\Phi(\mathrm{Y}_{1i}) + (1 - A_i)\left[\ln \phi \left(\frac{\varepsilon_{2i}}{\delta 2}\right) - ln\delta_2 + \ln((1 - \Phi)(\mathrm{Y}_{2i}))\right] \text{-- (6)}$$

Where $\mathrm{Y}_{ij} = \frac{(X_{i\beta\rho_{ji}/\delta_1})}{\sqrt{1-\rho_j^2}}$ j = 1, 2 with ρ_j = the correlation coefficient between ε_i (the error term of the selection equation) and the error term μ_{ji} of the outcome equations (5) and (6), accordingly.

3.4.2.2. Counterfactual analysis and treatment effects

ESR mode is very important model to compare the expected welfare of farm households that practice CD (7a) to farm households that did not adopt (7b). In addition to this, it is also possible to investigate the expected farm household welfare in the counterfactual case. That is, when farm households who have practiced CD did not practice (8a), and when farm households that had not adopted did adopt (8b). Following this approach not only solves selection bias due to unobserved heterogeneity, it also controls for selection bias due to observed heterogeneity.

The conditional expectations for household welfare in the four cases can be expressed as:

Adopters with adoption (actual adoption observed in the sample):

$$E(Y1i/Ai = 1) = \mathrm{Q}_{1\mathrm{i}}\alpha_1 + \delta_{1\varepsilon}\lambda_{1i} --------------------(7a)$$

Non adopters without adoption

$$E(Y2i/Ai = 0) = \mathrm{Q}_{2\mathrm{i}}\alpha_2 + \delta_{2\varepsilon}\lambda_{2i} --------------------(7b)$$

Adopters had they decided not to adopt

$$E(Y1i/Ai = 0) = \mathrm{Q}_{2\mathrm{i}}\alpha_1 + \delta_{1\varepsilon}\lambda_{2i} --------------------(8a)$$

Non adopters had they decided to adopt

$$E(Y2i/Ai = 1) = \mathrm{Q}_{1\mathrm{i}}\alpha_2 + \delta_{2\varepsilon}\lambda_{1i} --------------------(8b)$$

The expected values derived above helps to calculate unbiased estimates of TT. We can define the treatment effects as the difference between $(7a)$ and $(8a)$ or $(7b)$ and $(9b)$ i.e,

$$\mathrm{TT} = E(Y1i/Ai = 1) - E(Y2i/Ai = 1)$$

$$\mathrm{TT} = \mathrm{Q}_{1\mathrm{i}}(\alpha_1 - \alpha_2) + (\delta_{1\varepsilon} - \delta_{2\varepsilon})\lambda_{1i} \text{--- (10).}$$

By following similar procedure we can also calculate the effect of adoption on the non adopters (TU) which is the difference between $8(b)$ and $9(b)$. i.e.,

$$TU = E(Y1i/Ai = 0) - E(Y2i/Ai = 0)$$

$$TU = Q_{2i}(\alpha_1 - \alpha_2) + (\delta_{1\varepsilon} - \delta_{2\varepsilon})\,\lambda_{2i} ---------------- (11)$$

The difference between (TT) and (TU) in equation (10) and (11) represents the so called "transitional heterogeneity" (TH) which indicates whether the effect of practicing CD is larger or smaller for the adopters than for the non-adopters.

3.4.3. Variable description and priori expectation

A set of socioeconomic and environmental factors are included in the empirical models. Household head characteristics such as age, sex, literacy, family size and marital status, plot characteristics such as, fertility index, slope index, distance of the plot from home stead, and farm size are among the explanatory variables of this study. Moreover, household off-farm job, remittance from relatives, access to credit, climate shock, livestock, productive farm asset, crop varieties, rainfall, temperature, and Land tenure are also included. The dependent variables of this study are Crop diversification, household welfare (proxied by net farm revenue per hectare), and total family labor. The description, type, value and expected sign (depending on previous literatures) on adoption of crop diversification and household welfare are given in the following

Table. 1 Description and Expected Effect of Variables

Variable name	Type and description	Value	Expected sign		
			Adoption	Income	Labor
Household characteristics					
Family size	Family size	Adult Equivalent (AE)	+	+	+
Age	Age of the household head	Years	-	-	-
Education	Education level of the head	Years of education	+	+	-
Off farm	Off farm employment	1 if any of the household member is employed, 0 otherwise	-	-	+
Marital	Marital status of the head	1 if married, 0 otherwise	+	+	-
Remittance	Remittance	1 if remittance was received 0 otherwise	+	+	-
Gender	Gender of the head	1 if the head is male 0 for female	+	+	-
Asset holding					
Farm size	Total farm size	Hectare	+	+	+
Farm asset	Value of productive farm asset	Birr	+	+	+
TLU	Livestock holding	TLU	-	+	+
Input					
Organic	Organic fertilizer	Kilogram	-	+	+
Plot characteristics					
Fertility	fertility of the plot	Number	-	+	-
Slope	slope of the plot	Number	+	-	-
Shock index	Index of shocks faced the household	Number	+	-	+
Institutional factors					
Tenure	Ownership of the respective plot	1 if self owned,0 if not owned for	+	+	+

		self			
Credit	Credit access	1 if yes, 0 other wise	+	+	-
Information	Dummy for media information	1 if yes, 0 other wise	+	+	-
Extension	Dummy for government extension	1 if yes, 0 other wise	+	+	-
Market	Distance of input and output market from residence	Minutes	-	-	-
Climatic factors					
TEMP 0013	Average temperature (0c) 2000-2013		+	-	+
Rain fall 0013	Average growing season rainfall (mm) 2000-2013		+	+	-
CV rain	Rain fall variability		+	-	+
CV temp	Temperature variability		+	-	+
Crop types					
TEFF	Dummy for *Teff*	1 if the farmer grows Teff in his plot 0 otherwise	+	(±)	+
MAIZE	Dummy for maize	1 if the farmer grows Maize in his plot 0 otherwise	+	(±)	-
WHEAT	Dummy for wheat	1 if the farmer grows wheat in his plot 0 otherwise	+	(±)	-
BARLEY	Dummy for barley	1 if the farmer grows barley in his plot 0 otherwise	+	(±)	-
SORGHUM	Dummy for sorghum	1 if the farmer grows sorghum in his plot 0 otherwise			+

CHAPTER FOUR: RESULTS AND DISCUSSIONS

In this part of the study both descriptive and econometric results of the research are presented. First, descriptive statistics is discussed. In the second section, detail econometric results of the model are presented and discussed.

4.1. Descriptive Statistics

There are several factors that affect the extent of household's welfare and adoption decision of climate change adaptations strategies (Menberu *et al,* 2014). Household and socio economic characteristics of the sample farm household's like, age of the household head, level of education, Sex, family size, credit access, land tenure, off farm employment and other factors are included in the study. In the consecutive tables below the summary of descriptive statistics, which includes mean and standard deviations of variables for different categories of respondents, is presented.

As we can see in table (2) below the average age of adopter's non adopter's households is 52.3 and 50.5 respectively. Number of years of education also has an important implication in adoption of crop diversification. On average years of education for adopters is 1.6 year and 2 for non adopters. From this we can understand that the education level of adopters is lower than the non adopters.

Though farm household's take farming as their primary a base for livelihood, they are expected to engage in different off farm activities to finance their crop as well as cash short falls during non productive seasons. In line with this, 22 percent of non adopter households have participated in off farm employment while, 18 percent of adopters have off farm employment.

The statistic also shows that the average household size for adopters and non adopters is 7.9, and 7.6 adult equivalents (AE)[2] respectively. The total family size for the sample household is actually higher than that of the national average 5.5 of 2009 data (CSA, 2009).

[2] Note: AE (Adult Equivalent) is a common unit to describe family size of different age and sex categories as a single figure that expresses the total amount of family labor irrespective of the age and sex compositions

Table 2 descriptive statistics for household characteristics

	Adopter		Non adopter	
Variable	Mean	Std.Dev.	Mean	Std.Dev.
Household Characteristics				
Age	52.34	12.81	50.59	12.69
Marital Status	0.83		0.87	
Household size	7.90	0.31	7.60	0.3
Remittance	0.12		0.81	
Off farm employment	0.18		0.22	
Gender	0.88		0.87	
Education	1.65	2.85	2.06	3.13
Assets				
Farm size	1.80	0.63	1.60	0.68
VPFA	12456.53	0.63	11849	1.43
TLU	4.92	3.5	4.63	3.69
Institutional factors				
Credit	0.43		0.44	
Farm support	0.07		0.08	
Government extension	0.43		0.57	
Media information	0.19	0.59	0.26	0.67
Input market distance	50.00	0.12	50.02	0.12
Land tenure	0.87		0.8	
Inputs				
Pesticide	0.12	0.65	0.1	0.69
organic fertilizer	0.29		0.3	
Regional Decomposition				
Tigray	0.17		0.11	
Amhara	0.42		0.35	
SNNP	0.06		0.04	
Benishangul Gumuz	0.11		0.12	
Oromia	0.21		0.35	

Source: own calculation from (2015) survey

The average landholding of adopters is slightly larger (1.8hectare) than the non adopters (1.6hectares). The average landholding of farm households at national level is almost less than this result (1.18hectare) (CSA, 2007).

There is a difference in the average amount of pesticide application between the categories of sample households. For adopters the average amount of pesticide use is 0.12liter. For non adopters it is 0.65 liters. Furthermore, the difference in the pesticide application between adopters and non adopters might be accompanied to the weed suppression, disease and pest control potential of crop diversification. .

Owning productive farm assets (VPFA) is a key factor for being successful in farming activity (Cooper *et al*, 2008). Households are asked if they own different types of household and farm assets. Then their respective value in monetary terms is used to measure the value of all productive farm assets. The average VPFA for adopters is 12456.53 Birr, while it is 11849 Birr for non adopters.

In this study credit is defined as credit constraint. A dummy variable which takes 1 if the household needs credit but not available and 0 other wise is used. In the study area, 43 percent of adopters and 44 percent of non adopters are credit constraint. Credit access is one instrument to protect household welfare loss. When there is climate change credit can support farm households to buffer non productive seasons in many ways. First, it will allow farm households to participate in nonfarm business by acting as a source of paid up capital. Second it will help to finance the purchase of agricultural technologies. On average 8 percent of non adopters and 7 percent of adopters have get farm support. The average of farm households who receive remittance from their relatives is found 12 percent this is the same for adopters' non adopters.

Livestock ownership, measured by Tropical Livestock Unit (TLU)[3], is one of wealth indicator factors. Farm households who adopt crop diversification have 4.9 TLU. But who don't adopt crop diversification have 4.6TLU amounts of livestock. The average livestock ownership for the total sample is 4.8 TLU. The implication of higher livestock ownership for adopters can be attributed to its effect on wealth. When TLU increase it adds to the wealth of the household which implies wealthier households are more likely to adopt crop diversification.

Access to information from different sources about crop diversification is a crucial factor for the proper implementation of the practice. Farmers are asked if they have got information about crop diversification from different Medias like radio, television newspaper and other sources. Similarly the provision of extension service is also asked. Both frequency of extension contact and the personal valuation of framers about the qualification of the agents are asked. Based on this, information from different types of media is

[3] Note: TLU (Tropical livestock unit) is a common unit to describe livestock numbers of various species as a single figure that expresses the total amount of livestock present – irrespective of the specific composition

larger for non adopters than adopters. However the government extension coverage is equal for each of the two groups accounting 16 percent.

Application of organic fertilizer is the other factor that affects adoption of crop diversification. In this study, organic fertilizer is a dummy variable. It takes 1 if the household used manure in that specific plot and 0 other wise. The result indicates that, 29 percent of adopters and 30 percent of the non adopters use organic fertilizer.

As well, 87 percent and 80 percent of adopters and non adopters respectively are using their own land. This implies, tenure security is a crucial covariate for agricultural technology adoption like, crop diversification. Tenure security can develop sense of ownership and enable farmers to exert their maximum effort to safeguard their land. However, if there is no tenure security farmers will frustrate loss of the farm and fail to implement different land management practices.

Access to the nearest input market will help farm households to get different farm inputs like, improved seeds, chemical fertilizer, herbicides and pesticides easily. The time (minutes) needed to reach the nearest market (by walking) is used to measure market distance. For adopters and non adopters the average time to reach the nearest input market is found around 50 minutes

As far as the proportion of adopting crop diversification by region is concerned, Amahara region takes the highest share (42 percent) followed by Oromia (21 percent) and Tigray(17 percent) regions . Furthermore, 11 percent and 6 percent of farm households from Benishangul-Gumuz and SNNP regions are practicing crop diversification as a climate change adaptation strategy.

Plot characteristics

In order to fully capture heterogeneity among different plots, this study tries to incorporate different plot level characteristics. Mainly the following factors are included i.e., slope of the plot, fertility of the plot, shock index and plot distance to the home stead. A total of 4778 plots size are included in the study. The slope of the plot is an ordina1 variable which can take 3 different values 1 for flat slope, 2 for moderately steep slope and 3 for steep slope. Similar to this, fertility of the plot is an ordinal variable which takes 1 for low fertility, 2 for moderate fertility and 3 for highly fertile plot. And then farmers are asked about the perception of their plot characteristics.

The results of the descriptive statistics revealed that, the average slope for adopters and non adopter is found 0.47 and 0.48 respectively. Similarly, the fertility adopter is 0.83, while it is 0.82 for the non adopters. The slight difference in fertility index between adopters and non adopters can be taken as an indicator for the soil fertility enhancing potential of crop diversification.

Shock index is calculated by dividing shocks happened in a plot to the seven shocks which are given to farmers as alternative to answer whether they are happened or not. These shocks are drought, flood, erratic rainfall, pattern animal attack, landslide, hailstorms, and other shock specified by the respondent. And shock index is calculated by dividing the total number of shocks faced by that farm household at the considered specific plot by seven. As the shock index goes to 1 it indicates that the considered plot is affected by many shocks. The shock index for adopters and non adopters is found equal value (10percent)

Table 3 descriptive statistics for plot level variables

		Adopter		Non adopter		Total sample	
Variable		Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Plot characteristics							
Slope	Flat =1	0.61		0.60		0.60	
	Medium = 2	0.34		0.39		0..36	
	Steep = 3	0.05		0.01		0.04	
Fertility	Low = 1	0.11		0.14		0.13	
	Medium =2	0.49		0.53		0.50	
	High = 3	0.39		0.33		0.37	
Shock index		0.30	0.04	0.10	0.06	0.60	0.06
Plot distance		1.92	1.43	1.74	1.43	1.87	1.43
Crop Type							
Wheat		0.16		0.09		0.14	
Barley		0.13		0.09		0.12	
Teff		0.59		0.72		0.63	
Sorghum		0.05		0.03		0.04	
Maize		0.45		0.63		0.50	

Source: own calculation from (2015) survey

The effect of crop diversification on farm income will vary based on the type of the planted crop. So as to account this heterogeneity cereal crops like, Wheat, *Teff*, Sorghum and Barley are included in the study. On average 59 percent and 72 percent are *Teff* growing for adopters and non adopters respectively. This is followed by maize (45% and 62%), Wheat (16% and 9%), Barley (13% and 9%), and Sorghum (5% and 3%), for plots adopters and non adopters accordingly.

Climatic factors

Agro ecological and local climatic conditions are the basic determining factors for the decision to take climate change adaptation measures (Ginbo, 2014). The study incorporated different climate variables in the empirical model. The average monthly temperature (^{o}c) and the average growing season rainfall (mm) from2000 -2013 are included as a prime factor. Monthly rainfall and temperature data were collected from all the meteorological stations in the country. Then, the *Thin Plate Spline*[4] method of spatial interpolation was used to impute the household specific rainfall and temperature values using latitude, longitude, and elevation information of each household. This method is one of the most commonly used to create spatial climate data sets. Its strengths are that it is readily available, relatively easy to apply, and it accounts for spatially varying elevation relationships (Difalco *et al*, 2012). In addition, to account rain fall and temperature variability the coefficients of variations for both of the two are also included.

The average monthly temperature is found around 19.9 ^{o}c and 20^{o}c for adopter's non adopters respectively. The average of growing season rainfall is found around 681.89 mm and 753.45mm for adopter's and non adopters respectively. Adopters of CD have lower amount of growing season rainfall than non adopters. This is an indicator for the appropriateness of using crop diversification as a climate change adaptation strategy in low rain fall area

Table 4 descriptive statistics for climate variables

	Adoptr		Non adopter		Total sample	
Variable	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Climate variables						
Average growing season rainfall	681.89	230.79	753.45	233.75	701.37	233.76
Average monthly temperature	19.92	2.58	20.02	2.55	19.95	2.58
CV Temperature	0.1	0.02	0.09	0.02	0.1	0.02
CV rainfall	0.56	0.23	0.48	0.23	0.54	0.23

Source: own calculation from (2015) survey

4.1.1. Crop diversification and family labour

Family labor is one of the basic inputs needed to practice different climate change adaptation strategies and easily adopt agricultural technologies (Cooper *et al*, 2008). Theoretically some adaptation strategies are expected to increase agricultural productivity and reducing the amount of family labor requirement for farming activity, while others bear an additional labor cost higher than the convectional one. This study

[4] By definition, *Thin Plate Spline* is a physically based two-dimensional interpolation scheme for arbitrarily spaced tabulated data. The Spline surface represents a thin metal sheet that is constrained not to move at the grid points, which ensures that the generated rainfall and temperature data at the weather stations are exactly the same as data at the weather station sites that were used for the interpolation. In our case, the rainfall and temperature data at the weather stations are reproduced by the interpolation for those stations, which ensures the credibility of the method (see Wahba 1990)

tries to look at the family labor implication of practicing crop diversification as an adaptation strategy for climate change. Total Family labor requirement is calculated by summing up the amount of labor needed for each farming activity and then adult equivalent (AE) is used as a measurement tool. So as to show the gender biased effect of the considered adaptation strategy, labor requirement is disaggregated by Gender as male labor and female labor.

The average per hectare total amount of labor for weeding and the whole farming activities for both male and female household members is presented in the table below

Table 5 descriptive statistics for family labor requirements (number of person days /hectare)

	Male Labor (Mean)			**Female labour (Mean)**		
	Adopters	Non adopters	Total sample	Adopters	Non adopters	Total sample
Weeding Labor	18.4	20.7	19	15.6	22.9	17.6
Total Labor	28.5	33.9	30	18.8	24.7	20

Source: own calculation from (2015) survey

According to the results of the descriptive statistics there is a big difference between adopters and non adopters in their family labor need for farming activity. The average total number of male labors for adopters and non adopters is 28.5 and 33.9 person days per hectare respectively. The average female labor requirement for the whole farming operation is 18.8 and 24.7 person days per hectare for adopters and non adopters. Similar trend is also observed in the weeding.

We can make an easy comparison between total labor requirements across adoption and gender. The total labor for adopters is lower than the non adopters for both male and female adopters. Indeed, the labor requirement for female adopters is lower than their male counterparts. The above results supports the argument that crop diversification has an advantage of reducing family labor requirement especially female labor.

4.2. Empirical Results

In the following section the econometric results of the Endogenous Switching Regression model estimated by the FIML using STATA 13 are presented. Mainly the model is estimated for farm net income and family labor functions by including different tests like, instrument validity test for the selection model and treatment effects. The Wald test for overall significance of the model shows that the model is statistically overall significant and best fit.

4.2.1. Parameter estimates of crop diversification and farm income

Estimation results of the endogenous switching regression model for farm income are presented below in three tables (table 6, table 7, and table 8). Column (1) of the three tables report OLS regression results with a dummy variable of CD adoption which equals 1 if the smallholder farm household adopted, and equals 0 if the smallholder farm household did not adopt it. Column (2) of the three tables shows estimated coefficients of the selection equation while columns (3) and (4) of these tables state results of the outcome equations for CD adopters and non-adopters respectively

4.2.1.1.Determinants of adopting crop diversification

The selection model estimate result on the adoption of crop diversification is presented in tables (6 through 8). Many variables are found significant determinants of using crop diversification. Emphasis is given for those significant variables. The goodness of fit of the model is shown by the Wald test, which is highly significant indicating best model fit.

Climate variables

Farm households are expected to take different adaptation strategies for persistent and long term climate shocks. Therefore, it is thought that, climate variables like average temperature and rainfall can potentially determine adoption of crop diversification.

However many studies take average annual rain fall, the most important one is to take average growing season rain fall. In addition to this, other than the total amount of rain, the variability across different seasons is vital. The result of the study indicates that, average temperature and rain fall have a non linear effect to adopt crop diversification (CD).

An increase in mean temperature decreases the likelihood of adopting CD, which implies at lower temperature there is lower rate of adopting CD. However, this effect will be wiped out after some threshold level. This is indicated by the positive sign of average temperature square.

When the average temperature increases adoption of CD will be lower till some point and latter on the likelihood of adoption will increase with temperature. This shows that, CD will be effective at higher temperature and lowland areas. This could be emanated from the moisture conservation potential of CD.

In similar vein, the relationship between average growing season rainfall and its square with adoption of CD is found non linear. When average rainfall increases the probability of adopting CD will increase continuously, but after some optimal level this relationship will become reversal. This is also evidence that supports the effectiveness of CD in low rainfall areas. Since CD conserves huge moisture adoption will be fruitful when the areas are drearier. The result of Teklewold et al (2013) also states that adoption of crop system diversification is high in areas where rain fall is favorable in its timing, distribution and amount.

Furthermore, the variability of rain fall and temperature are also found the significant determinants of CD adoption. According to the model results rainfall as well as temperature variability increases the likelihood of adopting CD. When there is high rainfall variability farmers will need a way to avoid its negative consequence. By using CD they can be benefited more and smooth their farm productivity; as CD provide enough moisture and boost soil fertility.

Household Characteristics

In the literature it is thought that, education is a significant determinant for technology adoption (Solomon, 2010). However, in this study it is found insignificant. But the sign of the coefficient shows that level of education and CD adoption are positively related. This is due to the fact that, educated households can easily accept new technologies and can understand their importance quickly. This result is in line with the works of Akaakohol *et al* (2014); Rahima *et al* (2013).

Similarly, household size, gender and age of the household head are also found insignificant. Age and family size negatively influence adoption of CD, while gender affects it positively. The justification for the negative sign of age could be related to the non reluctant behavior of young farmers for new technologies. Indeed, old farmers are highly rigid for change and fail to accept new agricultural technologies rather they think that as their own way is the best one. Such negative relationship between age and CD adoption is found in the study by Ldow *et al* (2014) in Nigeria.

Due to the problem of dependency burden increase in family size will reduce the probability of adopting CD. On the contrary, employment in off farm activity affects adoption of CD positively and significantly. Off farm employment creates an opportunity for farmers to diversify their income sources. And this in turn assists them to buy different complementary inputs. Similar to this, remittance also affect adoption of CD positively and significantly. The study by Solomon (2010) is also in line with this result. Compared to farm households who haven't receive remittance from their relatives have lower chance of adopting CD than the receivers. Marital status of the household head is also the other significant determinant of adopting CD. Relative to married household heads the probability of adopting CD is higher for the non married one.

Plot characteristics

In order to account the plot level heterogeneities the study incorporated different plot level characteristics including, slope of the plot, soil fertility of the plot, shock index, plot distance and Organic fertilizer.

Shock index is found the significant determinant. However, slope and fertility are found insignificant. When the shock index of the plot increases the likelihood to adopt CD will also increase. This is because; higher shock index shows the incidence of many shocks in the plot. Therefore, in order to protect the negative effect of the shocks farmers will adopt CD.

Though it is in significant the sign of the fertility is found as per the expectation of the study. When plot fertility increases the probability of adopting CD will decline. Because, CD might appropriate for poorly fertile plots to augment the productivity of the plot by increasing its moisture content and the fertility of the soil. Similar study in SNNP of Ethiopia by Rahima *et al* (2013) has found the same result. The study indicates that, the positive relationship might because fertile plot is promising to increase production and yield.

For Farm households that apply organic fertilizer in their plot the probability of adopting CD is high. This may probably due to the complementarily nature of CD and organic fertilizer. CD coupled with organic fertilizer can easily boost agricultural productivity. Thus, farm households will benefit from this by implementing the two activities jointly.

The distance of the plot from the home stead is also found the other determining factor for adoption. Accordingly, the further the farm plot from the home stead the probability of adoption is higher and the reverse is true for nearly home stead plots.

Table 6 Climatic Factors, Household and Plot Characteristics

Model	OLS		Endogenous Switching Regression					
	F (41, 4717) =10.32 prob >f = 0.0000 R- squared = 0.093 Root MSE= 2.824		Wald chi2 (41) = 364.47 Log pseudo likelihood = -14166.533 Prob >chi2 = 0.0000					
Dependant variable	Household Farm incomefor pooled data		Adoption of CD		Household income for adopters of CD		Household income for non adopters of CD	
	Column 1		Column 2		Column 3		Column 4	
Explanatory variables	coefficient	Robust Std.Err	Coefficient	Robust Std.Err	coefficient	Robust Std.Err	coefficient	Robust Std.Err
Adoption of CD	0.24**	0.09						
Climate variables								
Average rainfall	-0.01***	0.03	0.01***	0.001	-0.009*	0.003	-0.01**	0.007
Average temperature	4.77***	1.02	-3.46***	0.49	6.65**	2.79	5.33***	1.12
Rain fall square	0.00	0.00	-0.001***	0.001	0.009	0.005	0.0001	0.008
Temperature square	-0.11***	0.03	0.09***	0.01	-0.16**	0.07	-0.13***	0.02
CV temperature	-56.02***	12.32	18.27***	6.84	25.23***	13.49	-70.22**	33.34
CV rain fall	-5.81***	1.73	6.15***	0.92	-6.44***	1.96	-8.25*	4.39
Household Characteristics								
Age	0.07**	0.02	-0.005*	0.01	0.06**	0.02	0.08	0.05
Age square	-0.07***	0.02	0.002	0.009	-0.006**	0.002	-0.008*	0.004
Marital status	-0.08**	0.04	-0.03**	0.01	-0.10**	0.04	-0.03	0.07
Education	-0.01	0.01	0.006	0.008	-0.02	0.01	0.01	0.03
Log household size	-0.50***	0.14	-0.03	0.07	-0.36**	0.16	-0.87***	0.30
Remittance	-0.13	0.13	0.14**	0.06	-0.17	0.14	0.02	0.27
Off farm employment	-0.16	0.1	0.11**	0.05	-0.15	0.12	-0.25	0.21
Gender	-0.23	0.16	0.004	0.07	-0.20	0.19	-0.16	0.29
Plot Characteristics								
Fertility index	0.08	0.25	-0.02	0.12	-0.18	0.28	0.90*	0.51
Slope index	-0.12	0.29	0.22	0.15	-0.13	0.33	-0.42	0.57
Shock index	0.18	0.70	0.55*	0.33	0.29	0.78	-0.25	1.45
Log plot distance	-0.04	0.03	0.08***	0.01	-0.05	0.03	-0.05	0.07
Organic fertilizer	0.15	0.1	0.09*	0.05	0.08	0.11	0.17	0.21
Sample size	**4778**		**4778**		**3477**		**1301**	

Note: Estimation by OLS (first column) and full information maximum likelihood for the remaining columns at the plot-level with zonal dummy, robust standard errors in parenthesis. Sample size: 4778 plots. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.

Assets

Assets of farm households including TLU, VPFA, and farm size are also included in this study as a determining factor. When VPFA is found a significant determinant of adoption, the remaining two are insignificant. When the amount of available productive farm asset increases the probability of adoption is found higher. Mesfin *et al* (2011) also found the same result with this study however in contradict with the study by Benin *et al* (2004). Similarly having more livestock ownership also increases adoption. This is due to the fact that, the two elements of household asset, TLU and VPFA are indicators of wealth and wealthier households have higher chance of adopting crop diversification, which implies crop diversification is not pro poor.

On the other hand, larger farm size contributes negatively for adoption of CD. This has actually an important implication. It indicates that, the best way to increase productivity is intensification than extensive farming. Probably farmers tend to increase farm income and household welfare by intensifying production. Farmers will increase their crop yield through intensification by using different yield enhancing strategies like, crop diversification at lower farm size. A similar result was found by Teklewold *et al* (2013) in Ethiopia.

Institutional Factors

The institutional factors considered in this study are credit constraint, land tenure, and farm support. Compared to farm households with credit access credit constrained households have found a higher chance of adoption. This is because credit is knowledge intensive and used mainly to control pest, crop diseases, and increasing soil fertility. Since it provide finance to buy pesticide, herbicides and fertilizer. But crop diversification can be a substitute for credit by controlling pest and weeds as well as by increasing soil fertility through increasing organic content of the soil (Lin, 2011). This reduces farmers cost of buying inputs and fertilizer. Due to this credit constraint farmers are highly exposed for adoption of CD. The results of Solomon (2010); Teklewold *et al* (2013) also support this argument.

The remaining institutional factor which determines adoption significantly and positively is land tenure. Those farm households with tenure security have high chance of adopting CD. Tenure security is the guaranty for farmers to develop sense of ownership in their plot. This motivates them to better safeguard the quality and wellbeing of the plot by using different activities. On the contrary if they are not secured with their land ownership, they will become careless in protecting their land. Due to this, farmers without tenure security will have lower likelihood of adaptation. The study of Mariara *et al* (2002) shows the importance of tenure security for technology adoption too.

Crop types

The effect of agricultural technology adoption is not crop neutral. In line with this, crop diversification is expected to inflict a differential effect based on the planted crop type. Compared to wheat, adoption is negatively related with Teff, Maize, and Barely crops at a sizeable level of significance. However, the probability is higher for sorghum planted plots relative to wheat. This is might be because, except sorghum the considered crops are expected to grow in high rain fall areas and CD is appropriate for low rain fall and high temperature areas. Thus, if the plot is planted either of these crops the likelihood of adoption tends to be lower.

Table 7 Assets, Institutional Factors and Crop Dummy

Model	OLS		Endogenous Switching Regression					
Dependent variable	Household income for pooled data		Adoption of CD		Household income for adopters of CD		Household income for non adopters of CD	
	Column 1		Column 2		Column 3		Column 4	
Explanatory variables	Coefficient	Robust Std.Err	Coefficient	Robust Std.Err	Coefficient	Robust Std.Err	Coefficient	Robust Std.Err
Assets								
Log VPFA	-0.02	0.03	0.03**	0.01	-0.03	0.03	-0.05	0.06
TLU	-0.08***	0.01	0.006	0.007	-0.07***	0.02	-0.09***	0.03
Log farm size	-0.40***	0.08	-0.007	0.04	-0.42***	0.10	-0.42*	0.16
Institutional factors								
Credit	0.25**		-0.03	0.04	0.20**	0.09	0.35**	0.18
Farm support	-0.16	0.16	-0.11	0.07	-0.27	0.19	0.03	0.30
Land Tenure	0.28**	0.13	0.33***	0.06	0.36**	0.16	0.13	0.24
Crop type								
Barley	-0.77***	0.13	-0.18**	0.077	-0.84***	0.15	-0.39	0.31
Teff	0.43***	0.19	-0.18**	0.09	0.56***	0.21	0.06	0.42

Maize	-0.75***	0.10	-0.35***	0.05	-0.73***	0.11	-0.66***	0.25
Sorghum	-1.16***	0.20	0.24**	0.11	-1.20***	0.22	-1.25**	0.55
Sample size	**4778**		**4778**		**3477**		**1301**	

Note: Estimation by OLS (first column) and full information maximum likelihood for the remaining columns at the plot-level with zonal dummy, robust standard errors in parenthesis. Sample size: 4778 plots. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.

Selection instruments

Information from different sources (Radio, Tv, News paper), government extension service and distance to input market are the selection instruments used in this study. The regression results of the selection instruments with admissibility tests are presented in table 8 below.

Information from different Medias and government extension service about CD has a negative effect on adoption and they are significant. Even though the result is not expected a priori, it will be accompanied to either of the following reasons. First the extension workers in the rural area might luck knowledge of agricultural farming. Second the farmers might be ignorant of such services. Rather than accepting the advice of extension workers they will depend on their own knowledge and farming experience. In addition farmers also fail to rehearse and implement appropriately the information provided through different Medias. Similarly, Fetin *et al* (2009) also showed that crop diversification is negatively affected by extension service. However our result indicates that information from different Medias affect the likelihood of adoption negatively, the results of Solomon (2010) are in contradict to our study.

Moreover, distance to input market affect adoption negatively and significantly. When the distance the nearest input market is large the possibility of adoption is will decline, because input markets are places where relevant complementary inputs for the farm activity are available. If there is no easy access to farm inputs the task of adoption will become difficult.

Table 8 **Selection instruments and Joint tests**

Model	OLS		Endogenous Switching Regression					
Dependent variable	Household income for pooled data		Adoption of CD		Household income for adopters of CD		Household income for non adopters of CD	
	Column 1		Column 2		Column 3		Column 4	
Explanatory variables	Coefficint	Robust Std.Err	Coefficient	Robust Std.Err	Coefficient	Robust Std.Err	Coefficient	Robust Std.Err
Selection instruments								
Media information			-0.12***	0.03				
Government extension			-0.02	0.01				
Log input market distance			-0.27*	0.16				
Constant	-24.08***	8.54	22.25***	3.82				
σ_i					0.05***	0.03	-0.15***	0.14
ρ_i					2.73	0.01	2.96	0.02
WTIE(χ2)			3.69**					
JTI(χ2, F-test)			15.89***(χ2)		0.82			
Sample size	4778		4778		3477		1301	

Note: Estimation by OLS (first column) and full information maximum likelihood for the remaining columns at the plot-level with zonal dummy, robust standard errors in parenthesis. Sample size: 4778 plots. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level: JTI= joint test on selection instruments, WTIE= Wald test of independent equations.

4.2.1.2. Determinants of net farm household's income

Comparing the farm income differential between adopters and non adopters of CD is one of the prime objectives of this study. Thus, income functions for the two groups are estimated. This enables us to know if farm households are benefited from adopting CD.

In order to assure the identification of the model some selected instrumental variables are used. We took government extension, media information about CD and input market distance as selection instruments of our study. These variables are expected to fulfill to main conditions to be considered as a valid instrument. First they should not be directly related with farm household's net farm income. They should directly affect the adoption of CD. For instance, if we take input market distance it directly affects the willingness of adopting CD however; it doesn't have a direct effect on farm household's income. Because farm inputs are crucial elements for increasing agricultural productivity, farmers without easy access to farm inputs will fail to adopt CD and vice versa.

Other than the above theoretical justification the validity of the instruments is approved by using two main tests. By using robust probit regression the effect of instruments on CD (the dependent variable in the selection equation) is jointly significant at 5% level of significance. The second test is conducted by using OLS regression on the outcome equation of non adopters with selection instruments and other covariates. The result of this test indicates that, the instruments joint effect on the non adopter's net farm income is in significant.

As we can see in the 1st column of tables 6, 7, and 8 above we have estimated the farm income function for the polled sample using OLS estimation technique by considering CD as an explanatory variable. The result shows that, adoption of CD has a positive significant effect on the income function. Column (1) of OLS regression in table (6) indicates that, other factors remain constant; farm households who adopted CD can get a 24% farm income increment than their non adopter counterparts. By adopting CD the income of farm households will increase by 24 percent. However, accepting this result as a correct measure for the effect of CD on farm income is not appropriate. Because in this regression it is assumed that there is strict exogeniety in adoption of CD. But it is the personal decision of farmers and potentially endogenous. Thus, the estimated results of this model are biased and inconsistent since it fails to account the problem of selection bias and unobservable heterogeneity. Indeed, it fails to identify the structural difference of income between adopters and non adopters.

To do so, the Endogenous Switching Regression (ESR) model for household farm income functions for adopters and non adopters is estimated. The last two columns of table 6, 7, and 8 indicate the determinants of net farm income for adopters and non adopters. As per the result, climatic variables, crop dummy, livestock ownership (TLU), and credit access are found the key determinants of the income functions of both adopters and non adopters.

The Wald test of independence is significantly different from zero, which indicates that in addition to the problem of selection bias, there is slope heterogeneity between adopters and non adopters. There are also some factors which affect adopters and non adopters differently. Thus estimating two separate income functions is mandatory.

Climatic factors

Both average rain fall and temperature are expected to have a non linear effect on farm income of adopters and non adopters. Therefore, average temperature and rainfall with their respective squares are included in this study. As per the expectation, the effect of temperature is found non linear and significant but rainfall square is insignificant for both adopters and non adopters.

When there is a unit increase in temperature the income of both adopters and non adopters will tends to increase. However the income of adopters is increased by larger amount than the non adopters. This is due to the fact that, the non adopter's farm income is compromised by the effect of high temperature. On the contrary adopters of CD are become beneficiary since CD reduce the effect of high temperature on crop yield by conserving moisture and increasing soil fertility.

After some point parallel increase in income with temperature, it tends o decline for both adopters and non adopters and this is shown by the negative sign of temperature square. Despite this result also confirms the advantage of adopting CD. Because when we look the turning point for the inverted u- shape relationship of temperature and farm income, the inflection point for adopters is found 10 percent larger than the non adopters. In other words, the farm household income of adopters increase for 10 percent amount even after the non adopter's income is declined. This implies, adoption of CD can help farm households to reduce the effect of climate change on their farm net revenue. On the other hand, increase in average temperature reduces income of farm households for both adopters and non adopters. This indicates that, CD is mostly effective in low rain fall or drier areas.

Apart from this, rain fall and temperature variability are the most crucial factors that affect farm household's income. Because though he total amount of rain during a given production year is enough, its timing and distribution is vital. If all of the total rain needed for one production season rains in the beginning of the production period it will be harmful for farmers. Thus giving attention for rainfall variability is very important.

The results of the study shows that, both rainfall and temperature variability are found significant determinants of household farm income for both adopters and non adopters. When the variability of rainfall increases the income of both adopters and non adopters will decline. But the reduction has very significant difference between adopters (-6.4) and non adopters (-8.2). Similarly an increase in rainfall variability has a negative effect on household's income. The income of farm households without adoption decreases by 70.2 and that of the non adopters by 52.2.

Form this it is worth mentioning two main implications. First in addition to the average rain fall and temperature attention is needed for their variability. Second, CD has not only an advantage of increasing farm household's income when there is change in average temperature and rain fall, but it can be a best buffer strategy during the time of high temperature and rainfall variability.

Household Characteristics

Family size is found one of the negative significant determinants of net farm income for both adopters and non adopters. Though the effect on non adopters (-0.87) is large relative to adopters (-0.36), it reduces farm household's welfare for both groups. Probably this will be due to the case when the household members are dependent and not contribute to the income portfolio of the household. Similar results are also found by Akaakohol *et al* (2014). However, the slight difference can be attributed to the revenue increasing effect of adopting CD.

The effect of age on income is expected to be non linear. The result shows both age and its square are the significant determinants with and without CD. Even though farm household's can increase their income with an increase in age this effect will be reversed after some years. This can be explained by the effect of productivity. Youngsters are more productive and workaholic than aged people. When the age of the head increases above some level, he/she will join the non productive dependent labor force group. Thus, they will become dependent and farm household's income will tend to decline (Sichoongme *et al, 2014*).

Education, remittance, off farm employment and gender of the household head are the other insignificant variables that affect household net farm income for both adopters and non adopters. From these factors education, off farm employment, and gender f the head are found with negative coefficient for both of the groups. On the other hand, remittance is found negative and positive determinant for adopters and non adopters respectively.

Crop types

The other profound result of this study is the heterogeneity of CD effect on net farm income for both adopters and non adopters based on the type crop they harvest. Compared to wheat producer's production of maze, sorghum, and barley reduces income for both adopters and non adopters. All the three crops are found significant determinants except the insignificance of barley for non adopters. On the other hand, *teff* production increases farm income for both adopters and non adopters relative to wheat production though in significant for non adopters.

Institutional factors

From the considered institutional factors in this study, credit constraint is found the only factor that determines farm income of adopters and non adopters positively and significantly. This is probably due to the same benefit generated from CD that could be generated form credit. But it is difficult to explain why it has positive effect on non adopters.

Assets

In this study size of cultivated land livestock ownership found negative significant determinants of farm household's income for adopters as well as non adopters. For the matter of fact, both of the two have important implications. The negative effect of land holding is related to intensification. Farmers will be benefited more if they build up their production in a small plot. Having large farm size will be very difficult to manage and will also increase cost of inputs. Thus, agricultural farm income will be maximized by being productive in a small farm size. In the same taken, high livestock ownership will reduce the time for agricultural work and farmers may not work on their farm appropriately. Thus, productivity will reduce and the incidence of crop failure will be very high. Productive farm asset holding also found a non significant determinant for both groups.

Plot characteristics

From the plot related variables incorporated in this study land tenure and fertility are found positive and significant determinants for wellbeing of adopters and non adopters accordingly. However, other factors like, slope of the plot, shock index, plot distance and organic fertilizer application are found insignificant for both groups. In line with this, the study by Mariara *et al* (2009) stressed the importance of tenure security to increase productivity of framers.

4.2.1.3. Average Expected Net farm income

From our previous result we have found that practicing CD has a positive significant effect on net farm income. However, this simple measurement is inappropriate as both observed and unobserved factors which may have an effect on the outcome variable may not be considered.

Therefore, the value of the outcome variable should be compared with the actual and counterfactual cases. In table 9 below the result on the expected farm income in the actual and counterfactual cases is presented. The result indicates that adoption of CD do not have the same effect on adopters had they been non adopter and non adopters had they been adopter.

The number in the first row first cell of table 9 is the average income value (3715.63) for adopters of CD. The number in the second cell (3137.23) indicates the average net farm revenue for adopters in the counterfactual case. Then the adoption effect on adopters can be found by subtracting the second from the first (578.54***). The result is positive and significantly different from zero. This suggests that, farm household's income for those who adopted CD is significantly higher than if they did not adopt.

By using similar procedure the adoption effect of CD on non adopters can be calculated from the same table. In the second row first cell of the following table we get the value of net farm income for non adopters in the counterfactual case, while the second cell in the same row represents the same value in the actual case. Then by taking the difference between the first and the second cell we can get farm income of non adopters (1566.55***). The result indicates that, farm income will increase significantly if they adopt CD than the actual case of non adoption. Similar studies by Difalco (2011); Kuntashula *et al* (2014); Bhattacharyya (2008); Bradshaw *et al* (2004) also reported the same result with our study.

Table 9 Adoption Effects of CD on Net Farm Income

	Decision stage		
	Adopters	Non adopters	Adoption effect
Adopters	3715.63 (59.92)	3137.23 (93.47)	TT= 578.54*** (113.45)
Non Adopters	2966.75 (80.9)	1400.20 (23.46)	TU = 1566.55*** (62.62)
Heterogeneity Effect			TH = -988.01

Note: TT=Adoption effect for adopters, TU= Adoption effect for non-adopters, TH (TT-TU) = transitional heterogeneity. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.

4.3. Parameter estimates of crop diversification and farm household Labor

An estimation result of the endogenous switching regression model for household labor is presented below in table 10. Column (2) and (3) of this table shows estimated coefficients of the outcome equation (Farm household's labor) for CD adopters and non-adopters respectively.

4.3.1. Determinants of Farm Household Labor

The other objective of this study is investigating the effect of CD on farm household's labor use. So as to address this objective an Endogenous Switching Regression model is estimated for farm household's total labor by using FIML estimation technique. In the following table (10) determinants of farm household labor are presented and discussed. For the sake of time and space the discussion is focused on significant factors only.

Age of the household head, livestock ownership, fertility of the plot, and pesticide application are found positive and significant determinants of household labor for both adopters and non adopters. As age of the household head increases the family labor use also increase however, after some point labor requirement will tends to decline. When farmers are on the age of youngsters they will cultivate many farms by share cropping, renting in and by using any other means's in addition to their own farm. This in turn put an extra burden on family labor.

In similar way, livestock ownership increases the family labor use. This is actually self evident, because livestock need its own labor for shepherding and improved food preparation. Therefore, as the farm household increases its livestock ownership its labor demand also increases.

Fertility is also the other positive and significant determinant of family labor use. High fertility is associated with high family labor use. Because large coefficient of fertility is an indicator of good plot quality, its productivity will be high and this increases the family labor in general and labor for harvesting and threshing in particular.

Climate variables are also found important determinants of family labor allocation. The effect of temperature on family labor is found non linear and significant for both adopters and non adopters. Initially farm household’s labor increases with an increase in temperature but after some point it exhibits an inverse relationship. This is because, when temperature increases farmers will take different measures to hedge from the effect of high temperature like, water conservation activities. However, when the effect of temperature becomes overwhelming, other than keep doing on their own farm, farmers will search for another nonfarm and off farm employment. Thus, there will be reduction in family labor use for the farming activity. Though it is not significant for non adopters an increase in rain fall reduces farm household’s labor use for both of the two groups. This is due to the fact that, enough rainfall can potentially reduce crop failure and enable farmers to save the time spent on water conservation activities.

Family labor use is also determined by the type of crop grown. Compared to wheat crops like, barley, sorghum and maize determine family labor allocation negatively and significantly. But *Teff* is found the only positive and significant determinant for both adopters and non adopters.

In addition to the above factors family labor use for adopters is affected by family size, off farm employment, ownership of productive farm assets, and application of organic fertilizer. Except off farm employment, the three factors become positive and significant determinants. Off farm employment has a decreasing effect on family labor significantly. Relatively farm households with off farm employment have a lower family labor requirement than their counterparts. This is because, farmers with off farm employment will share crop or rent their plot and focus on the off farm activity. Indeed, the uncertainties in the agricultural productivity coupled with the financial benefits that will be generated from off farm employment encourage farmers to do less on their farm and they will allocate low level of labor.

For non adopters plot distance and shock index are found the positive and negative significant determinants of family labor respectively. As the distance of the plot from the home stead increases the labor requirement also increases since farmers lost many of their time on going to the plot and getting back to their home. Thus, more labor is needed to compensate this big time loss. On the other hand, large number of shocks out break will reduce the family labor use. Because many number of shocks will be harmful for the harvest and it needs lower labor for collecting it.

Table 10 Determinants of Farm Household's Labor demand

Model	**Endogenous Switching Regression**			
	Wald chi2 (42) = 1054.39 Log pseudo likelihood = -8533.74 Prob> chi2 =0.0000			
Dependent Variable	Household labor for adopters of CD		Household labor for non adopters of CD	
Explanatory variables	Coefficient	Robust Std.Er.	coefficient	Robust Std.Err.
Climate Variables				
Average rainfall	-0.003*	0.001	-0.03	0.002
Average temperature	3.45***	0.47	2.58***	0.82
Rain fall square	0.002	0.002	0.00032	0.002
Temperature square	-0.08***	0.01	-0.06***	0.02
CV temperature	3.91	4.98	10.87	9.98
CV rain fall	-6.29***	0.85	-7.14***	1.46
Household Characteristics				
Age	0.01*	0.01	0.03**	0.01
Age square	-0.001	0.0001	-0.002*	0.0017
Log household size	0.10**	0.05	-0.10	0.10
Off farm employment	-0.17***	0.04	-0.03	0.07
Log VPFA	0.05***	0.01	0.01	0.02
TLU	0.03***	0.005	0.02***	0.008
Plot Characteristics				
Fertility index	0.17*	0.19	0.30*	0.16
Shock index	-0.12	0.25	-0.79*	0.43
Log plot distance	-0.01	0.01	0.04*	0.02
Organic fertilizer	0.10**	0.03	0.09	0.06
Pesticide	0.09***	0.02	0.07***	0.01
Maize	-0.30**	0.04	-0.31***	0.07
Barley	-0.47***	0.05	-0.53***	0.10
Teff	0.04	0.07	0.02	0.13
Sorghum	-0.22***	0.08	-0.56***	0.16
Sample size	**3477**		**1301**	

4.3.2. Average Expected Farm Household's Labor

By following a similar procedure like the farm income analysis the average expected farm household's labor in the actual and counterfactual case is estimated for both adopters and non adopters. This estimation helps to know specifically the treatment effect on adopters (TT), treatment effect on non adopters (Tu) and also the transitional heterogeneity (TH).

The number in the first row first cell of table 11 is the average family labor (32.85) for adopters of CD. The number in the second cell (90.67) indicates the average household labor for adopters had they been non adopter. Then the adoption effect on adopters can be found by subtracting the second from the first (-57.82***). The result is negative and significantly different from zero. This indicates that, farm household's can save 57.82 number of person days/hectare by adopting CD.

By using similar procedure the adoption effect of CD on non adopters family labor use can be calculated from the same table. In the second row first cell of table (11) we get the value of farm household's labor for non adopters in the counterfactual case, while the second cell in the same row represents the same value in the actual case. Then by taking the difference between the first and the second cell we can get farm household labor use of non adopters (-14.29***). The result shows that, Non adopter farm household's can get an advantage of family labor reduction amounted 14.29 person days per hectare if they adopt CD. This is in line with the works of Teklewold *et al (2013).*Finally the last cell in the second column gives the value for transitional heterogeneity (TH). This value is negative and significantly different from zero (-43.53) implying by adopting CD adopters are more benefited than the non adopters albeit both are beneficiaries from adoption.

Table 11 Adoption Effects of CD on family labor demand

	Decision stage		
	Adopters	Non adopters	Adoption effect
Adopters	32.85	90.67	TT= -57.82***
	(0.30)	(1.43)	(1.00)
Non Adopters	17.76	32.05	TU = -14.29***
	(0.15)	(0.51)	(0.40)
Heterogeneity Effect			TH = -43.53

Note: TT=Adoption effect for adopters, TU= Adoption effect for non-adopters, TH (TT-TU) = transitional heterogeneity. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level

4.4. Is There Synergy Or Tradeoff?

In the preceding sections of the study we have tried to discuss two main issues. First we have estimated net farm income function and discuss the effect of practicing CD as an adaptation strategy for climate change on net farm income for both adopters and non adopters. Indeed the factors that determine farm household's welfare along with the decision to adopt CD were also presented and discussed. Second by following the same procedure the effect of the considered adaptation strategy on family labor use was estimated. By using the estimated results of the family labor function, the effect of adoption on adopters and non adopters have been generated. Even though the discussions above tried to answer some of the research questions of this study, the study is also concerned about identifying the occurrence of synergy or tradeoff. Either synergy or tradeoff is expected to happen between increasing farm household's welfare by boosting productivity and the extra labor burden on the household labor use which is resulted from the adoption of Crop diversification. Therefore, in this section the results that indicate whether there is synergy or tradeoffs are discussed. In this study synergy and tradeoffs are defined as follows. Synergy will occur if crop diversification increase net farm income without adding extra labor demand on the household. On the other hand tradeoff is when crop diversification increase both farm income and family labor use.

Based up on the above common understandings, the study revealed that crop diversification not only reduces the total per hectare family labor use but also it increases net farm income. Therefore, it can be taken as a best strategy to maximize household's welfare both in terms of leisure (measured by the reduction in family labor) and net farm income.

As we can see the results in table 9 and 11, adoption of CD increase farm income by 578.54 birr per hectare for adopters and 1566.55 birr per hectare for non adopters had they been adopters. By the same taken the reduction in family labor due to adoption of CD is found 57.82 number of person days for adopters and 14.29 for non adopters had they been adopters. In both of the two cases the result indicates the double benefit of adopting crop diversification and they are statistically significant.

Therefore, the bottom line is using crop diversification as an adaptation strategy can rescue the effect of climate change. Indeed it better improves farm household's welfare by increasing their farm productivity and minimizing the total family labor use. This confirms that, crop diversification has a synergetic effect by increasing farm household's welfare through increasing net farm income and reducing family labor that can provide extra time for leisure.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The general objective of this study is to examine the effect of crop diversification on farm household's welfare. Specifically, it addresses the determinants of adopting CD, family labor use and net farm income. Synergies and trade offs are also explored. For the attainment of these objectives, the study used the 2015 survey database on 929 farm households collected in Nile Basin of Ethiopia by ECRE/EDRI. Our final analysis includes 4778 plots. In order to estimate the adoption effect on farm income along with the determinants of household net farm income and the adoption decision, simultaneous equation model which can capture the unobservable heterogeneity and selection bias was estimated. The following main conclusions can be drawn from the results of the study.

First, it was found that climate variables, household characteristics, and input market distance are the main determinants of adopting CD. The effect of both average growing season rainfall and temperature are found non linear. When temperature increases the likelihood of adoption declines up to some point but after maximum temperature the probability of adoption will decline. Off farm employment, remittance and marital status are also the key household characteristics that determine likelihood of adoption significantly. The results in crop dummy shows that, CD is mostly practiced in sorghum growing plots compared to wheat.

Second, Crop diversification is found to be adopted in plots which are located in further distance to home stead and have tenure security. Plots that are far from the home stead fails to get manure and other wastes that can serve as an organic fertilizer. Indeed farmers cannot visit continuously due to their distance problem. In the same vein, the uncertainties of losing plot in the mean time discourage farmer's adoption behavior.

Third, climate variables and institutional factors are the major determinants of net farm income for both adopters and non adopters. An increase in average temperature increases the income of both adopters and non adopters up to some point. But it will decline when temperature further increases above the maximum level. What is important here is the rate of increment and the optimal point by which the relationship turns to negative from positive is higher for adopters compared to non adopters. This is an indication for the importance of CD. In similarly words rain fall variability also highly affect negatively net farm income for both adopters and non adopters despite the extent is devastating for non adopters.

Credit constraint and land tenure are also found another positive determinants of farm income. Moreover, livestock ownership, household size and farm size determine farm household's welfare negatively and significantly for both groups. Except *Teff* all other crops are negative and significant determinants, while *Teff* is not significant for non adopters.

Fourth, for both adopters and non adopters diversifying crop can spur farm households welfare had they decided to adopt than they would if they had not adopt it. In addition, non adopters can get a largest payoff relative to adopters if both of the two groups decided to adopt.

Fifth, farm household's labor use is determined by many factors. Age of the household head, livestock ownership, and fertility of the plot are some of the key determinants and they have an increasing effect for both adopters and non adopters. Climate variables are also found positive and significant determinants. The effect of average temperature on family labor use is non linear. First labor requirement increases along with an increase in temperature up to some optimal point. But it will have a negative effect after maximum temperature. Though it is not significant for adopters an increase in average growing season rainfall reduces the total family labor use. This is because optimal amount of rain can reduce crop failure and allow farmers to save a sizable time spent on water conservation activities. Concerning the type of crop grown in the plot, *Teff* is the only crop that determines farm household's labor use positively and significantly.

Sixth, the average treatment effect of adopting CD on family labor use is also significant for both adopters and non adopters had they been adopters. By adopting diversification of crop, farmers reduce work load on their family and allowed to get extra time for leisure and other activities. In relative terms, the adopter's labor reduction is larger than the non adopters.

Finally, adoption of crop diversification has provided a double benefit for both adopters and non adopters. For both groups it can reduce family work load and increases the wellbeing of farm households at a time. More importantly, by adopting CD there is synergy than tradeoffs.

5.2. Recommendations

The findings of this study are highly essential for the effective development of policies and strategies that are aimed at the promotion and dispersal of crop diversification so as to improve the wellbeing of farm households in Nile Basin of Ethiopia. Motivated by the positive and significant results recognized by adopters, practicing CD should be advanced and encouraged for further implementation. Therefore, this study draws the following main policy implications.

- Institutional factors like, land tenure are found the most important factors which increase the likelihood of adoption. Thus, at most attention should be given by policy makers for the provision of tenure security for rural farm households. This enables them to develop confidence and sense of ownership in their land which motivates to take different sustainable land management activities and yield enhancing practices like crop diversification. Furthermore, distance to input market negatively affects the probability of adoption. Hence, alternative ways of accessing complementary inputs which are necessary for effective agriculture should be in place.
- Other than the annual total rainfall the average growing season rainfall along with its variability is the other significant factor that affects the adoption decision of farmers. Therefore, polices aimed at lessening the effect of climate change should give emphasis on the average growing season rainfall and rain fall variability.
- Farm size affects both household's welfare and the decision to adopt negatively. As farm size increases the likelihood of adoption and farmer's welfare will decline. This implies that, farm households are better productive and highly motivated to practice CD at lower farm size. Therefore, agricultural policies should invest more on mechanisms that enable farmers to be more productive in small land size. So as to augment agricultural productivity and to break the yolk of rural poverty it is binding to focus on intensification than depending on extensive farming.
- Rural farm household's welfare is highly affected by credit constraint. Even without enough access to credit, by using crop diversification farmers can improve their welfare substantially both in terms of labor reduction and farm income increment. Therefore, it is very advantageous to promote the adoption of CD in credit constrained farm households.
- Crop diversification can provide double benefit for rural farm households. On one hand, it enlarges net farm income on the other hand it reduces the family labor demand. Therefore, the current agricultural extension program should focus on the promotion and back-up of adopting CD to rescue rural farmers from the destructive effect of climate change.

- Even though both adopters and non adopters are benefited from adoption of CD, the extent of the treatment effect is not same and similar. This is an indication of the existed discrepancy between the two groups. So policy makers should take in to consideration this heterogeneity when they are attempting to advance the relevance of CD so as to unleash the full potential benefit of the practice.

REFERENCES

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. (2014). Farmers' perceptions of and adaptation strategies to climate change and their determinants; the case of Punjab province, Pakistan. *Earth System Dynamics Discussions*, *5*(2), 1359-1406.

Altieri, A., 1999. The ecological role of biodiversity in agro-ecosystems. Agriculture,

Amare, M., Asfaw, S., & Shiferaw, B. (2012). Welfare impacts of maize–pigeonpea intensification in Tanzania. *Agricultural Economics*, *43*(1), 27-43.

Arimi, K. (2014). Determinants of climate change adaptation strategies used by rice farmers in Southwestern, Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *115*(2), 91-99.

*Arndt,C., Paul, C., Sherman, Robinson, Kenneth, S. Finn,T., and James T.(2012).*Economic Development under climate change.

Asfaw, S. (2010). Estimating welfare effect of modern agricultural technologies: A micro-perspective from Tanzania and Ethiopia. *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Nairobi, Kenya*.

ATA (Agricultural Transformation Agency,) 2013/14. Transforming agriculture in Ethiopia.ATA, AddisAbaba.

Awotide, B. A., Diagne, A., & Omonona, B. T. (2012). Impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers' welfare in Nigeria: A Local Average Treatment Effect (LATE) Technique. In *African Economic Conference October*.

Benin, S. M., Smale, Gebremedhin, B., Pender, J. & Ehui, S. (2004), "The determinants of cereal crop diversity on farms in the Ethiopian Highlands", Contributed paper for the 25th International Conference of Agricultural Economists, Durban, South Africa.

Bent, G. (2008). What is Welfare? *Central European Journal of Public Policy*, *2*(1), 50-73.

Bewket W, Radeny M, and Mungai C. 2015. Agricultural Adaptation and Institutional Responses to Climate Change Vulnerability in Ethiopia. CCAFS Working Paper no. 106. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org.

Bezabih, M., Di Falco, S., & Mekonnen, A. (2014). *On the Impact of Weather Variability and Climate Change on Agriculture: Evidence from Ethiopia* (No. dp-14-15-efd).

Bhattacharyya, R. (2008). Crop diversification: a search for an alternative income of the farmers in the state of West Bengal in India. In *International Conference on Applied Economics–ICOAE* (p. 83).

Bola, A. A., Diagne, A., & Omonona, B. T. (2012). Impact of Improved Agricultural Technology Adoption on Sustainable Rice Productivity and Rural Farmers' Welfare in Nigeria: A Local Average Treatment Effect (LATE) Technique.

Bourguignon, F., Fournier, M., Gurgand,M., 2007. Selection bias corrections based on themultinomial logit model: Monte-Carlo comparisons. Journal of Economic Surveys 21,174–205.

Bradshaw B., H. Dolan, and B. Smit. (2004). "Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies": *Climatic Change*, 67: 119–141

Christiaan, G. (1982). *The conceptual basis of measures of household welfare and their implied survey data requirements* (No. 19). Development Research Dept., World Bank.

Cooper, J., & Dobson, H. (2008). The benefits of pesticides to mankind and the environment. *Crop Protection*, *26*(9), 1337-1348.

CSA (2009). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey 2009/2010 (2002 E.C.) (September – December, 2009) volume IV report on land utilization (private peasant holdings, Meher season).

Dahl, G. B. (2002) Mobility and the returns to education: testing a Roy Model with multiple markets. *Econometrica* 70: 2367–2420.

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(01), 23-31.

Deressa, T. T., R. M. Hassan, C. Ringler, T. Alemu, and M. Yesuf (2009). "Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia": *Global Environmental Change*, 19(2):248-255.

Deressa, T., 2007. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. World Bank Policy Research Paper No. 4342. World Bank, Washington, DC.

Deressa, T., R. Hassen, T. Alemu, M. Yesuf, and C. Ringler (2008), Analyzing the determinants of farmers choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethiopia'. International Food Policy Research Institute (IFPRI) Discussion Paper No. 00798, Washington, D.C.

Di Falco, S., Bezabih, M., Yesuf, M., 2010. Seeds for livelihood: crop biodiversity and food production in Ethiopia. Ecological Economics 69, 1695–1702.

Di Falco, S., Marcella Veronesi and Mahmud Yesuf, (2011). "Does Adaptation to Climate Change Provide Food Security? Micro Evidence from Ethiopia" *American Journal of Agricultural Economics* 93 (3):829-846.

Dubin, J and McFadden, D, (1984). "An econometric analysis of residential electric appliance holdings and consumption": *Econometrica* 52, 345–62.

Eid, H. M., El-Marsafawy, S. M., & Ouda, S. A. (2007). Assessing the economic impacts of climate change on agriculture in Egypt: a Ricardian approach. *World Bank Policy Research Working Paper*, (4293).

El-Shater, T., Yigezu, Y. A., Mugera, A., Piggin, C., Haddad, A., Khalil, Y., ... & Aw-Hassan, A. (2016). Does Zero Tillage Improve the Livelihoods of Smallholder Cropping Farmers?. *Journal of Agricultural Economics*, *67*(1), 154-172.

Ferede, T.,& Hailu, E. (2014). Credit constraints, Adaptation to Climate Change and Agricultural Productivity: Panel data evidence from Rural Ethiopia

Fetien A., Asmund B. & Melinda S. (2009), "Measuring on Farm Diversity and Determinants of Barely

Food Systems Resilience in Sub-Saharan Africa. FAO, Rome.

Heckman, J. J. (1979). Sample selection bias as a specification error (with an application to the estimation of labor supply functions).

Idowu, A., Ambali, O., and Onasanya, A. (2014). Living Condition, Livelihood and Crop Diversification among Rural Farm Households in Remo Division of Ogun State Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology.*

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. Summary for Policy Makers. World Meteorological Organization, Geneva.

IPCC, (2007). Fourth Assessment Report, Climate Change 2007 (AR4).

IPCC, (Intergovernmental Panel on Climate Change), 2014. Climate change 2014, impacts, adaptation and vulnerability. summary for policy makers

Jawahar, P. and S. Msangi. (2006). BMZ workshop summary report on Adaptation to Climate Change, April 24-28, 2006. Pretoria, South Africa, Pretoria,

Jhamtani, H., 2011. The green revolution in Asia: lessons for Africa. Climate Change and Food Systems Resilience in Sub-Saharan Africa. FAO, Rome.

Kabubo-Mariara, J., & Karanja, F. K. (2007). The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. *Global and Planetary Change*, *57*(3), 319-330.

Kabubo-Mariara, J., Linderhof, V., Kruseman, G., Atieno, R., & Mwabu, G. (2009). Household welfare, investment in soil and water conservation and tenure security: Evidence from Kenya. *Investment in Soil and Water Conservation and Tenure Security: Evidence from Kenya (December 22, 2009)*.

Kabubo-Mariaraa, J., Linderhofb, V., Krusemanc, G., Atienod, R., & Mwabue, G. (2006). Household Welfare, Investment in Soil and Water Conservation and Tenure Security: Evidence From Kenya.

Kassie, M., Hailemariam, T., Paswel, M., Moti, J. and Olaf E. (2014). "Production Risks and Food Security under Alternative Technology Choices in Malawi": Application of a Multinomial Endogenous Switching Regression: *Journal of Agricultural Economics.*

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., Mekuria, M., 2012. Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. Technological Forecast and Social Change. http://dx.doi.org/ 10.1016/j.techfore.2012.08.007

Kassie, M., Shiferaw, B., & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, *39*(10), 1784-1795.

Khanna, M., 2001. Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. American Journal of Agricultural Economics 83, 35–51.

Köhlin, G., & Amacher, G. S. (2005). Welfare implications of community forest plantations in developing countries: The Orissa Social Forestry Project. *American Journal of Agricultural Economics, 87*(4), 855-869.

Kuntashula, E., Chabala, L. M., & Mulenga, B. P. (2014). Impact of minimum tillage and crop rotation as climate change adaptation strategies on farmer welfare in smallholder farming systems of Zambia. *Journal of Sustainable Development*, *7*(4), 95.

Kuntashula, E., Chabala, L. M., & Mulenga, B. P. (2014). Impact of minimum tillage and crop rotation as climate change adaptation strategies on farmer welfare in smallholder farming systems of Zambia. *Journal of Sustainable Development, 7*(4), 95.

Kurukulasuriya, P. and R. Mendelsohn. (2006). Crop Selection: Adapting to Climate Change in Africa,

Lee, L.F., and R.P. Trost. (1978). "Estimation of Some Limited Dependent Variable Models with Application to Housing Demand": *Journal of Econometrics* 8:357-382.

Liebman, M., Dyck, E., 1993. Crop rotation and intercropping strategies for weed management.

Lin, B. B. (2011). Resilience in agriculture through crop diversification: adaptive management for environmental change. *BioScience, 61*(3), 183-193.

Luke, Olarinde, L. O., Adepoju, A. A., & Jabaru, M. O. (2014, April). Climate Change, farm level adaption measures and Impacts on Crop productivity and market participation: Implications for sustainable synergy between African and European Agriculture. In *presentation at the 88th Annual Conference of the Agricultural Economics Society, AgroParisTech, Paris, France* (pp. 9-11).

Maddala, G.S. (1983). Limited Dependent and Qualitative Variables in Econometrics. Cambridge, U.K.: Cambridge University Press.

Maddala, G.S., and F.D. Nelson. (1975). Switching Regression Models with Exogenous and Endogenous Switching, Proceeding of the American Statistical Association (Business and Economics Section), pp. 423-426.

Madina, G., 2014. Analysis of adaptation to climate variability and change in Uganda: a gender and household welfare perspective. University of Dare Salaam

Mendelsohn R, Dinar A & Dalfelt A, 2000. Climate change impacts on African agriculture.http://www.ceepa.co.za/Climate_Change/pdf/(5-22-01)afrbckgrnd-impact.pdf

Mesfin, W., Fufa, B., & Haji, J. (2011). Pattern, trend and determinants of crop diversification: empirical evidence from smallholders in eastern Ethiopia. *Journal of Economics and Sustainable Development*, *2*(8), 78-89.

Mikémina, P. 2013 Climate change impact on Togo's agricultural performance: A ricardian analysis based on time series data. *Ethiopian Journal of Environmental Studies and Management Vol. 6 No.4 2013*

mitigate climate change in sub-Saharan Africa. Resource guide version 1. http://

Moser, C. M., & Barrett, C. B. (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. *Agricultural Systems*, *76*(3), 1085-1100.

Moser, C. M., & Barrett, C. B. (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. *Agricultural Systems*, *76*(3), 1085-1100.

MoWR (Ministry of Water Resources), 1998. Tekeze River Basin Integrated Development Master Plan Project. Executive Summary, Federal Democratic Republic of Ethiopia MoWR (Ministry of Water Resources), Addis Ababa.

Msoo A. Akaakohol & Goodness C. Aye (2014) Diversification and farm household welfare in Makurdi, Benue State, Nigeria, Development Studies Research, 1:1,

Mulatu, D. W., Eshete, Z. S., & Gatiso, T. G. Emissions Impact on Agriculture Productivity and Household Welfare in Ethiopia: Computable General Equilibrium Analysis.

Nabikolo, D., Bashaasha, B., Mangheni, M. N., & Majaliwa, J. G. M. (2012). Determinants of climate change adaptation among male and female headed farm households in eastern Uganda. *African Crop Science Journal*, *20*(2), 203-212.

Ndambiri, Hilary K., Cecilia N. Ritho, and Stephen G. Mbogoh. "An evaluation of farmers' perceptions of and adaptation to the effects of climate change in Kenya." *Int. J. Food Agric. Econ* 1, no. 1 (2013): 75-96.

Negash, M., & Swinnen, J. F. (2013). Biofuels and food security: micro-evidence from Ethiopia. *Energy Policy*, *61*, 963-976.

Nhemachena, C., and Hassan, H. (2007). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D. C.

Nhemachena, C., and Hassan, H. (2008). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D. C.

Oyekale, A. S., & Oladele, O. I. (2012). Determinants of climate change adaptation among cocoa farmers in southwest Nigeria. *ARPN Journal of Science and Technology*, *2*(1), 154-168.

Pycroft, J. The Adoption and Productivity of Modern Agricultural Technologies in the Ethiopian Highlands: A cross-sectional analysis of maize production in the West Gojam zone.

Rahman, S. (2009). Whether crop diversification is a desired strategy for agricultural growth in Bangladesh?. *Food Policy*, *34*(4), 340-349.

Rehima, M., Belay, K., Dawit, A., & Rashid, S. (2013). Factors affecting farmers' crops diversification: Evidence from SNNPR, Ethiopia. *International Journal of Agricultural Sciences*, *3*(6), 558-565.

Mekong River Commission (MRC), 2010.*Review of climate change adaptation methods and tools*.

Rockström, J., Kaumbutho, P., Mwalley, J., Nzabi, A. W., Temesgen, M., Mawenya, L., ... & Damgaard-Larsen, S. (2009). Conservation farming strategies in East and Southern Africa: yields and rain water productivity from on-farm action research. *Soil and Tillage Research*, *103*(1), 23-32.

Roy, A. (1951). Some Thoughts on the Distribution of Earnings. Oxford Economic Papers. 3:135-145.

Seaman, J. A., Sawdon, G. E., Acidri, J., & Petty, C. (2014). The Household Economy Approach. Managing the impact of climate change on poverty and food security in developing countries. *Climate Risk Management*, *4*, 59-68.

Sherman,R., Willenbockel, o., Kenneth,S. (2012) A Dynamic General Equilibrium Analysis of Adaptation to Climate Change in Ethiopiarode_676 489..

Sichoongwe, K., Mapemba, L., Ng'ong'ola, D., & Tembo, G. (2014). *The determinants and extent of crop diversification among smallholder farmers: A case study of Southern Province, Zambia* (Vol. 5). International Food Policy Research Institute.

Sukallya, Kasem,., & Thapa, G. B. (2011). Crop diversification in Thailand: Status, determinants, and effects on income and use of inputs. *Land Use Policy*, *28*(3), 618-628.

Teklewold, H., Kassie, M. and Shiferaw, B. (2013). "Adoption of multiple sustainable agricultural practices in rural Ethiopia": *Journal of Agricultural Economics*, 64(3): 597–623.

Temesgen D, Claudia,R., Mahmud, Y., Rashid. M, and Tekie, A. (2008). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI. Discussion Paper No 00798 Washington, DC.

Temesgen, T., 2007. Measuring the Economic Impact of Climate Change on Ethiopian Agriculture. The World Bank Development Research Group

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability

Tsegaye, G. (2014). *Impacts of Climate Change, Variability and Adaptation Strategies on Household Food Security in Southern Ethiopia* (AAU).

United Nation. (2007). Climate Change an Overview Paper prepared by the Secretariat of the United Nations Permanent Forum on Indigenous Issues.

Wahba, G. .1990. *Spline Models for Observational Data*. Philadelphia: Society for Industrial and Applied Mathematics.

WB (World Bank), 2003. Africa rainfall and temperature evaluation system (ARTES), Washington DC.

WB (World Bank), 2013. Analyzing the World Bank's Goal of Achieving "Shared Prosperity"

Williams, R. 1976. *Keywords: A Vocabulary of Culture and Society.* Glasgow: Fontana

Winship, C., Mare, R. D., & Long, J. S. (1988). Endogenous switching regression models for the causes and effects of discrete variables. *Common problems in quantitative social research*.

Woodfine, A., 2009. Using sustainable land management practices to adapt to and mitigate climate change in sub-Saharan Africa. Resource guide version 1.

World Bank. (2005).Introduction to Poverty Analysis.

Wu, J.J., Babcock, B.A., 1998. The choice of tillage, rotation, and soil testing practices: economic and environmental implications. American Journal of Agricultural Economics80, 494–511.

www.caadp.net/pdf/Using%20SLM%20Practices%20to%20Adapt%20and%20Mitigate%

Yibekal, Tessema, Chanyalew, Aweke and Getachew. 2013. Understanding the process of adaptation to Climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia

Zeleke, Menberu Teshome, and Yohannes Aberra. "Determinants of the Adoption of Land Management Strategies against Climate Change in Northwest Ethiopia." *Ethiopian Renaissance Journal of Social Sciences and the Humanities* 1.1 (2014).

Zentner, R. P., Lafond, G. P., Derksen, D. A., & Campbell, C. A. (2002). Tillage method and crop diversification: effect on economic returns and riskiness of cropping systems in a Thin Black Chernozem of the Canadian Prairies. *Soil and tillage research*, *67*(1), 9-21.

APPENDICES

A1 Descriptive Statistics

Variable		Adopters		Non Adopters		Total Sample	
		Mean	Std.Dev.	Mean	Std. Dev.	Mean	Std.Dev.
Gender		0.88	0.31	0.87	0.33	0.65	0.47
Age		52.34	12.81	50.59	12.69	51.87	12.8
Marital status		0.83	0.36	0.81	0.38	0.61	0.48
Education		1.65	2.85	2.06	3.13	1.76	2.93
Remittance		0.12	0.32	0.12	0.33	0.09	0.29
Off farm employment		0.18	0.39	0.22	0.41	0.14	0.35
household size		2.07	0.31	2.03	0.3	2.06	0.31
Age square		2904	1414	2721	1381	2854	1407
log Farm size		0.49	0.63	0.5	0.68	0.49	0.64
Pesticide		0.12	0.65	0.1	0.69	0.11	0.66
log (Productive farm asset)		9.43	1.37	9.38	1.43	9.42	1.38
Tropical Livestock Unit		4.92	3.5	4.63	3.69	4.84	3.55
Credit		0.43	0.49	0.44	0.49	0.44	0.49
Support		0.07	0.26	0.08	0.28	0.08	0.27
Organic fertilizer		0.29	0.45	0.3	0.46	0.29	0.45
Media Information		0.19	0.59	0.26	0.67	0.21	0.61
Government extension		1.65	1.49	1.65	1.49	1.65	1.49
Slope	Flat	0.60		0.61		0.60	
	Medium	0.36		0.34		0.39	
	Steep	0.04		0.05		0.01	
Fertility	Low	0.12		0.11		0.14	

Medium	0.50		0.49		0.53	
High	0.37		0.39		0.33	
Shock index	0.1	0.06	0.1	0.06	0.1	0.06
Log (Plot Distance)	1.92	1.43	1.74	1.43	1.87	1.43
Log (Input market distance)	2.33	0.12	2.33	0.12	2.33	0.12
Land Tenure	0.87	0.33	0.8	0.39	0.85	0.35
Maize	0.45	0.49	0.62	0.48	0.5	0.5
Barley	0.13	0.33	0.09	0.28	0.12	0.32
Sorghum	0.05	0.22	0.03	0.17	0.04	0.21
Teff	0.59	0.49	0.72	0.44	0.63	0.48
Wheat	0.16	0.36	0.09	0.29	0.14	0.35
Average monthly temperature (oc)	19.92	2.58	20.02	2.55	19.95	2.58
Average growing season rainfall (mm)	19232	9596	22352	10507	20081	9949
Average Monthly Temperature square	403	108.5	407	108	404	108
Average growing season rainfall (mm)	681	230	753	233	701	233
Rain fall coefficient of variation	0.56	0.23	0.48	0.23	0.54	0.23
Temperature coefficient of variation	0.1	0.02	0.09	0.02	0.1	0.02
Tigray	0.17	0.38	0.11	0.32	0.16	0.36
Amhara	0.42	0.49	0.35	0.47	0.4	0.49
SNNP	0.06	0.24	0.04	0.21	0.06	0.23
Benshangul-Gumuz	0.11	0.31	0.12	0.32	0.11	0.32

Oromia	0.21	0.41	0.35	0.48	0.25	0.43

A2 Instruments Test

Instrumental variables	Model 1		Model 2	
	Adoption of CD 1/0		Net Farm income for Adopters	
	Coefficient	Robust Std.Err.	Coefficient	Robust Std.Err
Media Information	-0.13***	0.03	-0.01	0.03
Government extension	-0.02	0.01	0.01	0.15
Log input market distance	-0.29**	0.01	0.03	0.16
Test on instruments	Chi2 (3)*** = 15.89		F(3,1249) = 0.82	
Sample size	3477		4778	

Note: Model 1: Probit model; Model 2: ordinary least squares. Estimation at the plot level with zonal dummy. * Significant at the 10% level; ** Significant at 5%level; *** Significant at 1% level.

Declaration

I hereby declare that this thesis is my own work and has never been presented in any other university or I have not plagiarized in the preparation of this assignment and have not allowed anyone to copy my work. All sources of materials used for this thesis has been properly acknowledged.

Declared by:

Name: Fissha Asmare Marye

Signature: ____________________________

Date: 09/06/2016

As thesis advisor, I hereby confirm that this thesis is the output of research undertaken by Fissha Asmare Marye under my supervision and that it be submitted for the M.Sc. degree award.

Confirmed by Advisor: **Hailemariam Teklewold (PhD)**

Signature: ____________________________

Date: 09/06/2016

Addis Ababa University

Addis Ababa, Ethiopia