Dissertation

By

ASSEFA, Kalkidan

Haramaya University

Sources of risk and impact of climate change adaptation strategy on crop production: the case of soil and water conservation in Wolaita, Southern

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SOURCES OF RISK AND IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGY ON CROP PRODUCTION: THE CASE OF SOIL AND WATER CONSERVATION IN WOLAITA, SOUTHERN HIGHLANDS OF ETHIOPIA

M.Sc. Thesis

By

Kalkidan Assefa

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SOURCES OF RISK AND IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGY ON CROP PRODUCTION: THE CASE OF SOIL AND WATER CONSERVATION IN WOLAITA, SOUTHERN HIGHLANDS OF ETHIOPIA

A thesis Submitted to the College of Agriculture and Environmental Sciences of the
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MASTERS OF SCIENCE IN AGRICULTURE (AGRICULTURAL ECONOMICS)

By
Kalkidan Assefa

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HARAMAYA UNIVERSITY

As Thesis research advisors, we hereby certify that we have read and evaluated this Thesis prepared, under our guidance, by: Kalkidan Assefa, entitled:

> Sources of Risk and Impact of Climate Change Adaptation Strategies on Crop Production: The case of Soil Water Conservation in Wolaita, Southern Highlands of Ethiopia.

We recommend that is be submitted as fulfilling the Thesis requirement.

Dr. Million Tadesse	____________________	________________
Major Advisor	Signature	Date
Dr. Bekele Hundie	___________________	________________
Co-Advisor	Signature	Date

As members of the Board of Examiners of the Final MSc. Thesis Open Defense Examination, we certify that we have read, and evaluated the thesis prepared by: Kalkidan Assefa and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the degree of MSc in Agricultural Economics.

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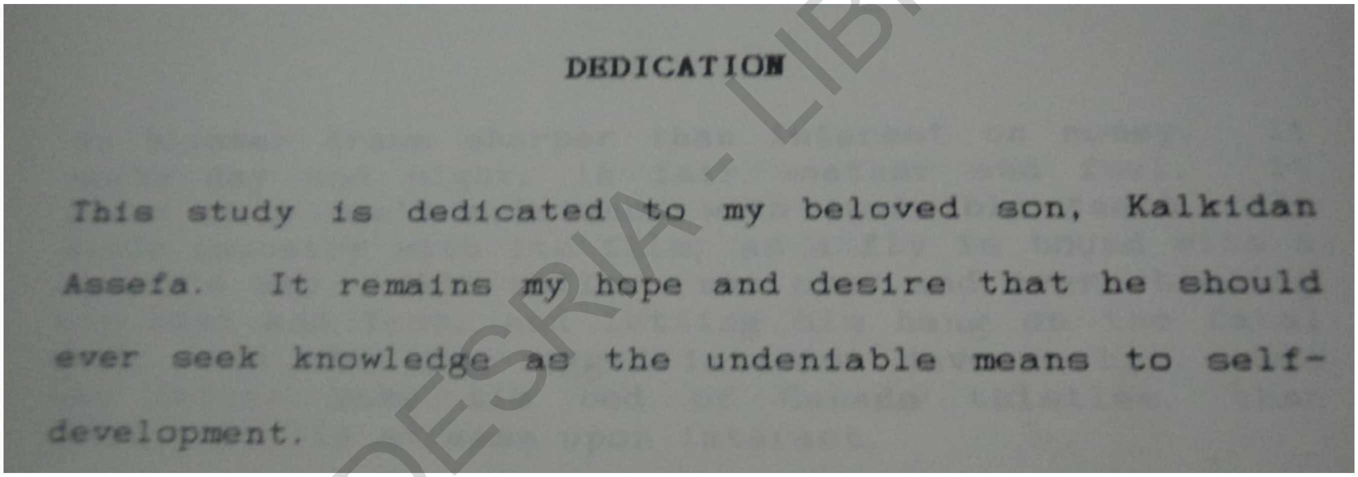
DEDICATION

I dedicate this thesis manuscript in loving memory of my late father, Assefa Kebede, who dedicated his thesis manuscript some 27 years ago and showed me to seek knowledge as undeniable means for self development. It is also my desire to forward the message transferred on to me to my coming children.



DEDICATION

This study is dedicated to my beloved son, Kalkidan Assefa. It remains my hope and desire that he should ever seek knowledge as the undeniable means to self-development.

Source: Assefa, 1986

STATEMENT OF AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced MSc degree at the Haramaya University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ACRONYMS AND ABBREVIATIONS

CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
CA	Conservation Agriculture
DFID	Department for International Development
GHG	Green House Gas
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FIML	Full Information Maximum Likelihood
FGD	Focus Group Discussions
GDP	Growth Domestic Product
HDI	Human Development Index
HH	Household
IWMI	International Water Management Institute
IDS	Institute of Development Studies
IPCC	Intergovernmental Panel on Climate Change
MoFED	Ministry of Finance and Economic Development
NGO's	Non Governmental Organizations
NMSA	National Meteorological Services Agency
PSNP	Productive Safety Net Program
SIDA	Swedish International Development Cooperation Agency
SNNPR	Southern Nation Nationalities and Peoples Region
SPSS	Statistical Package for Social Science
STATA	Statistical Software Package by STATA Corporation
SWC	Soil and Water Conservation
TLU	Tropical Livestock Units
UMB	Norwegian University of Life Sciences
UNDP	United Nations Development Program

ACRONYMS AND ABBREVIATIONS *(continued)*

UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor
WMO	World Metrological Organization
WoARD	Woreda Agricultural and Rural Development Office

BIOGRAPHIICAL SKECH

The author was born on April 27, 1983 in Meki town, East Shewa Zone of the Oromia Region. He attended his elementary and Junior Secondary educations at Kidane Meheret Catholic Elementary School, and attended his secondary education at Lideta Catholic Cathedral School, Addis Ababa. Upon completion of his high school studies, he joined Mekelle University in 2002/2003 for his BSc degree and graduated with BSc degree in Natural Resource Economics and Management on July 2006. Right after his graduation, the author was employed in International Water Management Institute (IWMI) as Research Assistant and worked for two years and International Livestock Research Institute (ILRI) and Save the Children (SC-UK) for short periods. Then after he joined Ethiopian Institute of Agricultural Research, Assosa Center (EIAR-ASARC) as Junior Socioeconomics Researcher and has served for about 3 years. After having five years of work experience in different institutions, he joined the School of Graduate Studies of Haramaya University for his MSc degree, Agricultural Economics in October, 2010.

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ABSTRACT

Climate change is the most important risk affecting agricultural production in Ethiopia. Farmers have adapted different copping and/or adaptation strategies to climate change. A better understanding of climate change induced agricultural production risks, farmers' perceptions of climate change, ongoing adaptation measures, and their decision making process is essential in the adaptive policy formulation process. In line with this, using three period panel data for 2005, 2007 and 2011years from survey of 204 farm households in four kebeles of Wolaita, SNNPR, this study presents the different sources of risks, the adaptation strategies used by farmers, the determinant factors influencing the decision to adopt SWC structures and analyze the impact of SWC adoption on farmers production using Endogenous Switching Regression Models. About 79 % of the farmers perceived that there was climate change in terms of rainfall shortage and increase in temperature in the last six years compared to the previous times. This was also confirmed by the values of the meteorological station data collected for 60 years in the study area. In response farmers in the study site have undertaken adaptation strategies such as Soil and Water Conservation, crop diversification (multiple cropping), fertilizer application, improved variety usage and changing planting dates. Household Fixed Effect Switching Regression model was used to see the determinant factors affecting the choice of SWC adaptation, the impact of SWC adoption on crop production and observe the temporal and cross sectional variability between SWC adopter and non adopter groups. According to the first stage of the model result, labour in man days, household size, extension contact on SWC, livestock holding in TLU, plot slope being mid hill have positive and significant impact on choice of SWC adaptation to climate change. Variables such as education level, farming experience, average annual rainfall, plot ownership, soil type being dark brown, plot slope being steep, erosion susceptibility, and no soil degradation have negative and significant impact on SWC adoption decision. The second stage model result indicates that there is positive and statistically significant difference in terms of production in value terms between SWC adopters and non adopters. Plots with SWC structures tend to produce about 1060 birr per ha more to 3979 birr per ha in production than plots which did not have such structures. Moreover, they also differ in terms of major household characteristics, and conventional input usage. This study concludes that climate change is the major source of risk affecting crop production negatively and adoption of SWC adaptation strategies to climate change have significant impact on crop production to farm households in the study area.

1. INTRODUCTION

1.1. Background

Climate change is rapidly emerging as one of the most serious threats that humanity may ever face (IPCC, 2010). And it has recently become a pressing issue in various development, environment and political forums at the national, regional and international levels. Many regional summits worldwide have dedicated discussion sessions on climate change based on the recognition that the global climate is changing and this has become more evident in recent years. Although no country is immune from the potential impacts of climate change, the impacts are highly significant in developing countries who have contributed least to greenhouse gas emissions (IPCC, 2010). These countries have limited adaptive capacity as compared to the developed countries because of their limited financial resources, skills and technologies, high levels of poverty, and their excessive reliance on climate sensitive economic sectors such as agriculture (Reid and Huq, 2007).

Agricultural production in Africa is also adversely affected by climate change (Haile, 2005). It is widely recognized that climate variability and the occurrence of extreme weather conditions are among the major risk factors affecting agricultural production and food security in Africa and especially in Sub-Saharan Africa (SSA). In the region, the rainfall pattern is influenced by large-scale inter-seasonal and inter-annual variability resulting in frequent extreme weather events such as droughts (Haile, 2005). According to projection by IPCC in the coming decades with climate change, rainfall variability and extreme climatic events are expected to adversely affect agricultural production and food security (Christensen *et al.,* 2007). By 2020 yields from Africa's rainfed crop production could decrease by 50% as a result of changes in climatic conditions (Boko *et al.,* 2007).

Ethiopia is one of the world vulnerable countries to climate variability and change (Aklilu and Alebachew, 2008; FDRE, 2011). Vulnerability and poverty mapping in Africa put Ethiopia as one of the country's most vulnerable to climate change with the least capacity to respond (Orindi *et al.,* 2006; Stige *et al.,* 2006). Over the past several decades, the country has been hit by repeated droughts, famine and epidemics that relate to changing climatic condition. Ethiopia has already suffered from extremes of climate, manifested in the form of frequent drought in 1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, and 2002 and recent flooding in 1997 and 2006 (Mahmud *et.al.*, 2008).

The Ethiopian economy is supported by its agricultural sector, which is also a fundamental instrument for poverty alleviation, food security, and economic growth. However, the sector continues to be undermined by land degradation (depletion of soil organic matter, soil erosion, and lack of adequate plant-nutrient supply), population pressure, and low agricultural production (Grepperud, 1996; Pender *et al.*, 2006; Pender and Birhanu, 2007). There is, plenty of evidence that these problems are getting worse in many parts of the country, particularly in the highlands. Furthermore, climate change is anticipated to accelerate the land degradation in Ethiopia (Pender *et al.*, 2006).

According to Di Falco *et.al.*, (2011) since future global warming will be inevitable, climate change adaptation will be the best alternative for a country like Ethiopia. Adaptation helps farmers achieve their food, income, and livelihood security objectives in the face of changing climatic and socioeconomic conditions, including climate variability, extreme weather conditions such as drought and floods, and unpredictable short-term changes in local and large-scale markets. And promotion of soil and water conservation (SWC) technologies has been suggested as a key adaptation strategy for countries in the developing world, particularly in sub-Saharan Africa to mitigate growing water shortages, worsening soil conditions, and drought and desertification (Kurukulasuriya and Rosenthal, 2003).

Different soil and water conservation structures are promoted to increase yield, reduce yield variability and also to produce mitigation benefits. Understanding and analyzing their impacts is important to identify appropriate agricultural practices that can act as adaptation strategies as part of an effort to promote adaptation to climate change at the farm level. This paper tries to study the different sources of risk, the factors affecting the choice of SWC adaptation strategies to climate change, and the impact of SWC adoption on crop production.

1.2. Statement of the Problem

Ethiopia is one of the least developed countries in the world, with a gross domestic product (GDP) of US$ 31.71billion and a population of 84.73 million (MoFED, 2010; NBE, 2011). At present, agriculture dominates the Ethiopian economy, accounting for nearly half of GDP and for the vast majority of employment. However, owing to natural and man-made causes the country has not properly benefited from its abundant natural resources conducive to agricultural development, and consequently failed to register the desired economic development that would enable its people pull out of poverty. The major impediments to agricultural development are the predominance of subsistence agriculture and lack of more business/market-oriented agriculture; adverse climatic changes; failure to use agricultural land according to appropriate land use management plan and resource base; limitation in information base; lack of supply and dissemination of appropriate technology; failure to integrate relevant activities; and lack of adequate implementation capacity (MoFED, 2006).

Agricultural production in Southern Nations Nationalities and Peoples Region (SNNPR) in general and Wolaita in particular; is low due to low use of improved agricultural inputs, erratic rainfall, decreasing soil fertility, climate variability, environmental degradation, shortage of land and land fragmentation caused by increased population (Endrias, 2003, Million and Belay, 2004). Moreover, agricultural production becomes highly risky due to adversely changing environmental conditions and erratic nature. Weather change, price fluctuations, diseases and pest outbreak also make smallholder production risky. Because of the many risks households face, they often experience shocks leading to a wide variability in their yield and income.

The study area Wolaita; is well known for its high population density. Due to population growth farm holding is getting progressively smaller and smaller and even subsistence level production becomes unsustainable. According to Bush (2002) major events of widespread hunger have occurred with increasing frequency in 1984, 1994, and 1999/2000 and chronic poverty is well-established feature of rural life in Wolaita. During times of food stress, the term *"Green Famine"* is often used to describe the situation (UNDP, 2000).

Due to the above facts, smallholder farmers have developed many traditional as well as modern risk adaptation strategies that can help to address the limitations to production. Use of new crop varieties, crop diversification, dependency on mixed crop livestock farming system, adoption of soil conservation measures, planting of trees, changing planting dates are some of the adaptation strategies used to improve their production. However, little information is available on how climate change induced adaptation strategies affect farm household's crop production. Furthermore, very few and area specific studies have been conducted to understand about household sources of risk associated with climate change, determinant factors of farmer's climate change adaptation strategies and the impact of the decision of adaptation strategies on crop production in Ethiopia.

For instance, Temesgen *et al.*, (2008) have conducted an integrated quantitative vulnerability assessment for SNNPR (where Wolaita is located) and according to his finding, although the SNNPR was found to be less vulnerable compared to the other seven regional states in Ethiopia, the area was one of the vulnerable regions to climate change impacts out of seven regional states. The authors have acknowledged that their data were highly aggregated. The researcher of this study also believes that aggregate information for SNNPR may not represent the situation in Wolaita. Therefore, further study is needed at local levels, particularly at district levels, one of the gaps this study is aimed at filling.

Hence, understanding the sources of risk and analyzing adaptation strategies is therefore important for shaping agricultural policy choices and finding ways to help farmers adapt in the rural economies. Therefore, the following research questions were elicited to better approach the research questions indicated above.

i. What are the major sources of risk to crop production?
ii. Do farmers perceive climate change have occurred and if so have they begun to adapt?
iii. What are the major climate change adaptation strategies implemented by the households?
iv. What factors determine the adoption of SWC measures as an adaptation strategy for climate change?
v. Are farm households who adopt SWC measures as an adaptation strategy better off in terms of crop production?

1.3. Objective of the Study

The major objective of this thesis is to identify the sources of risks and the impact of SWC adaptation strategy that farmers use on crop production. The specific objectives include:

1. to assess the different sources of risks in the face of changing climate;
2. to analyze the determinants of households choice of SWC adaptation to climate change and
3. to evaluate the impact of SWC adoption on crop income.

1.4. Significance of the Study

Carrying out such empirical research obviously has both basic (academic) and applied (practical) purposes. Academically, since literature concerning agricultural production risk and climate change adaptation is scarce in the study area and in Ethiopia, the finding of the study is expected to contribute towards bridging the existing gap in understanding the sources of risks, determinants of SWC adaptation strategy and impact of SWC adaptation strategies on crop production. With the practical purpose, the empirical findings can be utilized by development partners like extension agent, NGOs, research organizations, planners, policy makers and other development agencies for the formulation of new sound policies and strategies. More specifically, the result of this study will add to the existing body of knowledge (literature) on climate change induced risks and impact of SWC adaptation on crop production that has been less researched in Ethiopia and the study area in particular.

Previous climate change impact and adaptation studies mainly used cross-sectional data. This is mainly due to the high costs of data collection. So that many risk and climate change related researches adopted an approach that enables the use of cross-section data sets to measure impact of adaptation strategies by strongly assuming temporal variation to be explained by cross-sectional variations (assessed the problem of climate change at one point in time while its impact will require longitudinal data). The present study addresses the impact of SWC adoption on crop production and dynamics of climate change using panel data set and climate variables (rainfall and temperature) for the last 6o year.

1.5. Scope and Limitations of the Study

The scope of this study is restricted to Damot Sore Woreda of Wolaita Zone, SNNPR. This study used a panel data set collected in 2005, 2007 and 2011 from a sample of 204 households living in four *kebele's* of Damot Sore woreda. The study is limited to identify the sources of risks, determinants of choice of SWC adaptation and impact of SWC adoption on crop production.

Three important limitations are inherent in this study. First, it is impossible to deal with every sources of risk all at once. Risk may arise in yields, costs, prices, health, and resources. In this study, the major risks that are related to household crop production are considered. Second, it is expected that a risk-averse farm household in Ethiopia particularly in the study area could be engaged in production of different types of crops per a given plot. One important limitation of this study is that it lumps all crops per a given plot into one category in value terms (plot production per hectare in birr). It is known that different crop types are affected differently by climate change, hence the need for further disaggregation. While this disaggregated selection of crop types was beyond the scope of this study, making analysis for each crop type will be necessary as a second step to conduct more crop specific analysis. The third limitation of this research is the consideration of the impact of one specific adaptation strategy, SWC; among the many adaptation practices in the study area. The researcher strongly believes that, in order to capture the whole picture of climate change and impact of SWC adaptation choice of farmers on their crop production, it is necessary to observe the impact of different adaptation strategies employed by farmers differently. Therefore, the result of this study will be interpreted in light of these limitations.

1.6. Organization of the Thesis

The remaining part of the thesis is divided in to five parts. Section two discusses the literature on terms and definitions of concepts and different research findings. The third section describes the data, the study area, and the method of analysis employed. Results and discussion are presented in section four. In last section, conclusion and policy implications are presented.

2. LITRATURE REVIEW

This chapter comprises definition and concepts of risk, vulnerability and climate change adaptations. Moreover, empirical studies on risk, determinants of household's choice of adaptation strategies and impact of climate change adaptation strategies on crop production are discussed.

2.1. Definition and Concepts

The analysis of various definitions of the key terms and concepts demonstrates that definitions vary across institutions and different groups of stakeholders. And there could be many definitions and concepts given in different literatures for the same terms but this thesis tries to look the most frequent and working definitions of the key terms.

Climate change: The climate of a place or region is changed if over an extended period (typically decades or longer) if there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use. Note that the definition of climate change used in the United Nations Framework Convention on Climate Change is more restricted, as it includes only those changes which are attributable directly or indirectly to human activity (UN/ISDR, 2004).

Climate is simply the weather that is dominant or normal in a particular region; the term climate includes temperature, rainfall and wind patterns. Geography, global air and sea currents, tree cover, global temperatures and other factors influence the climate of an area, which causes the local weather. The world's climate has always been changing between hotter and cooler periods due to various factors. However, for the first time in the earth's history it has now been firmly established that its human inhabitants are altering the climate through global warming as a result of greenhouse gas emissions. Although the basic science is now clear, the full range of effects due to human influenced climate change is still not fully understood (Pender, 2010).

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extreme.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC TAR, 2001 a).

Greenhouse effect: The Greenhouse Effect is a natural process through which various gasses and water vapor in the atmosphere affects the earth's climate. It is so named because it acts like a glass greenhouse for plants by preventing the incoming heat from the sun from leaving causing warming of the earth just as the inside of a greenhouse warms. The Greenhouse Effect can also be likened to being under a blanket in the sunshine; the body under the blanket will heat up and the blanket will keep the heat from escaping causing warming. Greenhouse gases in the atmosphere block this infrared radiation from escaping directly from the surface to space (Williams, 2002).

Houghton (2005) explains that 'by absorbing infra-red or 'heat' radiation from the earth's surface, "greenhouse gases" present in the atmosphere, such as water vapor and carbon dioxide, act as blankets over the earth's surface, keeping it warmer than it would otherwise be. The existence of this natural "greenhouse effect" has been known for nearly two hundred years; it is essential to the provision of our current climate to which ecosystems and we humans have adapted'.

As research has accumulated on climate change, scientists have become more and more certain that global warming is happening and clearer as to its effects. The Fourth Assessment Report of the IPCC published in 2007 stated that: 'Most of the observed increase in global average temperatures since the mid- 20th century is *very likely* due to the observed increase in anthropogenic (human caused) greenhouse gas concentrations (Alley *et al.*, 2007).

Fundamentally, there are two choices to deal with the problem of climate change: mitigation and/or adaptation. Mitigation refers to taking steps today to reduce greenhouse gas emissions so as to delay further global temperature increases and other related effects. Adaptation refers to the efforts of (future) generations to adjust in ways that will substantially reduce the negative impacts of climate change (Adane *et al.*, 2012).

Climate change mitigation: 'Climate Change Mitigation' which refers to efforts to reduce greenhouse gas emissions or to capture greenhouse gases through certain kinds of land use, such as tree plantation. Climate change mitigation is the main response that must be made to prevent future impacts of climate change (Huq, 2006). It consists of measures such as switching from using coal, to petrol/oil, to natural gas, which are progressively better in terms of greenhouse gas emissions. Natural gas is the least polluting fossil fuel. Better still is the use of renewable sources of energy. The majority of greenhouse gasses are contributed through energy emissions, while the remainder is related to land use (Stern, 2006).

Climate change adaptation: The word 'adaptation' has evolved from the term 'adapt', which means 'making things/situations better by changing' (Ahmed, 2006). Adapting to changes around us to have a better way of life is a basic human response and due to the slow action of industrialized countries to implement mitigation measures to reduce their greenhouse gas emissions communities will need to adapt to the already inevitable effects of a changing climate. Adaptation to climate change is therefore the process through which people reduce the negative effects of climate on their health and well-being and adjust their lifestyles to the new situation around them. 'In a nutshell adaptation is being better prepared or adapting to climate change, not fighting it, but learning to live with it' (Rahman, 2009).

Risk: Is the probability that a situation will produce harm under specified conditions. It is a combination of two factors: the probability that an adverse event will occur; and the consequences of the adverse event. Risk encompasses impacts on human and natural systems, and arises from exposure and hazard. Hazard is determined by whether a particular situation or event has the potential to cause harmful effects (Australian Greenhouse Office. 2003).

Vulnerability: is the degree to which a system is susceptible to, and unable to cope with, adverse effect of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2010).

Plot: A plot is the smallest unit of land devoted for a particular crop or intercrop under similar management practice in a given time/cropping season.

2.2. Sources of Risk and Farm Household Risk Management

Rural households face numerous sources of risk, which are manifested through changes in asset values, returns on asset and general well being (e.g. health status). Risk with respect to nature and environment, market, policies and institutions, household health, social and political systems can impact household welfare and decision making both during and between years (Patrick, 1984).

There are different types and sources of risks in agriculture. Moisture stress is one of the major challenges of crop as well as livestock production in Ethiopia. Late rains, early cessation and insufficient rains are rainfall related problems, which negatively affect crop production of a given household. Problems related to livestock production include feed and water shortage, disease, low production of the local breeds and lack of grazing land. Major animal health problems which can cause production loss are external parasites, internal and contagious diseases (Upton, 1973).

Risk is everywhere and is substantially unavoidable. Yet it can be reduced using appropriate risk management strategies. Management of risk is also one part of management of farm, since every farm management has risk implications. According to Hardaker *et al.,* (2004), risk management means identifying the range of option for treating each particular risk, then evaluating those options, selecting the most suitable one and implementing it.

Households in risky environments have developed management strategies to reduce the impact of shocks. More concrete risk management strategies can be grouped into three categories: prevention strategies to reduce the probability of an adverse event occurring, mitigation strategies to reduce the potential impact of an adverse event, and adaptation/coping strategies to relieve the impact of the risky event once it has occurred (Heltberg *et al.,* 2008).

In general, societies are dynamic and they use all possible strategies to reduce the vulnerability to climatic impacts. There are two kinds of responses to crisis that overlaps across the temporal scale, coping responses and adaptation strategies. Coping responses are the actual responses to crisis on livelihood systems in the face of sudden unwelcome situations, and are considered as short-term responses and sometimes develop to adaptive strategies (Berkes and Jolly, 2001). Adaptation strategies are the strategies in which a household, a sector or a region responds to changes in their livelihood through long term planned strategies (Campbell, 2008).

2.3. Climate Change Mitigation and Adaptation Options in Agriculture

The capacity to mitigate and adapt to climate change varies across countries, social groups and regions over time (Darwin *et al.*, 1995; Kabubo-Mariara & Karanja, 2006). These capacities will depend to a large extent on the availability of natural resources, their level of development, their resource base, technological knowhow and level of information about climate change, and their scientific & technical capacity. Greater economic resource availability increases both the adaptive and mitigation capacity while the lack of it limits both adaptation and mitigation options. Hence, mitigation and adaptation measures are very much related to socio-economic conditions of the country and community given basic forms of mitigation and adaptations (Kabubo-Mariara and Karanja, 2006; Darwin *et al.*, 1995).

The agriculture sector has the capacity to mitigate and adapt to impacts of climate change provided that technologies and management changes have been undertaken relatively quickly (Mendelsohn, 2000). In agriculture, mitigation and adaptation strategies to climate change can takes place at individual, groups within society and organizations and government levels on behalf of society. Some measures such as farm level soil and land management, water management and conservation of agro-bio-diversity may be taken at individual level. Others like rainwater harvesting, building dams, releasing new cultivars that are more drought resistance require collective actions (Maddison, 2006; Hassan and Nhemachena, 2008; Kurukulasuriya and Mendelsohn, 2008). These time societies have inherent capacities (knowledge, skills, technology, institutional arrangements and strategies) to mitigate and adapt to climate change.

2.3.1. Mitigation options in agriculture and climate change

Mitigation of climate change is a global responsibility which needs human intervention aimed at reducing the sources or enhancing the sinks of greenhouse gases (IPCC, 2010). Agriculture and natural resource (forestry) provide, in principle, a significant potential for GHG mitigation. Mitigation in the natural resources sector focuses on the following major subsectors, namely: forestry, rangeland, livestock, and fisheries. The classical mitigation options in the agricultural sector at large include forest-related measures of reducing deforestation and forest degradation and increasing afforestation and reforestation, along with forest management interventions to maintain or increase forest carbon density, and efforts to increase carbon stocks in wood products and enhance fuel substitution (FAO, 2008).

Soil carbon sequestration: is one of the most promising options with a wide range of synergies by increasing carbon concentrations in the soil through better management practices (FAO, 2008).This option offers benefits for biodiversity, soil fertility and production, and soil water storage capacity. Further, integrated crop and animal production, use of intermediate and cash crops and cover crops, compost application, crop rotation and diversification, and zero or reduced tillage have potential to improve soil carbon sequestration and reduce GHG emissions (IPCC, 2010; FAO, 2008).

Crop land mitigation: These measures remain unexplored although many adaptation options also contribute to mitigation. Among these measures are: soil management practices that reduce fertilizer use and increase crop diversification; promotion of legumes in crop rotations; increasing biodiversity, the availability of quality seeds and integrated crop/livestock systems; improving the control of wildfires and avoiding burning of crop residues; and promoting efficient energy use by commercial agriculture and agro-industries.

Livestock management: Livestock production is one of the agricultural activities which is responsible for significant GHG emissions (FAO, 2008). Mitigation options to reduce these emissions include: improving livestock waste management through covered lagoons, improving ruminant livestock management through improved diet, nutrients and increased feed digestibility, improving animal genetics, and increasing reproduction efficiency. In general, for the most vulnerable people as well as regions, the potential for implementation of the above mitigation measures is rather low and adaptation is the major concern.

2.3.2. Adaptation options in agriculture and climate change

Adaptation actions are an essential and often overlooked part of the response to climate change; however they are not intended as a substitute for mitigation actions. For if runaway climate change is not stopped the cost of adaptation measures will raise higher and higher and the risks of the poor and vulnerable will be increased due to an increasingly hostile environment (Rahman, 2002). There may also come a point when due to the severity of climate change effects in many places, adaptation measures will be ineffective. Therefore Huq (2006), at the 2nd International Workshop on Community Based Adaptation to Climate Change stated: “Mitigation is the best form of adaptation”.

There are a number of household agricultural practices and investments that can contribute to climate change adaptation (McCarthy *et al.*, 2011). For instance SWC, planting of different crop varieties, crop diversification, application of irrigation, and agro-forestry investment are some of the adaptation strategies in agriculture which can give long term benefits to households from adopting such activities in terms of increasing yields, reducing variability of yields and making the sector more resilient to changes in climate

SWC adoption as an adaptation strategy: Adoption of SWC measures is one of the most important adaptation strategies to climate change and thereby improves agricultural production in areas with high land degradation and limited access to modern inputs (Bekele *et al.*, 2008). Land degradation, soil erosion, and nutrient depletion contribute significantly to low agricultural production and thus food insecurity and poverty in many hilly areas of the developing world (Pagiola, 1999; Nakonya *et al.*, 2006). In response, considerable public resources have been mobilized to develop SWC technologies and promote them to farmers. Examples of technologies advanced throughout the developing world include structural methods, such as soil and stone bunds; agronomic practices, such as minimum tillage, grass strips, and agro-forestry techniques; and water harvesting options, such as tied ridges and check dams (Bekele *et al.*, 2008).

The primary reasoning behind using these technologies in mountainous regions is to reduce movement of soils, water flow velocity, and the broader effects of erosion, such as siltation of rivers, lakes, and dams. SWC techniques also reduce soil loss from farmers’ plots, preserving critical nutrients and increasing crop yields, and this is the chief selling point for farmers.

Planting of different crop varieties: Planting of different varieties of the same crop is considered to be one of the most important adaptations to climate change (Pender, 2010). Altering inputs, varieties and new species for increased resistance to heat shock, drought and flooding and further increase agricultural productions are considered as one adaptation strategies in agriculture.

One of the many adaptations to climate change involves the use of different varieties of seed, for example the use of early maturing varieties or drought resistant ones to increase farm household production.

Crop diversification: Crop diversification is one of the risk transfer mechanisms that are included in adaptation strategies both at national and household level. Crop diversification to reduce dependency on specific crop types is particularly important for farmers that rely on narrow ranges of climate sensitive sectors, such as agriculture. Crop diversification is also an important adaptation strategy discussed within the context of UNFCCC (FAO, 2008).

Irrigation: It is one of the adaptation strategies in agriculture involves, managing water bodies (such as rivers, lakes) for more efficient delivery of water requirements for the improvement of agricultural production and to prevent water logging, erosion and nutrient leaching. It also involves making wider use of technologies to "harvest" water and conserve soil moisture; use and transport water more effectively by altering amounts and timing of irrigation and other water management.

Agro-forestry: Agro-forestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and in reducing crop output variability (Ajayi *et al.,* 2009; Mercer, 2004). Trees and bushes may also yield products that can either be used for food consumption (fruits), fodder, fuel, sold for cash (coffee), building materials, or firewood, leading to greater average household income, and contributing to household risk management via reduced income variability (Ajayi *et al.,* 2009; Franzel *et al.,* 2004). Planting trees and bushes also increases carbon sequestered both above and below ground, thereby contributing to GHG mitigation (Vercht *et al.,* 2007).

In terms of benefits, empirical evidence suggests that where gains to farmers from reducing soil and water erosion are high (e.g. hillsides), where gains from water management are high (e.g. water deficit regions) and where climate variability is high, agro-forestry options are more likely to be adopted. Also, agro-forestry options that yield multiple benefits in the form of food, fodder, cash income and fuel are usually more attractive.

Conservation agriculture/tillage (CA): Conservation agriculture incorporates a wide range of practices aimed at minimizing soil disturbance, and minimizing bare, uncovered soils (Blanco & Lal, 2008). FAO includes crop rotation as an essential component of conservation agriculture (FAO, 2008). Reduced or zero tillage plus incorporation of residues or other mulches reduces wind and soil erosion, increases water retention, and improves sol structure and aeration (Blanco and Lal, 2008). Reduced erosion, improved soil structure, and greater water retention reduce yield variability due to weather events in general. Thus conservation tillage practices can increase farm system resilience and improve the capacity of farmers to adapt to climate change.

2.4. Climatic Change, Rainfall Trends and Ethiopian Economy

Climate change is a great concern for agriculture and its effects are likely to vary between different regions and in different scales. Climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, and high temperature. And current climate variability is already imposing a significant challenge to Ethiopian economy by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters.

Large inter annual variability which is clearly reflected in the prevalence of recurrent drought is the characteristic feature of the country's climatic system (Gissila *et al.*, 2004). According to the long term rainfall and temperature data of Ethiopia, the country's rainfall is characterized by a high degree of spatial and temporal variability. If seasonal rainfall fails or its amount or timing deviates from the norm, agricultural production will be negatively affected (World Bank 2006) with a damaging consequences for the country's overall economy and food security. Studies by (NMSA, 2010) indicate that the mean temperature and precipitation have been changing in the country. The annual average minimum temperature has been increasing by about 0.25 ^{o}C every 10 years and the maximum by 0.1 ^{o}C every decade. Over time, amount of rainfall is also exhibiting a declining trend with increasing variability (NMSA, 2010).

Ethiopia's economy is mainly based on rainfed agriculture; as a result food production is highly vulnerable to the influence of adverse weather conditions such as drought. According to Von Braun (1991) a 10% decline in the amount of rainfall below the long run average leads to a 4.4 % reduction in the country's national food production. In the future too, studies show that rainfall is expected to decline (Funk *et al.,* 2009) and also becoming more irregular. Drought has been an increasing occurrence over the last decades in Ethiopia as the proportion of the population adversely affected by it. For example, Berhanu (2003) indicates that the proportion of drought affected people doubled from 8% of the total population in 1975 to 16% in 2003. Consequently, the country has been dependent on food aid to bridge its huge food gap. Even in a year where rainfall is favorable, it is estimated that around 4-5 million Ethiopians depend on food aid supported from Productive Safety Net Program (Devereux, 2006).

In general, this high dependency of the agriculture sector on nature combined with backward farming practice, low technology adaptation, low irrigation, increasing population pressure makes climate change a big challenge in affecting the production of the sector and the Ethiopian economy. Thus, increasing food production and ensuring its steady access to the fast growing population on one hand, and designing effective drought mitigation strategies on the other remains to be a major challenge for Ethiopia's development endeavor.

2.5. Conceptual Framework for SWC Adoption Analysis

In the literature, there are several climate change adaptation strategies implemented by farmers and there are also different theoretical approaches of modeling farm technology adoption decisions (Feder *et al.,* 1985). Among the available different adaptation strategies, this study will focus on SWC adoption as one of the basic climate change adaptation strategies considered in most literature.

Whether or not a household adopts SWC technology depends on the costs and benefits of each technology (Bekele and Holden, 2001). The assumption is that a household maximizes utility when choosing technology. However, we do not observe its utility, but only its choice of technology. In the analysis, we therefore apply a random utility model (McFadden, 1973). The utility from adopting SWC and not adopting SWC were in turn determined by a set of exogenous variables, *Z,* and an error term. The exogenous variables are both household and plot level characteristics.

Adoption is assumed to occur if the utility from adopting SWC measures is higher than the utility without SWC measures; i.e.,

$$\text{if } A_{ip}{}^{*} = A^{sc}{}_{ip} - A^{nsc}{}_{ip} \text{ or } \qquad \text{if } Z_{ip}\gamma + u_{ip} > 0 \tag{1}$$

(The indices *i* and *p* refer to household i and plot p). If the variable A_{ip} reflects the soil conservation adoption decision and equals 1 if there is a SWC structure by household *i* on plot *p* and otherwise equals zero. The model can be specified:

$$\begin{aligned} A_{ip} &= 1 \quad if\,(Z_{ip}\,\gamma + u_{ip}) > 0 \\ &= 0 \quad if\,(Z_{ip}\,\gamma + u_{ip}) \leq 0 \end{aligned} \tag{2}$$

Hence, the adoption decision Z_{ip} is a vector of both endogenous and exogenous variables, including land size, market characteristics, human capital, and social characteristics (Feder *et al.*, 1985; Rogers, 1995); γ is a vector of parameters; and u_{ip} is an error term. The error term includes measurement error and factors unobserved to the researcher but known to the household. The variable A_{ip} is a dichotomous choice variable (dependent) and can be consistently estimated using a limited dependent variable model, such as binary probit (Maddala, 1983).

To examine the impact of SWC adoption on crop income, one has to estimate yield functions for plots with and without SWC measures as a simultaneous system. Since plots with and without SWC are mutually exclusive, they cannot be observed simultaneously on a particular plot. Adoption of SWC may affect and even alter input use patterns and decisions (Kaliba *et al.,* 2000).

The households may also be both adopters and non-adopters if they have more than one plot. Therefore, we specified two separate yield functions for plots with and without SWC:

$$y_{ip1} = \mu_1 + X_{ip1}\beta_1 + \eta_i + \varepsilon_{ip1}, \ (if\ A^*_{ip} > 0) \text{ , and} \tag{3a}$$

$$y_{ip0} = \mu_0 + X_{ip0}\beta_0 + \eta_i + \varepsilon_{ip0}, \ (if\ A^*_{ip} \leq 0) \tag{3b}$$

The variables y_{ip1} and y_{ip0} are continuous variables, representing the value of output per hectare if A_{ip} equals 1 or 0, respectively in equation (2) above. X_{ip} *is* a vector of explanatory variables and β_1 and β_0 are vectors of unknown parameters. Finally, η_i is an unobserved household specific plot invariant effect and (ε_{ip1}, ε_{ip0}) are error terms. This error structure allows control for unobserved effects, such as farming ability and intra-household correlation due to unobserved cluster effects.

In this study, we tried to see two important issues that we needed to address in a model describing farmer behavior. First, farmers' SWC adoption and production decisions may be simultaneous (Feder and Slade, 1984). This simultaneity may also be due to unobserved variables correlated with both adoption and production decisions. Second, households do not make adoption decisions randomly; instead, they are based on expectations of how their choices affect future crop performance. Consequently, adopters and non-adopters may be systematically different. These differences may also manifest themselves in crop production and could be confounded with differences purely due to SWC adoption. The results would be biased if we did not address this self-selectivity problem (Greene, 2003).

2.6. Past Empirical Results

Different studies regarding risk, vulnerability and climate change adaptation strategies were carried out in different countries. Girma (2002) analyzed the risk management strategies of farmers in Kalu district, South Wollo zone of Ethiopia using stochastic dominance programming method. His findings indicated that the farming communities in the study area are appreciably dealing with the risk of moisture stress in a pertinent and pragmatic way. Land allocation to different crops is dependent on the moisture level anticipated by the farmers. Drought tolerant crops dominate the cropping system in a situation of moisture stress. The resource allocations and crop type adopted by the households show that risk management is part of the household's strategy to minimize the risk of food insecurity.

Million and Belay (2004), have conducted a research on the identification of the important factors which influence adoption of soil conservation measures in Gununo areas of Wolaita zone. Using cross sectional data on 120 sample households, the authors specify a binomial logit model to identify factors that determine adoption of physical soil conservation measures, namely soil bunds and fanyajuu in Gununo area where some of the sample villages are also included in this thesis for a border analysis using the panel data used in this thesis. The empirical results show that the major factors influencing adoption of physical soil conservation measures in the study area are: farmers' perception of soil erosion problem; the number of economically active family members; farm size; family size; wealth status of the farmer; and the location of the farmland.

Adaptation is viewed as a vital component of climate change impacts and vulnerability to strengthen local capacity to deal with forecasted and unexpected climatic conditions (Smith and Lenhart, 1996; Smit *et al.,* 1999). The study made by Mendelsohn *et al.,* (1994) and Di Falco *et al.,* (2011) also find that there are significant and non negligible differences in food production between the farm households that adapted and those that did not adapt to climate change. Their research found that adaptation to climate change increases food production. However, farmers who adapted tend to have a production above the average whether they adapt or they don't. And the impact of adaptation on production is smaller for the farm households that actually did adapt than for the farm households that did not adapt in the counterfactual case that they adapted.

Mahmud *et al.,* (2008) also used Psedo-fixed-effect model and the two-stage least square (2SLS) method in order to study the impact of adaptation on food production. The result obtained from the models indicated that farmers who adopted climate change adaptation strategies had higher food production than those who didn't. Based on the marginal effect estimates of their results, households with climate change adaptation measures tended to produce about 95 kg to 300 kg more food per hectare than those who did not take such measures: This account for 10 to 29 % of change in output in their study site. According to their findings, the effect of climate change will be reduced by such a magnitude if households take adaptation measures.

Kato *et al.* (2009) used the Just and Pope framework using Cobb-Douglas production function to investigate the impact of different soil and water conservation technologies on the variance of crop production in the face of climate change in the Nile Basin of Ethiopia. The study both from household and plot level data set revealed that soil and water conservation technologies have significant impacts in reducing production risk in Ethiopia and could be part of the country's climate-proofing strategy. The results also show the performance of these technologies is location specific, given the differences in agro ecologies and other factors.

A number of empirical studies have also examined the production impacts of different land management practices, especially in Ethiopia and in developing countries in general. Most of these studies, however, have tended towards soil conservation as a production enhancing technology. In the case of Ethiopia, Bekele's (2005) research showed that plots with soil conservation bunds produce higher yields than those without. Menale and Holden (2006) also used Switching Regression model using cross-sectional–plot-level data to demonstrate that in high-rainfall areas, such as those in northwestern Ethiopia, soil conservation (*fanya-juu* terracing) has no production gains. Benin (2006) found a 42 percent increase in average yields due to stone terraces in lower-rainfall areas of the Amhara region. Consistent with this, Pender and Birhanu (2006) used a sample from the semi-arid highlands of Tigray and found an average increase of 23 percent due to stone terraces. Holden *et al.,* (2001), on the other hand, showed that soil and water conservation measures in the form of soil bunds and fanya-juu terraces have no significant short run impact on land production.

Although there is substantial evidence on the adoption and production impacts of soil and water conservation measures in Ethiopia, the evidence of adoption and production impacts results are still mixed. Research has also shown that in Ethiopia the economic returns on physical soil and water conservation (SWC) investments, as well as their impacts on production, are greater in areas with low-moisture and low agricultural potential than in areas with high-moisture and high-agricultural potential (Birhanu *et al.*, 1999; Benin, 2006; Menale *et al.*, 2011). In wet areas, investment in soil and water conservation may not be profitable at the farm level, although there are positive social benefits from controlling runoff and soil erosion (Nyssen *et al.*, 2004).

Results from other countries also support the importance of land management practices and specifically soil conservation measures in enhancing land production. Zikhali (2008) found that contour ridges have a positive impact on land production in Zimbabwe. Shively (1998) reported a positive and statistically significant impact of contour hedgerows on yield in the Philippines. Results by Kaliba and Rabele (2004) also supported a positive and statistically significant association between wheat yield and short- and long-term soil conservation measures in Lesotho.

Two points are worth mentioning about the existing literature on the role of SWC in small-scale agriculture. First, the results are very case specific, both in the type of SWC and in the agro-ecological characteristics of the study areas. In particular, these studies indicate that the economic returns on physical soil and water conservation investments, as well as their impacts on production, vary by rainfall availability. Specifically, it indicates that these returns are greater in low-moisture and low-agricultural potential areas than in high-moisture and high-agricultural potential areas (Menale *et al.*, 2011). Therefore, one cannot generalize about the impact of SWC on agricultural production. Second, the divergence of empirical results is partly related to methodological differences, which in turn emanates from the desire to establish theoretically sound and empirically efficient methodological approaches.

This paper takes a step towards filling this gap by systematically exploring plot level production gains associated with adoption of different soil and water conservation structures.

3. RESEARCH METHODOLOGY

In this section, description of the study area, methods of data collection, sampling procedure and the theoretical framework of the study and methods of data analysis are indicated.

3.1. Description of the Study Area

Location: This study is conducted in Damot Sore Woreda, which is one of the seven woreda's in Wolaita Zone of the Southern Nation Nationalities and Peoples Regional State (SNNPR). It is found North 06^{0} 55.375 East 037^{0} 38.913 and located about 360 kms south of Addis Ababa. Damot Sore Woreda consists of 18 kebeles and the woreda shared boundaries with Sodo Zuria woreda in the South, Kindo Koysha in the West, Boloso Sore woreda to the North, and Damot Gale woreda to the East (WoARD, 2011) (Figure 1).

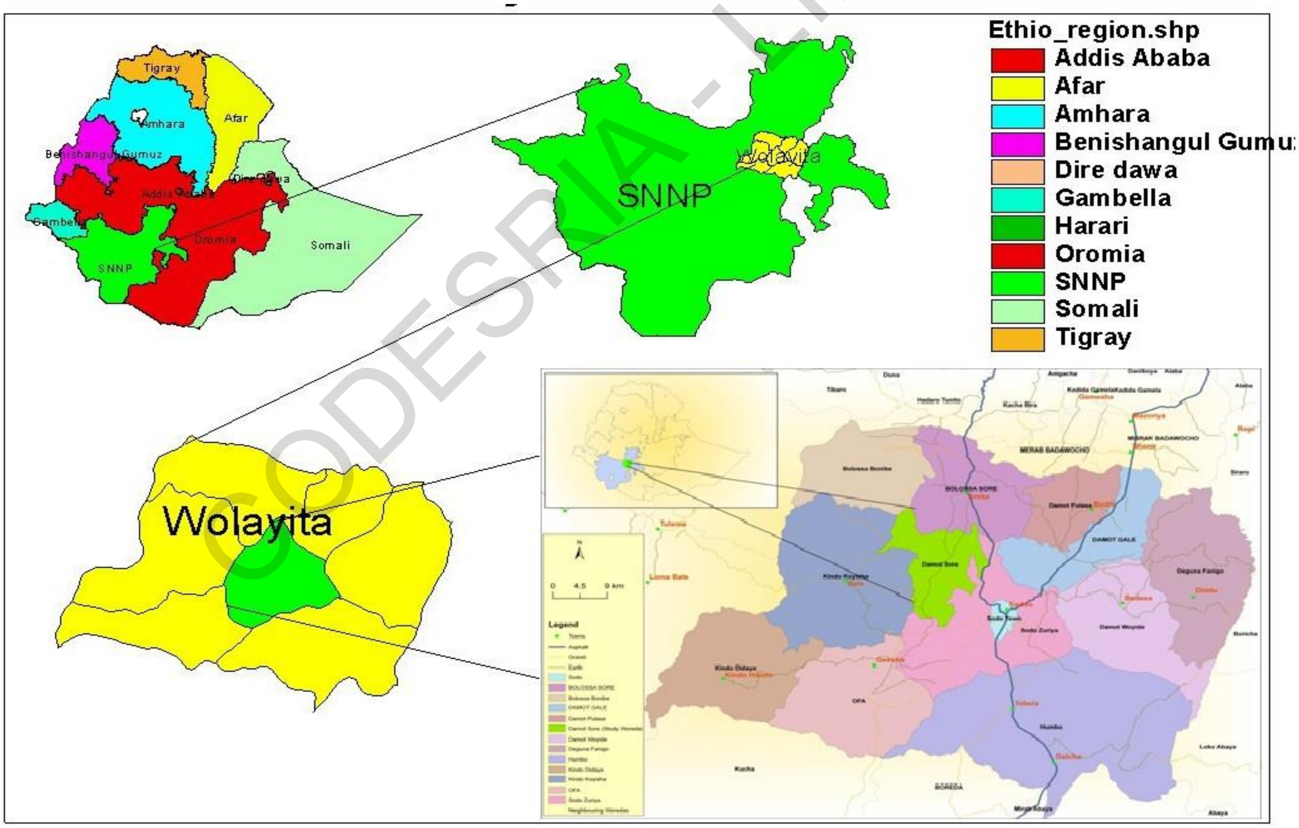

Figure 1: Location of the study area, Damot Sore Woreda, Wolaita Zone, SNNP

Demographic condition: The study woreda is densely populated. The population density is estimated about 758 persons/square km (CSA, 2007), which is greater than the national average of 141, and the Zonal average 330. There are about 6 to 7 individuals per household, which is higher than the national average of 5. The total population is around 106,180 which constitute 51,899 male and 54,281 female (CSA, 2007).

Climatic, geographic indices and land distribution: The agro-ecology of the study woreda consists of 11% lowland or kola, 74 % mid highland or Woina Dega and 15 % highland or Dega. The mean annual minimum and maximum temperature are 20 and 25 degree centigrade respectively. The rain-fall is erratic with an annual average ranging from 850-1200ml. The landscape is characterized by hilly terrain traversed by large plains, valleys and gorges. Around 40% of the land mass is steep slope or hilly and the remaining 60% is undulating plains. The altitude ranges from 1500 to 2100 meters above sea level (m.a.s.l.). In many parts of the area, torrential rains usually results in flashing flood which causes a serious soil erosion and crop damage during planting season (WoARD, 2011). The total area of the woreda is estimated at 14,382 ha (140.14km$^{2)}$ out of which cultivated, forest, grazing, wet land, damaged/waste land and other unused land accounts for 10,249 ha, 2052 ha, 413 ha, 368 ha, 350 ha and 950 ha respectively (WoARD, 2011) (Table 1).

Table 1: Land use and distribution by households in Damot Sore Woreda

Classification	Woreda land size in ha	Cultivated land in ha	Forest land in ha	Wet land in ha	Waste land in ha	Grazing land in ha	Unused land (ha)
Total Land	14,382	10, 249	2,052	368	350	413	950
Land category	< 1ha	1.01-2.00	2.01-3.01	3.01-5.01	5.01-7.01	> 7 ha	Total
HH numbers	12,164	3790	424	99	6	-	16,483
Land holding	4,334	4,522	1,007	331	36	-	10,230

Source: Damot Sore WoARD land administration annual report, 2011 HH = household head

Crop Production: Mixed crop and livestock farming system is a common practice in the woreda. Crop production is carried out in both *meher* and *belg* seasons although the main cropping season is *meher*. The major types of crops grown in the area are maize, haricot been, sweet potato and *teff* whereas false banana (*enset),* coffee, *chat* and cassava are the major perennial crops. *Enset* and cassava serve as the major staple foods while in terms of income generation coffee ranks *first*. Generally, Maize is the leading crop both in land coverage and production followed by Haricot bean, Sweet potato and false banana (*enset*).

Table 2: Average production by crop type in 2011

Crop Type	Maize	Sorghum	Teff	Barley	H/bean	S.Potato	I. Potato	Taro	Beet root
Yield (Qt/ha)	27	19	10	13	12	140	119	125	150
Crop Type	Yam/Boye	Cassava	Cabbage	Onion	Carrot	Tomato	Garlic	Wolaita Potato	
Yield (Qt/ha)	140	157	170	167	170	150	110	51	

Source: Damot Sore WoARD, 2011.

According to Damot Sore woreda agricultural and rural development office (WoARD, 2011), maize, haricot bean, and *teff* produced 27, 12 and 10 quintals per hectare using fertilizer, respectively whilst the production of sweet potato reached 120-160 quintals. The production of these crops is extremely low without fertilizer which is 10-15 quintals per hectare for maize and 2-3 quintals for *teff*.

Livestock production: Livestock production is one of the major components of the farming system in the study district. It contributes to the subsistence requirement of the population in terms of milk, milk products and meat, particularly from small ruminants, providing draught power and source of cash income. According to WoARD (2011), there are about 47,668 cattle, 10,004 sheep, 2,165 goats, 41,585 poultry and 2,858 local, 200 transitional and 104 modern beehives in the woreda. There are livestock losses due to disease, pests or drought in the area. The major livestock diseases in the woreda are *Tripanosomiasis,* Black leg, Anthrax (Soil born disease), external and internal parasites caused by feed and management problems. Moreover, according to the woreda experts, the production of livestock now a day's become very low due to shortage of grazing land, lack of improved breeds and poor forage management. Because of these reasons, the livestock production in the woreda has been adversely influenced.

Agricultural extension: Agricultural extension services are very important in assisting farmers by giving information for their production problems and by making them aware of opportunities for improvement. Agricultural extension service plays a major role in increasing crop production through the use of improved seeds, fertilizers, chemicals, SWC and improved farming systems. Currently, the focus of the agricultural extension services in the zone is on crops, livestock and natural resources conservation, in an integrated development approach.

With regard to the extension services of Damot Sore district, as elsewhere in the country, development agents (DA), who live within the *kebele's*, provide agricultural extension services. The farmer development agent ratio is one important issue, which needs attention in this regard. Moreover, the quality and efficiency of the extension services depend partly on the number of farmers that an agent has to serve. At present, there are about 21 development centers and 63 development agents serving 18,627 farming households in the study area. The ratio of farmers to development agent in the year 2011 is 296:1 (WoARD, 2011).

3.2. Data Type, Method of Collection and Sampling Procedure

3.2.1. Data type

The assessment of household's sources of risk and climate change impact study requires the use of longitudinal (panel) data sets, where the same households are tracked over a number of periods which enables the estimation of inter-temporal variation of climate change adaptation at the household level.

To study the different sources of risk, the determinant factors of the choice of SWC adaptation for climate change and the impact of SWC adoption on plot production in Birr, were used data from three round surveys conducted in 2005, 2007 and 2011 in Damot Sore woreda. The 2005 and 2007 data were collected by the Norwegian University of Life Science (UMB) as part of Dr. Million Tadesse's PhD studies in Wolaita zone (Million Tadesse, 2010 for more description on data and study areas). Data from the 2011 CIMMYT UMB collaborative research project funded by research Council of Norway as part of Dr. Million Tadesse's post-doctoral studies was used and the author of this thesis has been fully engaged in data collection, moderating focus group discussions, supervising enumerators and analyzing the panel data for Damot Sore woreda sample households. Information on sample of 204 randomly selected households and around 4274 plots in each survey rounds for Damot Sore woreda is used for the current analysis. In other words, at first 204 farmers were randomly selected in 2005 and the same surveyed farmers were then tracked in the 2007 and 2011 survey periods.

Collected data over the past six years include household's characteristics, changes in crop and livestock production, drought situation, land ownership and land rental markets, access to extension, incidence of different climatic and related risks, perceptions of climate change, and adaptation strategies. Moreover, temperature and rainfall data for the surveyed seasons as well as for the last six decades (1951-2011) were obtained from CIMMYT-GIS section[1].

The nature of the data is balanced panel[2] (equal number of households used for all periods) and the number of households between the survey rounds are constant and representative. The survey result gave major information about the study area. Moreover, in order to compliment it, seven focus group discussion (FGD) and key informant interview were also made with the farmers selected from the four kebeles'.

3.2.2. Method of data collection

In order to answer the research questions, both primary and secondary data were considered. Primary data were obtained through a household questionnaire survey, FGDs, key informant interviews, direct observation, and expert interviews. FGDs' were conducted with selected members of the community and gender mixed groups. These individuals were thoroughly interviewed using a checklist of guiding questions. The key informants interviewed include experienced people and community elders. Agricultural experts at woreda level were interviewed on selected topics.

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[1] I would like to thank UMB-CIMMYT collaborative project and the project leader, Dr. Million Tadesse for providing the 2005, 2007 and 2011 data including the long term rainfall and temperature data.

[2] Panel data set is a type of data set where the same households are tracked over a number of periods which enables the estimation of temporal and spatial (inter-temporal as well as cross-sectional) variation of households, an area or environment.

Secondary data collected include information on the sources of risk and climate change adaptation strategies, climate change (weather variability) indicators such as rainfall and temperature, drought and flood occurrences collected from NMSA, the woreda agriculture office, non government organizations, and similar literatures.

3.2.3. Sampling procedure

This study specifically makes use of a longitudinal data set collected from randomly selected farm households in Damot Sore Woreda, Wolaita Zone. Two stages random sampling technique was followed in 2005 and all the subsequent two surveys use the same households with less than 1 % sample attrition rate over the three years period.

In the first stage, four kebele's were randomly selected out of a total of 18 kebele's in Damot Sore Woreda. In the second stage, a total of 204 households were drawn by employing a random sampling procedure from the selected 4 kebele's for the household questionnaire survey. During this process, the list of household heads in each kebele's was used to make random selection of the farmers.

Table 3: Name of *kebeles*, plots and number of respondents selected from each *kebeles*

Kebele names	Number of Plots	Percent	Number of sample hh
Doge Shakisho	1,532	35.84	73
Gununo 02	1,522	35.61	71
Doge Mashido	1,071	25.06	51
Demba Zamine	149	3.49	9
Total observation	4,274	100	204

Source: Survey results (2005, 2007, 2011) hh= household

3.3. Method of Data Analysis

Both household and plot level information were collected during the three periods of the data collection. And both descriptive and econometric analysis was used in this study.

3.3.1. Descriptive analysis

Qualitative data was summarized using tables of frequency and percentages. In addition, simple descriptive statistics like means, standard deviations, medians and percentages were employed. The result that was obtained from different categories of the respondents was interpreted accordingly. Analysis was made using inductive reasoning to describe the data as well as for the interaction, generalization and classification of the data into categories. The data was analyzed using STATA 11 software. And beyond descriptive analysis, econometric analysis was employed.

3.3.2. Econometric model analysis

Both adoption and impact models that this research considered used panel data two stage approaches in relating the explanatory variables with their outcome variables. The following sub sections discuss the econometric model used to know the determinant factors affecting farmer's choice of SWC adaptation (the first stage from the switching regression model); the econometric model used to study the impact of SWC adaptation to climate change on production (the second stage from the switching regression model); fixed effect panel data estimation techniques and advantage of switching regression model.

3.3.2.1. Modeling determinants of SWC adaptation strategy

According to Di Falco *et al.* (2011), the climate change adaptation decision and its implications in terms of production can be modeled in the setting of a two-stage framework. A switching regression model, which uses a binary choice panel probit model, is used for this study. In the first stage, we use a selection model for climate change adaptation where a representative risk-averse farm household chooses to implement SWC adaptation to climate change on his plot if it generates net benefits. Let A^* be the latent variable that captures the expected benefits from the adaptation choice with respect to not adapting. We specify the latent variable as:

$$A^*_{it} = Z_{it}\,\alpha + u_{it} \text{ with } A_i = \{ 1 \text{ if } A^*_{it} > 0 \qquad (4)$$

$$= \{0 \text{ otherwise,}$$

that is farmers will choose to adapt (Ai = 1) if A* > 0, 0 otherwise, where A* represents the expected benefits of adapting with respect to not adapting, Z is a vector of variables that determine the decision to adapt or not to climate change, such as household characteristics such as age, gender, education, marital status, farm household size and if he has an off-farm job, the farm plot level characteristics (e.g. soil fertility, slope and erosion level), climatic factors such as average annual temperature, average annual rainfall, and extension information about climate change. And in the selection model, α represents a vector of parameters and u_{it} is the error term.

Probit and logit models are the most commonly used models in the analysis of agricultural technology adoption research (Maddala, 1983, Greene, 2003, Cameron and Trivedi, 2009). Binary probit or logit models are employed when the number of choices available is two, whether to adopt or not (Cameron and Trivedi, 2009). These models have also been employed in climate changes studies pertaining to the conceptual similarities in agricultural technology adoption and climate change studies (Di Falco *et.al.*, 2011).

The first stage of the Switching Regression model analysis presented in this study identifies the important determinants factors of SWC adaptation choice to climate change. This helps to provide information about the different factors affecting farmer's choice of SWC adaptation measures.

3.3.2.2. Modeling impact of SWC adaptation to climate change on crop production

In the second stage of the switching regression model, the effect of adaptation on production via a representation of the production function is modeled. There are different functional forms to study the impact of adaptation on crop production. This research uses Endogenous Switching Regression model to analyze the impact of climate change adaptation strategies on crop production.

The simplest approach to examine the impact of adaptation to climate change on farm households' production would be to include in the crop production equation as a dummy variable equal to 1 if the farm household adapted to climate change, and then, to apply ordinary least squares (OLS). This approach, however, might yield biased estimates because it assumes that adaptation to climate change is exogenously determined while it is potentially endogenous. The decision to adapt or not to climate change is voluntary and may be based on individual self-selection.

Farmers that adapted may systematically have different characteristics from the farmers that did not adapt, and they may have decided to adapt based on expected benefits. Unobservable characteristics of farmers and their farm may affect both the adaptation decision and production, resulting in inconsistent estimates of the effect of adaptation on production. For example, if only the most skilled or motivated farmers choose to adapt and we fail to control for skills, then we will incur upward bias.

This study accounts for the endogeneity of the adaptation decision by estimating a simultaneous equations model of climate change adaptation and production with endogenous switching by full information maximum likelihood (FIML). For the model to be identified it is important to use as exclusion restrictions, thus as selection instruments, not only those automatically generated by the nonlinearity of the selection model of adaptation (A_{it}=1) but also other variables that directly affect the selection variable but not the outcome variable.

To account for selection biases the model adopts an endogenous switching regression model of crop production where farmers face two regimes (5a) to adapt, and (5b) not to adapt defined as follows:

$$\text{Regime 1: } y_{1it} = X_{1it}\beta_{1} + \varepsilon_{1it} \qquad \text{if } A_{it} = 1 \qquad (5a)$$

$$\text{Regime 2: } y_{2it} = X_{2it}\beta_{2} + \varepsilon_{2it} \qquad \text{if } A_{it} = 0 \qquad (5b)$$

where y_i is the log of plot level value of crop production in regimes 1 and 2, and Xi represents a vector of inputs (e.g., seeds, fertilizers, manure, labor), and of the farmer head's and the farm household's characteristics, SWC choice, soil's characteristics, assets, and the climatic factors included in Z.

An important implication of the error structure is that because the error term of the selection model, equation (4) u_{it} is correlated with the error terms of the production functions (5*a*) and (5*b*) (ε_{1it} and ε_{2it}), the expected values of ε_{1it} and ε_{2it} conditional on the sample selection are non zero (Maddala, 1983). If the estimated $\hat{\sigma}_{1\eta}$ (the covariance of u_{it} *and* ε_{1it}) and $\hat{\sigma}_{2\eta}$ (the covariance of u_{it} *and* ε_{2it}) are statistically significant, then the decision to adapt and the quantity produced per hectare are correlated, that is we find evidence of endogenous switching and reject the null hypothesis of absence of sample selectivity bias. This model is defined as a "switching regression model with endogenous switching" (Maddala and Nelson, 1975). An efficient method to estimate endogenous switching regression models is by full information maximum likelihood estimation (Lee and Trost, 1978).

Conditional Expectations, Treatment and Heterogeneity Effects

The endogenous switching regression model is used to compare the expected crop production of farm household plots that have adapted SWC (6a) with respect to farm household plots that did not adapt (6b), and to investigate the expected plot level crop production in the counterfactual hypothesis cases (6c) that the farm household plots which do not have SWC having SWC structures, and (6d) that the farm household plots which have SWC did not have SWC. The four cases of the conditional expectation for the farm household plot level production in value terms are presented below and see Appendix 4 in detail.

(6a) $E(y_{1i} / A_i = 1) = X_{1it}\,\beta_1 + \sigma_{1\eta}\lambda_{1i}$ (6c) $E(y_{2i} / A_i = 1) = X_{1it}\,\beta_2 + \sigma_{2\eta}\lambda_{1i}$

(6b) $E(y_{2i} / A_i = 0) = X_{2it}\,\beta_2 + \sigma_{2\eta}\lambda_{2i}$ (6d) $E(y_{1i} / A_i = 0) = X_{2it}\,\beta_1 + \sigma_{1\eta}\lambda_{2i}$

Cases (6a) and (6b) along the diagonal of (Appendix 4) represent the actual expectations observed in the sample. Cases (6c) and (6d) represent the counterfactual expected outcomes. In addition, following Heckman *et al.* (2001) and Di Falco (2011), we can calculate the effect of the treatment to adapt on the treated (TT) as the difference between (6a) and (6c), which represent the effect of plot level SWC adaptation to climate change on plot level crop production of the farm households that actually adapted SWC to climate change on specific plots. Similarly, we can calculate the effect of treatment on the untreated (TU) for the farm household plots that actually did not have SWC structures to climate change as the difference between (6d) and (6b).

We can use the expected outcomes described in (6a) - (6d) to calculate also the heterogeneity effects. For example, farm household plots that did not have SWC may have been exposed to lower production levels than farm household plots that have SWC regardless of the fact that they decided not to adapt in a specific plot. But it could be also because of unobservable plot and farmer level characteristics such as their preferences and abilities to choose to adapt SWC on specific plots. So that following De Falco (2011), Carter and Milon (2005) approach, we can calculate the effect of Base Heterogeneity for the group of farm household plots that have SWC as the difference between (6a) and (6d). Similarly for the group of farm household plots that did not have SWC, the effect of Base Heterogeneity is the difference between (6c) and (6b).

Finally, we can investigate the Transitional Heterogeneity (TH) that is whether the effect of adapting to climate change is larger or smaller for farm household plots that actually have SWC to climate change or for the farm household plots that actually did not have SWC in the counterfactual case that the plots having SWC. That is the difference between (TT) and (TU) (see Appendix 4).

3.3.2.4. Panel data model analysis

The objective of this section is to introduce about panel data and impact analysis models. Panel data also called longitudinal data is a data collected repeatedly (t-times) from the same n observations which give a data of n x t observations. In panel data, there are two kinds of information. The first is the cross-sectional information which is reflected in the difference between observations and the second one is the time series information which is reflected in the changes within observations over time (Cameron and Trivedi, 2009).

In panel data analysis, econometric estimates are done by applying two prominent data models: Fixed Effects and Random Effects models (Chan and Gemayel, 2004). Fixed Effects and Random Effects models, by virtue of their capacity to account for inter temporal as well as individual differences; they provide a better control for the influence of missing or unobserved variable effects (Chan and Gemayel, 2004).

$$y_{itp} = \beta X_{itp} + \eta_{ip} + u_{itp} \qquad (7)$$

Where:

y_{itp} is the household i log of plot level (p) value of crop production at time t.

X_{itp} is a vector of explanatory variables for household i at time t on a specific plot p

β is a vector of coefficients.

η_{ip} denotes unobserved household specific effects which are assumed to be fixed over time and vary across household i and p.

u_{itp} is the error term

The assumption behind the relationship between X_{itp} and η_{ip} makes the fixed effects and random effects models different. The fixed effects approach assumes that η_{ip} is treated as non-random and hence makes the correlation between the observed explanatory variables (X_{itp}) and η_{ip} possible (Wooldridge, 2002). On the other hand, the random effects approach is applicable under the assumption that η_i is random and not correlated with X_{itp} and puts it into the error term (Wooldridge, 2002; Cameron and Trivedi, 2009). Hausman test was used to check whether there is such a correlation between the observed explanatory variables and η_{ip} so that the suitable model specification was decided. According to Hill *et al.* (2008) if there is no correlation, in large samples the results obtained in applying the two estimators should be alike. Yet if there is correlation, the estimated results of the two estimators are different. Specifically, in the presence of such a correlation the random effects estimator is inconsistent whereas that of the fixed effects remains consistent.

3.3.2.5. Advantage of panel fixed effect and endogenous switching regression model

Recent econometric papers focused on estimating panel data models either with standard fixed effect model or unobserved individual specific random effects. Use of a standard fixed effect model has an obvious advantage over random effect and other nonlinear models such as Tobit or truncated regressions (Wooldridge, 2002). It enables us to produce consistent parameter estimates by controlling unobserved heterogeneity that might be correlated with observed explanatory variables both across cross-section and over time (Wooldridge, 2002). So that the inclusion of the fixed effect in this study is very important to control household plot and time invariant characteristics such as farmer’s skills, management abilities, average plot fertility and unobserved plot level variability’s such as unobserved variation in plot quality, plot specific production shocks (e.g. microclimate variation in rainfall, frost, floods, weeds, pests and disease infestations).

So that it is important to model both the individual household plot and time effect. This approach is referred in the literature as Mundlak’s approach (Mundlak’s 1978). This approach relies on the assumption that unobserved effects are linearly correlated with explanatory variables. The use of fixed effects techniques and Mundlak’s approach also helped to address the problem of selection and endogeneity bias, if selection and endogeneity bias are due to time (plot)-invariant unobserved factors, such as household heterogeneity (Wooldridge, 2002). If we failed to control for these factors, we would not obtain the true effect of SWC adoption.

In terms of selection of two stage models, Kyriazidou (1997) proposed a two-step estimation method which provides consistent and asymptotically normal estimators for estimating a panel data sample selection model with latent individual specific effects in both the selection and regression equations. In the first step, the unknown coefficients of the selection equation are consistently estimated and in the second stage, the estimates are plugged into the regression equation of interest. Therefore the choices of Endogenous Switching Regression Model in this study is also important to account the endogeneity problem of the adaptation decision by estimating a simultaneous equation model by using full information maximum likelihood method.

3.3.2.6. Variable specification and working hypothesis

i. **Dependent variables:** This study used switching regression model to study the determinant factors affecting the choice of SWC adaptation to climate change and to study the impact of SWC adaptation to climate change on plot level crop production. That means there are two dependent variables used in this model, SWC adaptation (dummy) and log of plot level value of crop production (continuous).

SWC adoption: This is the dependent variable for the first stage (selection equation) and a dummy explanatory variable for the outcome equation (second stage) of the switching regression model. According to Temesgen (2010), farm household characteristics (such as age of the household, gender, education, farm and nonfarm income), access to extension service and information, farm experience influence a farmer to choose climate change adaptation strategy. In this study, it was hypothesized that farm household characteristics (age, gender, marital status, household size), farm and non-farm income, access to extension service and information, farming experience, farm size, livestock ownership determine the choice of SWC adaptation strategy. It is also hypothesized that adaptation of SWC has a positive impact on plot level crop production.

Log of plot level value of crop production: This is the dependent variable for the second stage of the switching regression model (outcome equation). Log of plot level value of crop production in Birr by household h on plot p, depending on its SWC adoption status on that specific plot was used as a dependent variable. This approach of aggregating all crops on a plot into a single measure of value of crop production has been used in many previous plot-level-based micro-econometric studies in Ethiopia and sub-Saharan Africa (Pender *et al.*, 2004; Benin 2006; Pender and Birhanu 2007; Kato *et al.*, 2009). We used woreda average crop prices to estimate aggregate crop production at the plot level.

The central focus of this study is to investigate if SWC adaptation strategies adopted by farm households do really have any impact on crop output. This level of analysis is advantageous because it captures more spatial heterogeneity and also helps to control for plot-level variability that affect crop production and hence help to minimize the omitted variable bias (Kato *et al.*, 2009).

Both plot-level and household-level covariates (explanatory variables) have been considered in the study. The plot level covariates included plot area, biophysical characteristics (e.g. soil type, slope, soil depth, fertility status), inputs used on the plot (e.g., labor, fertilizer, manure). Household-level covariates included characteristics of the household head (sex, age, education level, farming experience). Therefore, Table 4 depicts the hypothesis made in this study.

ii. **Explanatory variables:** The explanatory variables for the model include: sex of the household head, age, education level of the household head, farming experience, marital status, household size, information through extension contact on SWC, plot characteristics (soil type, soil depth, plot quality, slope, degrees of degradation, and susceptibility to erosion), number of plots a farm household owns, plot distance from homestead, wealth (non-farm income, farm/plot size and livestock ownership), labor, seed, fertilizers, manure, rainfall and temperature variability, and SWC adaptation measures (where adaptation measured by a dummy variable obtained from the selection model influence the production in the second stage of the model). In general, the following explanatory variables are hypothesized to affect household choice of SWC adaptation strategy and plot level production.

Sex of the household head: Male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female-headed households (Asfaw and Assefa, 2004). Moreover, Tenge *et al.,* (2004) argued that being female- household head is negatively related to the adoption of soil and water conservation measures because they have limited access to information, and other resources due to traditional social barriers. In addition to this, Wagayehu (2005) found that household head sex was not a significant factor influencing farmers' decisions to adopt conservation measures. This study followed and hypothesized that male headed households is positively related to adaption of SWC and crop production as compared to female headed households.

Age of the household head: The influence of *age* on these choices has been mixed in the literature. Some studies found that age had no influence on a farmer's decision to participate in soil and water management activities (Wagayehu and Drake, 2003). Others, however, found that age is significantly and negatively related to farmers' decisions to adopt (Dolisca *et al.,* 2006; Nyangena, 2007; Anley *et al.,* 2007). Okeye (1998) and Bayard *et al.,* (2007) found that age is positively related to the adoption of conservation measures. In this study we hypothesize that age of the household head has both positive and negative impacts on SWC adaptation measures. In this study it is assumed that old age is associated with more farming experience and expected older farmers to adapt SWC to climate change. However, we also expect young farmers to have a longer planning horizon and to take up long-term adaptation measures such as SWC. It is also expected that the variable age of the head affects crop production negatively.

Education level of the head in years: Education is one of the important factor which influence SWC adaptation decision and production. Several studies have shown that improving education is an important policy measure for stimulating local participation in various development and natural resource management initiatives (Dolisca *et al.,* 2006; Anley *et al.,* 2007; Tizale 2007). Better education can improve awareness of potential benefits and willingness to participate in local natural resource management and conservation activities. However, Clay *et al.,* (1998) found that education was an insignificant determinant of adoption decisions, while Okeye (1998) and Gould *et al.,* (1989) found that education was negatively correlated with such decisions. In this research it is hypothesized that improved education can positively influence the probability of farmers' decisions to take up SWC adaptation measures and intern increase land production positively.

Farming experience in years: Farming experience is the other important factor which influences SWC adoption decision and crop production. Experience improves awareness of potential benefits and willingness to participate in local natural resource management and conservation activities. More experienced farmers are expected to have more knowledge and information about climate change and agronomic practices that they can use in response (Maddison, 2006). Therefore this research also hypothesized that farming experience has a positive impact on SWC adoption decision and crop production.

Household size: It refers to the total number of household members in a family. Adoption of SWC technology requires considerable labor for the construction of the different types of structures. For instance Million (2010), argue that households with a larger pool of labour are more likely to adopt SWC agricultural technology. And it is hypothesized that households with large household size to be more likely to adapt SWC adaptation to climate change. In addition, it is hypothesized that household size and plot level production are positively related.

Land holding: It refers to the total land holding owned by the household in meter squares. Regarding the relationship between land holding and adoption of improved technologies, there are two schools of thought. One argues that the variable has a positive influence on adoption of new farm technologies as farmers with large land holding generate more income (Shiyani *et al.*, 2000). Another argument advocates that farmers with small land holding utilize their limited resources more efficiently and adopt new technologies at faster rate (Endrias, 2003). In the present study, the latter argument is hypothesized since there is probability that smaller farms will adopt improved SWC structures. So a negative relationship is expected between land holding and choice of SWC adoption decision. Moreover, it is also hypothesized that land holding is negatively related to land production.

Plot ownership status: A number of studies have demonstrated that security of plot ownership has a substantial effect on the agricultural performance of farmers (Menale *et al.,* 2012; Deininger *et al.,* 2009). The variable is categorical taking values (1=Own 2=Rented in 3=Rented out 4=Shared in 5=Shared out). In an area where land is scarce and search costs are high, tenants are likely to apply more short-term inputs and management techniques in rented in plots rather than long term conservation structures such as SWC. This is due to treat of eviction from use of the plot (Menale *et al.,* 2012). And in this study it is hypothesized that own plot ownership status affect SWC adoption decision positively.

Number of plots a farmer has per year: Number of plots that a given farmer has in a given year is one of the explanatory variables expected to have an impact both on farmer's choice of SWC adoption decision and crop production. We expected households with more number of plots are less likely to invest in SWC structures due to the possible plot fragmentation that may potentially affect investment in SWC measures and plot level output. Accordingly it is hypothesized that total number of plots a given farmer has is negatively related to SWC adaptation and crop production.

Plot distance from homestead in meters: It is hypothesized that as distance to plot from homestead increases, SWC adaptation to climate change decreases. Plot proximity to homestead is also an important determinant both to SWC adoption and production presumably because as the plot is near to the homestead there could be a continuous follow up and management which also increases production. Therefore it is also hypothesized that plot distance and production are negatively related.

Household livestock holding (in TLU): Livestock plays a very important role by serving as a store of value, source of traction (especially oxen) and provision of manure required for soil fertility maintenance (Chilot, 2007). Thus, for this study, livestock ownership is hypothesized to increase SWC adoption decision and further increase the household crop production positively.

Non-farm income: Non-farm income represents the amount of income the farmers earn in the year out of on-farm activity. It is argued that participation in non-farm income generating activities will help in conservation adaptation decision that requires financial capacity of farmers

(Franzel, 1999; Knowler and Bradshow, 2007). And the households engaged in non-farm activities are better endowed with additional income to purchase inputs which can increase farm production (Yishak, 2005). In this study, it is hypothesized that the availability of non farm income is positively associated with the probability of adopting SWC measures to climate change and further in increasing crop production.

Labor in person days: Labor is the most important input which directly contributes to crop production and the decision to adopt SWC measures. Labor in person days refers to the total number of actual days the household spends for specific crop on a given plot. It is based on one person days equal to eight hours of daily work. According to (Adugna, 2008), it is assumed that adequate labor supply positively contribute to SWC investment decision and crop production. In this study it is hypothesized that the number of labor input in person days positively influence both SWC adoption decision and crop production.

Chemical fertilizer uses: It is dummy variable taking value 1, if the farmers used chemical fertilizers on a given plot and 0 otherwise. The use of fertilizer has been perceived as improving yield per unit area. Hence, it is hypothesized that the households using fertilizer are expected to be more productive than the non-users.

Manure applied in kg: This is a continuous variable calculated in kg if the farmers used (applied) manure on their plots. It is one of the most important input variables which can improve crop production. Manure contributes as one of the organic agricultural inputs that can improve the fertility of the soil and it augments agricultural production by boosting overall production, which in turn contributes to attaining household's food security. Hence, it is hypothesized that using manure and production are positively related. However, the relationship between manure use and investment in SWC may be negative.

Soil characteristics (plot quality, degree of degradation, susceptibility to erosion, soil type): Plot quality degree of degradation, susceptibility to erosion, soil type, slope and soil depth are categorical variables taking values poor medium and good for the variable plot quality. High, moderate and no degradation for the variable plot degrees of degradation. Highly susceptible, medium, low and non-susceptible for the variable plot susceptibility to erosion; black, dark brown, red and white are the categories for the variable soil type. Previous studies have found that plot quality, plot slope, soil type, to be a positive and significant determinants of SWC choice and impact on farm production (Amsalu and De Graaff, 2006; Wagayehu and Darke, 2003; Marenya and Barrett 2007). In this study it is hypothesized that all soil characteristics are the major factors that are expected to affect farmer's decision for SWC adoption and crop production positively.

Frequency of extension contact: Agricultural extension is one of the sources of agricultural information. Extension on crop and livestock production and information on climate represent access to the information required to make decision on SWC adaptation to climate change. Various studies in developing countries including Ethiopia reported a strong positive relationship between access to information and the adoption behaviors of farmers (Chilot, 2007). Moreover, Maddison (2006), and Nhemachena and Hassan (2007 and 2008) showed that access to information through extension increase the chance of adapting to climate change and enhance household level production. Thus, it is hypothesized that frequency of contact with extension workers will increase the likelihood of adopting SWC adaptation strategy to climate change and intern increase their production.

Climate variables such as temperature and rainfall: Detailed analysis of the relationships between climatic variables such as temperature and rainfall on adaptation requires a time serious data of how farmers have behaved over time in response to changing climatic conditions. Thus, given the farming situation in Ethiopia, it is hypothesized that farmers adapt to increasing temperature and decreasing rainfall, as more warming and less precipitation adds more pressure on the already water scarce agriculture.

Table 4: Variable definition and expected effects

Dependent Variables	**Definitions**	**SWC Adoption**	**Production Effect**
SWC Adoption	Dummy=1 if the household adopted SWC to mitigate the effect of climate change and 0 otherwise		
Log of plot level output in Birr	Log of plot level output in Birr (continuous variable)		
Explanatory variables			
HH Characteristics			
Sex/Male	Dummy=1 if the household head is male, 0 otherwise	+	+
Age of the head	Age of the household head	+/-	-
Marital status	0= Not married 1=Married 2=Divorced 3= Widowed	+	+
Education in years	Education level in years	+	+
Farming experience	Farming experience in number of years	+	+
Household size	Number of Household members	+	+
Asset			
Plot size	Plot size in m^2	-	-
Land holding size	Total land holding size in m^2	-	+
Plot ownership status	Categorical (1=Own 2=Rented in 3=Rented out 4=Shared in 5=Shared out	+	+
Number of plots	Number of plots a farmer has per year	-	-
Plot distance	Plot distance from homestead in meters	-	-
TLU	Livestock holding (ownership) in Tropical Livestock Units (TLU)	+	+
Non-farm income	Annual non-farm income amount obtained in value terms (in birr)	+	+
Inputs			
Labour	Labor use in man days per hectare	+	+
Chemical Fertilizer	Plot level chemical fertilizer use in kg	+	+
Manure	Plot level manure use in kg	+	+
Plot level Soil Characteristics			
Plot Soil type	Categorical (1=Black 2=Dark brown 3=Red 4=White (poor in qality)	+	+
Plot quality	Categorical (1=Poor quality 2=Medium quality 3=Good quality	+	+
Degrees of degradation	Categorical (1=Highly degraded 2= Moderately degraded 3=Degraded 4=No degradation	-	-
Plot slope	Categorical (1=Plain/Meda 2=Foot hill/Tedafat 3=Mid hill/Daget 4= Steep slope/Gedel	+	+
Plot susceptibility to erosion	Categorical (1= Highly susceptible 2= Medium susceptible 3= low susceptibility 4=Non Susceptible to Erosion	+	+
Extension contact frequency /FEC/			
FEC for SWC	Frequency of the farmer contacted by an extension agent for SWC	+	+
FEC for fertilizer	Frequency of the farmer contacted by an extension agent for fertilizer	+	+
FEC for improve seed	Frequency of the farmer contacted by an extension agent for improved seed	+	+
Climatic Factors			
Rainfall	Average annual rainfall rate in mm	-	+/-
Temperature	Average annual temperature in degree Celsius	+	-/+

4. RESULT AND DISCUSSION

The results and discussion part is presented in four sections. The first section deals with the sources of risks, and vulnerability. The second section deals with households risk coping and adaptation strategies to respond to climate change. While the third section deals with the socioeconomic conditions of the sample farmers in the three survey periods comparing SWC adopters and non adopters, the econometric model result is discussed in section four.

4.1. Major Sources of Agricultural Risks and Climate Change in Wolaita

Different sources of risk constrain agricultural production in the study district. The risk sources identified are climate change, drought, production risks (insect pest and animal diseases), market risk, and health related risks (Table 5).

4.1.1. Climate change as source of risk

In consultation with farmers and agricultural experts in the study site, different types of sources of risks were identified. The sample farmers were asked to rank the frequent and the most important sources of risk that affected their farming activity. The result of the subjective assessment of the sample farmers are summarized in Table 5.The surveyed households reported to have encountered many environmental shocks mainly high temperature, hailstorms and drought. Over the previous 10 year period, the households reported that 45% of the shocks were high temperature, 28% were hailstorms and 15% were drought (Table 5). According to the farmers, the relative increase in temperature of the area in the last ten years was related to the drought occurrence shock which affected the farmers.

Erratic rainfall pattern makes decision in agricultural activities uncertain and very suspicious. Farmers explained that they usually do not get the rain showers when they want to have them. Such uncertain rainfall was usually manifested through some heavy falls and frequent dry-spells. This was considered as the major sources of production risk.

Moreover, when climate change shifts occur, there were also other directly and indirectly related problems such as children death, prevalence and spread of diseases and pests, livestock death, selling of asset to survive the existing problem, and migration. Family members would scatter to different places and sometimes the household heads abandon their children because they were unable to feed their children. Most farmers in the FGD mentioned that more than half of their population left the area in search of daily labor and other job opportunities to towns because of the impact of the existing problems.

Table 5: Frequent sources of risks in the last 10 years

Rank	Frequent sources of risks/shocks in 10 Years	Frequency	Percent
1	High temperature	91	45.05
2	Hailstorms	56	27.72
3	Drought	31	15.35
4	Illness of family member	9	4.46
5	Floods	8	3.96
6	Rainfall shortage	4	1.98
7	Crop disease/pests	2	0.99
8	Shortage of food	1	0.50
	Total	202	100

Source: Own computation from survey result, 2011

Similarly, the result of descriptive statistics of most important risk with respect to the effect on their farming activity showed that 33 percent of the sample farmers reported that rainfall shortage was the first and most important risk that affected the farming activities of the surveyed farmers. Flood occurrence (14%) and unexpected drop in output price (12%) were the second and third most important risks that affected the farming activities of farmers (Table 6).

In this study, it is observed that some of the most frequent and highly ranked risks have less effect on farming activities where as the less frequent risks has serious effect on crop production (farming activity). For example, the result implies that the most frequent risks that were ranked 1st and 2nd (high temperature =45% and hailstorm=28%) in table 5 are ranked least in terms of affecting the farming activities of farmers (only 2% for both high temperature and hailstorm) in table 6, which is also consistent with the result obtained from focus group discussion.

Table 6: Most important risks that affected farming activity in the last 10 years

Rank	Most important risks that affected farming activity	Com Freq	Com Percent
1	Rainfall shortage	199	32.84
2	Flood	83	13.69
3	Unexpected drop in price	70	11.55
4	Illness	65	10.73
5	Bad investment/credit related risk	51	8.42
6	Crop disease/pest	43	7.09
7	Loss of land ownership status	38	6.27
8	Sudden death of family members	11	1.82
9	High temp	10	1.65
10	Hailstorm	9	1.49
11	Others	27	4.46
	Total Size	606	100

Source: Own computation from survey result, 2011

In general, based on the frequency of occurrence and their effect on farming activity, risk related to climate change are the most important sources of risk. The farmers also mentioned that each year there are climatic events that represent risks in their area. These risks arise from normal day to day, seasonal and year to year variability in rainfall and temperature.

4.1.2. Drought and food shortage

Water is an essential resource for all life and requirement for food production, good health and sanitation (Stern, 2006). It is a critical input for agriculture, industry and essential for sustainable growth and poverty reduction. Climate change will alter patterns of water availability by intensifying the water cycle. So that drought and floods will become more severe in many areas. Through times, differences in water availability between different regions will become increasingly pronounced and areas that were relatively dry are likely to become drier (Stern, 2006).

Households in the study area had several experience of food shortage for the last 12 months and last six years due to drought occurrence and other production loss. Results from Table 7 indicate that households on average face food shortage about 5.58 months per year and on average 1.12 year for the six years period. This implies farmers in the study area almost face food shortage for more than 5 month per year and more than a year out of every 6 years.

Table 7: Mean number of months the HH face food shortage in year 2011 and the past 6 years

Food Shortage in Months	Numb of Obs.	Mean in months/years	Std. Err.	95% Conf. Interval	
Food shortage last 12 month/2011	193	5.58	0.4843	4.62	6.53
Food shortage last six years (2005-11)	200	1.12	0.4955	12.32	14.27
Total sample households	204				

Source: Survey result in 2011

A great majority of the farmers (about 98.03 percent) have encountered food shortage at least one month in the last six years. Most of the households (about 94.60 percent) face food shortage two to eight months during the last twelve months (year 2011).

Although drought is not a new phenomenon in the study area, it has become severe and frequent in recent years. As compared to past decades, the drought cycle is repeated almost every year or two, giving no time to recover from its impacts (Table 9). Particularly, the last ten years have seen more frequent and prolonged droughts. During the recent drought, the rains were not only insufficient but also extremely unpredictable.

4.1.3. Illness as sources of risk

Climate change is expected to have wide-ranging consequences for human health. For the health of communities depends on sufficient food, safe drinking water, comfortable homes, good social conditions, and a suitable environmental and social setting for controlling infectious diseases. All of these factors can be affected by climate (Williams, 2002).

Illness of family member was also another risk factor that occurred frequently in the last ten years. Sample farmers mentioned and ranked this factor in 4th place both in terms of frequency of occurrence and its effect on farming activity. The result indicated that 11 percent of the surveyed farmers mentioned that illness of the household head which is related to climate change, is the most important source of risk which affected their farming activity.

The personal or health risk is the most important sources of risk faced by the farmers in the study area. This has a considerable impact on their production. Illness due to malnutrition, diarrhea, malaria, and other water-borne diseases caused by climate change considerably undermine the potential return for labour availability in the study area.

4.1.4. Other sources of risk

Market price as source of risk: Related with the market, result from the surveyed farmers indicates that both high input prices and unexpected drop in output prices are the major sources of risk faced by the farming community. Especially in cases of crises, the farming community supplies to sell what it has, not for profit generation but to settle costs of living. And the farmers are certain about how much they would be underpaid for their products and how much they would be overcharged for input goods and services. The farmers are asked to pay unreasonable prices for what the market supplies and in return they are given a lower price for their products.

Population as sources of risk: The other source of risk in the area is high population pressure. The study area is well known with high population growth. And this population growth has resulted in out migration due to lack of capacity for a given household to support the needs of all the family members. The focus group discussion result showed that the rapid population growth coupled with a stagnation of agricultural technology makes it difficult for agricultural production to keep pace with the rising demand for food. Furthermore population growth is also becoming one of the major sources of risk which brings about migration.

4.2. Climate Change and Adaptation Strategies in Wolaita

There is growing evidence that climate change is increasing the frequency and intensity of climate-related hazards (IPCC, 1995). Farming is the primary occupation for almost all of the households in the study sites although they combine some level of non-farm income sources. This high degree of dependence on farming calls for major adaptation in the farming sector as it is directly affected by climate change. Farmers in the study area have perceived and adopted different strategies to cope up with the consequences of climate change.

4.2.1. Farmers perception of climate change

Farmers' perception of climate change is the condition for their initiation of adaptation practices. As many studies indicated a large numbers of agriculturalists already perceived that the climate has become hotter and the rains less predictable and shorter in duration (CEEPA, 2006). Such understanding is the main derive for farmers and policy-makers to initiate adaptation strategies.
The analysis of the perception of farmers to climate change indicates that most of the farmers for this study are aware of the fact that temperature is increasing. To get information on their perceptions to climate change, farmers were asked if they have observed changes in rainfall or temperature over the past six years. Table 8 shows how farmers perceive changes in the major indicators of climate change.

Table 8: Farmers perception of climate change in last 6 years compared with the previous time

Perception Indicators	Number of respondents	Yes		No	
		Number	Percent	Number	Percent
Shortage of rainfall	203	148	72.91	55	27.09
Increase in temperature	202	170	84.16	32	15.84

Source: Survey result, 2011

Summary statistics from Table 8 shows that about 78.52% of the respondents were of the opinion that there have been some changes in the climate over the last 6 years. Of the total respondents, 73 % perceived that there was shortage of rainfall in the last 6 years compared to the previous times. And 84 % perceived that there was increase in temperature in the last 6 years compared to the previous periods (before 2005). The majority of the farmers observed changes in the amount of rainfall during the main season, delay in timing, a reduction in the number of rainy months. Indeed this perception is in line with the finding from the FGD that weather fluctuation, drought and food shortage were the most important challenges faced by most families. These are also the most important economic stresses and risks challenging most families in the community.

The result from surveyed farmers and FGD results indicate that there are changes in the on-set of rainfall. In previous times the rain starts in January (*tire*) but after 2003 onwards it is starting in February, March or in April. That means in previous periods the dry period per year is for almost four months but this time especially since 2003, the dry period per year increased to eight months (starting from September to April it is dry period). And rainfall shortage problem mostly occurs between the months of January and April. This is the critical period for *belg* season production where all farmers of the study woreda fulfill their annual demand. These days, starting from January to April it is a period of high temperature and occurrence of frequent drought. That means on average most farmers face four months of drought period per year. The famers also mentioned that the drought situation is directly related with the rainfall shortage. But FGD farmers mentioned that even if rain shortage occurs they wouldn't always face drought. This is because they try to manage through planting their crops according to the onset of the rainfall and most of the times by re-sawing their crops.

Table 9: Percentage of years of dry spell and rainfall shortage occurrence in the last 10 years

Group	Years of dry spell of the total 10 years	Years of RF shortage of the total 10 years
1	5	6
2	4	4
3	6	6
4	6	6
5	4	4
6	5	4
7	4	4
Average	4.48 years	4.48 years

Source: Survey result, 2011 RF=Rainfall

In general, the frequently experienced climatic shocks are increase in temperature and prolonged drought, delay in the onset of rain, erratic and low precipitation, and heavy and unseasonal rainfalls. The interviewed households perceived the overall increasing temperature and downward trend of precipitation. The FGD result also indicated that the challenges are severe and more frequent since the last 10 years. And it is observed that in almost five years out of ten years, there was occurrence of both drought and rainfall shortage which makes the frequency of drought in the area to be once every other year's i.e. one drought year in every two years (Table 9).

Therefore, it is observed that the responses from the farmers' and their perceptions show their good level of understanding of the majority on climate change occurrence and it is in line with the long term rainfall and temperature result from CIMMYT-GIS database, which depicted an increasing trend in temperature and decreasing trend in precipitation in the next section. However, while still significant proportion (21.47 %) failed to perceive the change from the survey result. This should be considered as a target for the extension system which is helpful to provide information on climate change related issues.

4.2.2. Climate change and variability

Climate change, today, is one of the greatest economic and environmental challenges faced by the world and every individual. The Intergovernmental Panel on Climate Change refers to climate change as any change in climate over time, whether due to natural variability or as a result of human activity. The United Nations Framework Convention on Climate Change, however, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Climate change is a complex biophysical process. Even though it is difficult to predict precise future climate conditions, there is a scientific consensus that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades (IPCC, 2010).

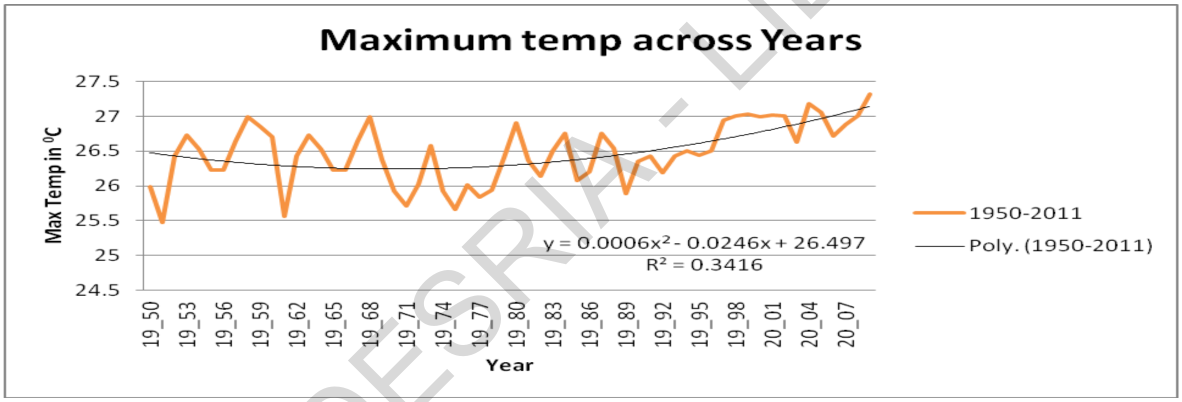
Climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures), etc. Current climate variability is already imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters. Moreover, climate change is a great concern for agriculture and its effects are likely to vary between different regions and different scales (global, regional, and local).

To understand the long-term climate change and variability, the historical mean annual temperature and rainfall data in Damot Sore district from 1950 to 2011 (61 years), were analyzed. Analysis of pattern of the local climate (rainfall and temperature pattern) in the study area over the last six decades also reveals that there has been increased rainfall variability and temperature rise (Fig 2 and 4).

4.2.2.1. Temperature trend

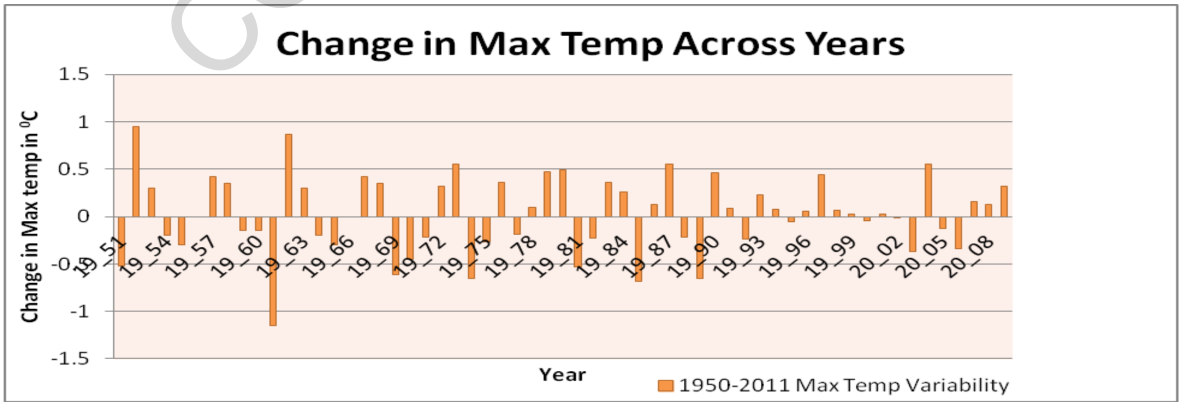
The long term climatic change related to temperature change is the most likely cause of drought in Ethiopia in general and the study area in particular. The long term temperature data analysis (1950-2011) from Wolaita provides the year to year variation of annual maximum temperature, expressed in terms of temperature differences from the mean. The result shows that the area experienced both warm and cool years over the last 61 years. However, the recent years are the warmest, compared to the early years. According to NAMSA (2011), the annual average maximum temperature has been increasing by about 0.1^0c every 10 years and the minimum by 0.25 ^{0}c every decade. The data from this study reveals that there has been a warming trend in the annual maximum temperature over the past 61 years. Temperature has been increasing by about 0.162 ^{0}c every ten years, which is higher by 0.062 ^{0}c from the national average (Figure 2 & 3).

Figure 2: Historical trends of maximum temperature in Wolaita (1950-2011).



Source: CIMMYT-GIS database and NMA

Figure 3: Patterns of annual temperature variability in Wolaita (1950-2011).



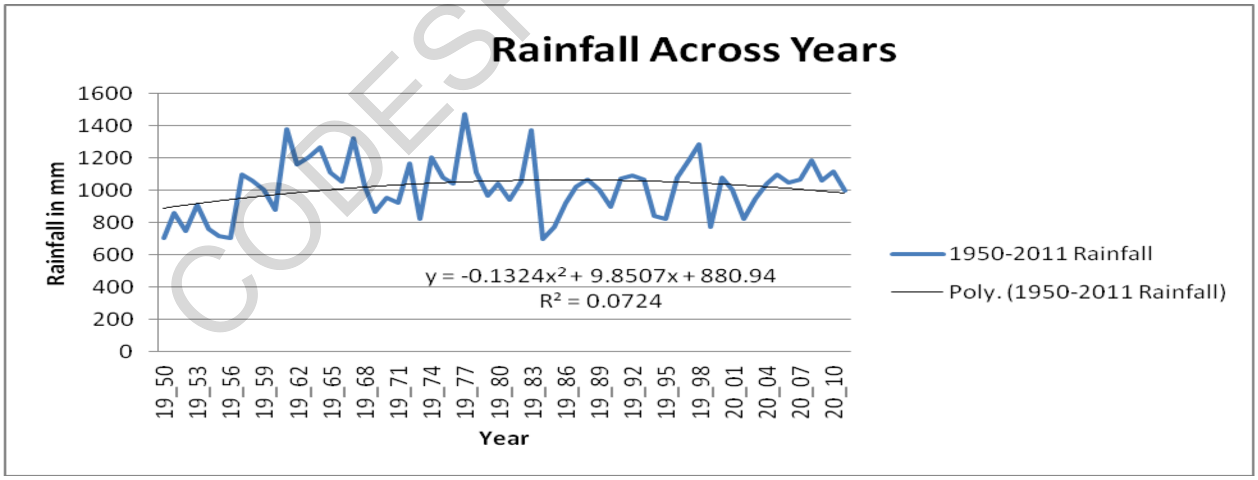
Source: CIMMYT-GIS database and NMA

Moreover, it is well recognized that small increases in temperature can result in measurable impacts on the health of human beings and livestock as well as the availability of water, food and feed resources. Hence, the changes in the patterns of rainfall and temperature have already created pressure on the availability of water, forest, and range resources thus exacerbating food and feed shortage and making the environment more vulnerable and less resilient to future climate changes. As a result, the people in the study area are exposed to the risks of several climate related hazards such as drought, flooding, epidemics, migration and pest occurrence, etc.

4.2.2.2. Rainfall variability

Rainfall (Weather) variability is one of the major challenges of crop as well as livestock production. Late rains, early cessation and insufficient rains are rainfall related problems, which negatively affect crop production in the study area. Farmers in the study area mentioned that erratic rainfall pattern makes decision in their agricultural activities doubtful and very vigilant. And they explained that they usually do not get the rain showers when they want to have them. Such precarious rainfall, usually manifested through some heavy falls and frequent dry-spells, is the major sources of production risk.

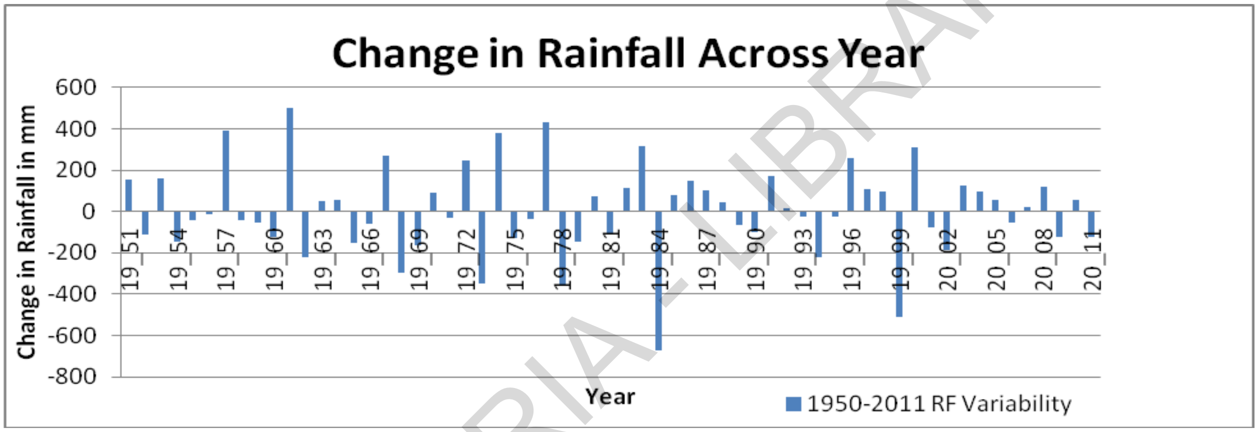
Figure 4: Historical trends of rainfall in Wolaita (1950-2011)



Source: CIMMYT-GIS database and NMA

According to the long term metrological data analysis, rainfall distribution in the study area is also characterized by high degree of inter-annual variability. The data shows that the area has experienced both dry and wet years over the last 61 years. Over the 1950-2011 periods, the average annual rainfall was 1034.19 mm and further, analysis of the linear trend of annual rainfall indicates a decrease from 1950 to 2011. According to NASA (2011), over time the amount of the national rainfall is exhibiting a declining trend with increasing variability. Similarly, according to the long term rainfall data from the study area, the average annual rainfall trend in the past five to six decades showed a declining trend, which is in line with the finding of NAMSA (Fig. 4 & 5).

Figure 5: Year to year rainfall variability in Wolaita (1950-2011)



Source: CIMMYT-GIS database and NMA

Farmers also mentioned that they use traditional ways of climate change adaptation for weather fluctuation. This includes changing the timing of planting based on the rainfall situation. This is practiced by many farmers in the area due to inadequate information service about rainfall and temperature patterns in the forthcoming season. The farmers understood that the weather is changing and what they currently doing are to follow the onset of the rain and adjust their planting date accordingly. And there are times that they re-sow their field 2 or 3 times and sow other crops if the rain was interrupted. So, they are coping through changes in plantation timing. However, the farmers are also facing a big challenge in forecasting what is going to happen in the future. In previous times, they have the ability to predict about the weather and even they knew the day when the rain will start and act accordingly but these days they are unable to do that.

4.2.3. Major coping and adaptation strategies of the farm households

This part of the research identified the main coping and adaptation methods used by farmers to climate change and the barriers to adaptation. The important coping strategies used by farmers in the study area include: sale of animal, reduce consumption, rely on social network (*eqiub)*, skipping meals, using low cost food and renting out land and animals.

Important adaptation options being used by farmers include iddir/local insurance participation, fertilizer application/usage, increased use of soil and water conservation techniques, planting of improved variety, crop diversification, changes in planting dates, and planting root and tuber crops such as sweet potato, cassava, yam and *enset* etc.

4.2.3.1. Coping strategies

Most of the surveyed farmers who reported to have experienced different shocks have also adapted their own ways of coping mechanisms through long time experience for the respective shocks/risks. Farmers use different coping strategies such as selling livestock, consumption reduction and skipping meals (breakfast or lunch) as coping strategies, respectively. The other utilized coping strategies include: relay on social network (*eqiub*), using low cost food, rent out land and animals, and borrowing money from creditors. Table 10 describes the different types of traditional coping strategies practiced by farmers under different climatic shocks in percent.

Sale of animals: Livestock selling is the most common coping strategy for sudden stress and shocks. 34% of the surveyed farmers who experienced shocks over the past ten years sold livestock to cope. Implication of livestock selling during times of shocks has an asset depletion effect to most resource poor farmers in the study area.

Reduce consumption and skipping meals: Consumption reduction (28%) is the second most effective traditional risk coping mechanism used by the sampled farmers in the study site. During acute disasters, households change their normal food intake and adjust their consumption to the available household resources. Consumption smoothing usually involves adjusting diets to cheap food items, supplementing with edible wild plants and fruits, and reducing the amount and frequency of meals. And out of the surveyed farmers 9 percent were skipping meals such as breakfast or lunch as coping strategy.

Table 10: Most effective traditional risk coping mechanism practiced by surveyed farmers

Rank	Traditional risk coping mechanism	Percent
1	Sale animals	33.66
2	Reduce consumption	28.22
3	Rely on social networks such as *eqiub*	13.37
4	Skip meals such as breakfast or lunch	8.91
5	Depend on locally available low cost food	7.92
6	Rent out land	2.97
7	Rent out animals	0.99
8	Rely on saving	0.99
9	Working daily labor work	0.99
10	No effective means of coping	0.99
11	Selling home material	0.5
12	Borrow many from credit association	0.5
	Total	**100**

Source: Survey result, 2011

Rely on social networks such as *eqiub*: The descriptive result shows that, 13% of the surveyed farmers use informal institutions such as *eqiub* as coping strategies when they face sudden shocks. And they sometimes benefit from assistance obtained from friends and relatives. Farmers can take credit from local informal institutions when they face a shock, but the *eqiub* will not be sufficient to help all households in the community. And this time, because of the different problems families face, it is not possible to get assistance from friends and relatives. Instead the assistance is changed in to lending money with high informal interest rate during the times of stress and cultural festivals.

Copping strategies such as depend on locally available low cost food, rent out land, rent out animals, working daily labor, selling home material, borrowing money are some of the mentioned copping strategies by the sample farmers in the study area.

4.2.3.2. Farmers adaptation strategies to climate change

The effect of the climate change variations and climatic constraints in the study area are numerous. The prolonged and increasing temperature, combined with the declining of rainfall and frequency of drought, as well as the marked degradation of soils, have resulted in a succession of bad crop years.

There are a number of household agricultural practices and investments that can contribute to climate change adaptation. The adaptation methods most commonly practiced in the study area include soil and water conservation, fertilizer application (usage), *iddir* /local insurance participation, planting of improved variety, crop diversification, change in planting dates, planting root and tuber crops and tree plantation for conservation (Table 11). Thus, there are often long term benefits to households from adopting such activities in terms of increasing yields and reducing variability of yields, making the system more resilient to changes in climate.

***Iddir* / local insurance participation:** From Table 10 it can be observed that *iddir* / local insurance participation is the major adaptation strategy used by the farmers. Almost all (98.51 %) of the farmers have *iddir* / local insurance as an adaptation. And this type of adaptation is used mainly during times when a household lose one of its family members due to death. And it is not common to give the *iddir* / local insurance for other activities such as crop failure or livestock death. And the researcher assumes that as *iddir* / local insurance participation as an adaptation strategy is not directly related to agricultural productivity or climate change, the strategy is not considered to study the impact on crop production.

Table 11: Major adaptation strategies used by surveyed farmers in 2011

		Users		Non-users	
Adaptation strategy	Total No. of HH	Freq	Percent	Freq	Percent
Iddir/local insurance participation	202	199	98.51	3	1.49
Fertilizer application or usage	204	186	91.18	18	8.82
Soil and Water Conservation	204	131	64.22	73	35.78
Planting of improved variety	204	47	23.04	157	76.96

Source: Survey result, 2011.

Fertilizer usage: About 91% of the respondent households across all villages have used fertilizer at least in one of their plots in the last six years. However, about 9% of the surveyed households however never applied or used fertilizer on their plots. One can observe that a significant proportion of farmers have used fertilizer as a means of adaptation strategy to improve production on their plots.

However, the average intensity of fertilizer used per plot in the study area is too small (3.5 kg per hectare). This makes that there is no proper application of fertilizer as per the research recommendation and to the extent to consider as an adaptation strategy.

Thus because of the limited application of fertilizer per hectare in the study are, fertilizer application as an adaptation strategy to climate change is not considered in this study even if the percentage of usage is high (91%). Instead SWC adaptation strategy is considered to study the impact on agricultural crop production as it can represent the real situation in the area.

Soil and water conservation: From Table 11 above, about 64% of the respondent households across all villages have used plot level Soil and Water conservation as an adaptation strategy. Again 36 % of the surveyed households do not practice SWC as an adaptation strategy (lack SWC structures in their farm).

Typical SWC technologies used in the study area include grass strips, traditional ditches, planting of banana strip, *enset*, crop-residues/trash line, stone/soil bunds, raised boundary bunds, cut off drains, construction of artificial water ways and *Fanya juu*. These structures are mainly built to control runoff, thus increasing soil moisture and reducing soil erosion. Different alternative SWC methods are being used by farmers according to their preference based on consideration of the cost, the efficiency and sustainability. According to the farmers soil and stone bunds are relatively costly as compared to the other structures and they use alternative methods of SWC structures such as grass strips, traditional ditches and artificial water ways to control runoff, increase moisture and to reduce soil erosion.

Planting improved crop varieties: The use of different types of improved varieties for different crops (23%) is another strategy adopted by farmers (Table 11). The use of different improved crop varieties as an adaptation method could be associated with the lower expense and improved access for some of Maize, Haricot bean and root crops such as Sweet Potato, Yam (Boye), Taro (Boyena) from the nearby Areka Agricultural Research Center. However, 77% of the sample farmers mentioned that they lack the access for having improved varieties for different crop types they grow. Instead they were forced to use their own source of seed, purchase local seeds from other farmers or purchase from market in order to minimize production risk.

Crop diversification: As the farmers in the study area faced different climatic related problems, they have now learned from their past experience to plant different drought resistant crop types in order to prevent the risk that will result from single crop dependence. Intercropping is also one means of crop diversification which is practiced by most farmers. Most of the time farmers rely on crops which are drought resistant such as false banana, root crops (potato, sweet potato, yam, taro), cereals (maize and wheat), pulses (haricot bean) and coffee. According to the surveyed farmers, a given farmer on average had more than 8 plots with different crop types in different times. Table 12 shows the average number of plots per farmer increased from 7 to 10 between the periods 2005 to 2011. This implies that farmers are increasing their crop diversification behavior in order to minimize the risk that is caused by climate change.

Table 12: Number of plots owned by farmers across different years

Variable	Year	Obs.	Mean	Std. Dev.	Min	Max
Number of Plot	2005	1287	7.26	2.64	2	14
Number of Plot	2007	1190	6.67	2.43	2	16
Number of Plot	2011	1797	10.17	3.95	1	27
Total/Average		4274	8.03			

Source: Survey data result in 2005, 2007 and 2011

Changes in planting dates: Farmers in the study site mentioned that they use traditional ways of climate change adaptation for weather fluctuation. This includes changing planting dates based on the rainfall situation. This is practiced by many farmers in the area due to inadequate information service about rainfall and temperature patterns in the forthcoming season. Farmers understood that weather is changing and what they currently doing are to follow the onset of rain and adjust their planting date accordingly. And there are times that they re-sow their field 2 or 3 times and sow other crops if rain was interrupted.

Participant farmers in this study also reported that rainfall unpredictability is important challenge in recent years compared to previous years. In previous times they have the ability to predict about the weather and even they knew the day when the rain will start and act accordingly but these days they are unable to do that because of climate variability and lack of information. So, they are coping through changes in planting dates and other immediate responses.

As it is observed in the study area, farmers have more coping strategies compared with the available adaptation strategies. This could be due to lack of information on appropriate adaptation options due to scarcity of research on climate change and adaptation options. Lack of money also hinders farmers from getting the necessary resources and technologies that facilitates adapting to climate change. This is true since adaptation to climate change is costly. Poor irrigation potential of the study woreda is one reason most likely associated with the lack of adequate adaptation strategies for climate change. Shortage of land has been associated with high population pressure in the area, which forces farmers to intensively farm a small plot of land. Given the high percentage of households without any adaptation, it shows the importance of having strategies for adaptation to climate change.

4.3. Socioeconomic Characteristics of Sample Households

Descriptive analysis of the socioeconomic characteristics of the household in the SWC adopters and non adopters groups are presented in Table 13.The results of the analysis show that there is a statistically significant difference in mean values of the two groups with respect to age, household size, income, farm size, livestock holding in terms of TLU, oxen holding, farming experience and in terms of input use such as fertilizer application all at 1% level of significance. Whereas other variables like total plot number, labour in man days show significance difference at 5 %level. But the t-ratio shows that there is no statistical difference between SWC adopters and non adopter household groups in terms of years of education of the head, total number of working force group (adult labor) in the household and manure application.

The detailed description of each variable for both SWC adopters and non-adopters groups of farmers in terms of their socioeconomics characteristics are discussed below in Table 13.

Household age: Age of head of the household is one important variable which characterizes different households. The survey result shows that the average age of the head of household was 44.05 and 45. 32 years for SWC adopters and non-adopters, respectively. Age of head of household was significant at 1% between SWC adopters and non-adopters.

Table 13: Socioeconomic characteristics of sample farmers (continuous variables)

Differences for plots with and without soil and water conservation, mean comparison test					
Variable	without SWC	with SWC	Differences	S.DV	|t|-ratio
Age of the household head	45.32	44.05	1.27	13.27	4.15***
Education level in years	4.11	4.18	-0.07	4.08	0.56
Household size	7.28	7.55	-0.27	2.44	4.80***
Nonfarm income /other source of income	984.53	1582.42	-597.89	2774.65	9.40***
Total Income (farm income + nonfarm income)	10482.23	14122.54	-3640.31	14487.37	10.99***
Plot size in meter square	770.79	731.65	39.14	1009.42	1.67*
Total Land size owned by the farmer	6033.52	7426.80	-1393.28	9517.09	6.38***
Total livestock holding in TLU	2.67	2.86	-0.18	1.71	4.62***
Total number of oxen owned by the farmer	0.96	1.10	-0.13	0.69	6.38***
Farming experience in years	25.41	26.92	-1.51	12.47	5.16***
Plot level labour input in man days	7.60	9.89	-2.29	41.99	2.37**
Plot level manure applied in kg	1072.87	428.62	644.26	20978.18	0.95
Plot level Urea applied in kg	1.86	9.76	-7.90	37.13	3.79***
Plot level Dap applied in kg	4.61	6.54	-1.93	9.08	5.49***
Plot distance from the homestead in meters	92.77	152.36	-59.59	403.85	6.20***

*** = Significance at 1% level of significance**= significance at 5% level of significance *= significance at 10% level of significance

Family Size: As is true in many low income countries, household membership in Ethiopia is a declining function of age due to high birth rates and low life expectancies. The total fertility rate is 5.9 children per woman, which ranks among the highest in the world and nationwide, life expectancy at birth is a 42.5 years (UNDP 2006).

The average family size of the sample households was 7.37 with a range from 1 to 15 persons and standard deviation of 2.44. The majority of the sample farmers 90 % had more than five members. About 10 % of them had less than five members. The average family size of sample farmers was higher than the national average of 4.7 for the country and 4.9 for SNNPR. According to the survey data collected in 2005, 2007 and 2011, the average family size in Damot Sore woreda was 7.365, 7.374 and 7.366, respectively; which is almost constant (Table 14). During the six years time, average household size increased only from 7.365 to 7.367 persons (about 0.2 percent). This tells as that there is an observed very small fractional change in average household size along the past six years.

Table 14: Average household size in the study area by age for the three period surveys

	Average and Change in Household Size and Age Distribution							
	Household Size		Age 0-15		Age 16-55		Age 55 +	
Year	Sample Average	Δ FPP	Sample Average	Δ FPP	Sample Average	Δ FPP	Sample Average	Δ FPP
2005	7.365293	-	4.271333	-	3.468416	-	0.3097345	-
2007	7.37395	0.008657	3.749155	-0.52218	3.313395	-0.155021	0.2563025	-0.053432
2011	7.366722	-0.007228	5.041971	1.292816	4.549632	1.236237	1.16129	0.9049875

Source: own computation Δ FPP= Δ From Previous Period

The increased average household size is speculated due to the high birth rate and it turns out that children contributed the highest additional membership to households, and that actually the percentage of children between the age of 0 to 15 in a household increased from 58 percent in 2005 to 68 percent in 2011. It seems that not only did the percentage share of children in a household increased in the sample area but also the percentage of average young adults between the age of 16 and 55 in a household increased from 47 percent in 2005 to 62 percent in 2011. This may contradict with the small fractional change of average household size (0.2 percent) making it insignificant as compared to the average change both in terms of number of children and young adults.

In addition, results indicate that in all the three rounds of the data those households who adopt SWC strategy tend to have slightly more household/family size than the non adopter ones. There is a 1% significance difference between SWC adopters and non-adopters in terms of family size (Table 13). This indicates that, households with SWC are better endowed with active labour resource which is vital for construction of soil and water conservation structures.

Educational Level: The descriptive statistics result of all the surveyed period showed that 29.45 % of the farmers did not attend formal schooling and 54.07 percent of the sample farmers attended elementary school (grade 1-8), while 16.48 % of the farmers attended high school (grade 9-12).

Moreover, the descriptive statistics results also showed that 24 and 32 percent of SWC adopters and non-adopters did not attend formal schooling. Out of the total sample household heads, 64 and 50 percent of SWC adopters and non-adopters, respectively; attained from 1 to 8th grade educational level. However, the mean difference in terms of years of educational was not statistically significant between the categories of SWC adopters and non-adopters (Table 13).

Land holding: In the study area, mean landholding over all three survey periods was almost exactly 0.650 hectare, and 45 percent of households had more than 0.5 hectares. And 85 percent of households had farming less than 1 hectare. On average, households had 8 plots, but 33 percent had 6 or more plots with a range from 1 to 27. The mean plot size of 0.076 hectares was the overall mean area devoted for a particular crop or intercrop with similar management practices in a given period of time (a plot[3]). And a total of 4274 plots and plot level information were

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[3] A plot is the smallest unit of land devoted for a particular crop or intercrop under similar management practice in a given time (cropping season).

collected and analyzed in all the three survey periods. Therefore both plot and household level information were collected and analyzed in this research.

In addition, the result of the statistical analysis shows that there was statistically significant difference between SWC adopters and non-adopters in terms of number of plots, plot size, and farm size (Table: 13 & 15).

Table 15: Average plot size, farm size, plot numbers observed across years

Variables	Year			Overall mean in ha
	2005	2007	2011	
Average Plot size (m^2)	878	884	588	0.076
Average farm size (m^2)	6389.5	5724	7079	0.650
Average number of plots per hh	7.26	6.67	10.17	8.316
Total plots observed	1287	1190	1797	
Total number of households				204
Total number of plots observed				4274

Source: own computation using 2005, 2007, 2011 survey data Hh= household

Livestock Holding: Livestock is an integral part of smallholders' production system in Ethiopia. It can serve as a critical input in farm operations as it enhances production and is also an important source of capital through which considerable income is generated. In the analysis of all the surveyed periods the two groups of farmers noticeably differ in the number of livestock (cows, oxen, sheep and goats) owned, more livestock in terms of TLU was kept by households that adopted SWC.

The overall average livestock holding of the sample households was 2.73. The average livestock holding of the sample households was 2.86 and 2.67 for SWC adopters and non-adopters respectively. As the result of the study indicates, there was statistically significant difference at 1 % significance level between the two SWC groups in terms of livestock holding (Table 13).

The result in Appendix Table 5 also implies that better of households in terms of livestock ownership tend to respond to adoption of soil and water conservation strategies positively compared to the non adopter groups. This result confirms the importance of asset ownership in household decision for adoption of soil and water conservation.

The average animal holding and the standard deviation for the major animal types during the three survey rounds was presented in Appendix Table 6. Average holding in terms of TLU first decreased from 2005 to 2007 and virtually increased from 2007 to 2011. The total animal holdings were looked stable during the whole times in all categories from 2005 to 2011with average overall value of 2.73 TLU.

Moreover, oxen and bulls are one of the most important resources for farm households. The result of the descriptive statistics also showed that the three period's average number of oxen and bulls in the district were found to be 1 and 0.74 per household head respectively. In terms of adoption decision, the average number of oxen was 1.1 and 0.96 for SWC adopters and non-adopters respectively and it is statistically significant at 1% significance level.

Mean crop output harvested: One of our hypotheses was to test whether there were significant differences in production (in value terms) between plots with and without SWC. And SWC adoption would also lead to saving of other inputs, improvement of management skill and increase of labour use. The result in (Table 13) reports that the mean difference in various characteristics for plots with and without SWC adoption, using the t-test to test the null hypothesis of equality of means. It is apparent that plots with SWC have a higher and significant yield value. Unlike previous studies, e.g. by (Pagiola, 1994), there are a 1 % significant difference in mean value of crop yield for plots with SWC adoption in comparison with plots without SWC.

Plots with SWC have a significant difference with regard to input use compared to plots without SWC. We found a clear significant difference with respect to labour in man days, and fertilizer inputs. However, with regards to manure use, we didn't find clear differences between SWC adopters and non adopters.

Input usage (Manure, Urea and DAP usage, Labour in man days): In all three rounds of the survey, SWC adopters tend to use significantly large amount of commercial fertilizer (Urea and DAP) than their counter parts. In each of the cases the analysis reveals that the difference is statistically significant at 1% level of probability. Whereas, in terms of manure usage; the result show that the non-adopters used significantly higher (1073 kg per plot) amount of manure than the SWC adopters (429 kg per plot). However, there is no statistically significant manure usage difference between the two groups. The major reason could be due to their income difference between the two groups. In terms of labor usage in man days, the result showed that the SWC adopter households employ (spend) more number of labor in man days (10 man days) than the non-adopters (8 man days) and the difference is statistically significant at 5% (Table 13).

Frequency of extension agent contact: Extension on crop and livestock production represents access to the information required to make the decision to adapt to climate change. Various studies in developing countries, including Ethiopia, report a strong positive relationship between access to information and the adoption behavior of farmers (Chilot 2007). Studies on climate change adaptation decisions in Africa reveal that access to information on SWC through extension increases the likelihood of adapting to climate change (Maddison 2006; Nhemachena and Hassan 2007).

From all the three rounds of the data, the farmers who adopted SWC on their farm have got more extension contact/advice on SWC techniques than their counterparts. Similarly, in all the three rounds the SWC adopters group has got more extension contact on manure application techniques than the non-adopters. In each of the cases the analysis reveals that the difference is statistically significant at 1% and 10% respectively. This indicates that these households who adopted SWC on their farms are better endowed with access to information which is vital for agricultural production under climate change.

Differences in plot characteristics with and without SWC: Plot characteristics such as plot quality, plot soil type, slope, soil depth, and erosion occurrence also seemed to determine whether to choose to adopt SWC or not. About 39 (697/1780) percent of plots with poor soil quality type had SWC, compared to 61 percent without SWC (1083/1780). But about 27.6 percent (702/2541) of plots with good soil quality type had SWC, compared to 72.3 percent (1839/2541). There were also statistically significant differences in the proportion of poor quality plots with SWC, compared to those without (Table 13 & 16).

Table 16: Difference in plot quality between SWC adopters and non-adopters

Plot quality==1*				Plot quality==2**				Plot quality==3***			
SWC	0	1	Total	SWC	0	1	Total	SWC	0	1	Total
0	3,860	1,083	4,943	0	3,020	1,923	4,943	0	3,104	1,839	4,943
1	1,798	697	2,495	1	1,451	1,044	2,495	1	1,793	702	2,495
Total	5,658	1,780	7,438	Total	4,471	2,967	7,438	Total	4,897	2,541	7,438

Source: survey data result (2005-2011) 1*= Poor plot quality 2**= Medium plot quality 3***=Good plot quality

We used Chi-square test to test whether there were significant differences with respect to plot characteristics for plots with and without SWC for each of the categories of the plot characteristics. There were also statistical significant differences in slope, soil type, susceptibility to erosion, plot degrees of degradation with SWC, compared to those without (Appendix Table 1).

The null hypothesis that plot soil type, plot slope, plot quality, plot susceptible to erosion and plot soil degrees of degradation have similar characteristics between SWC adopters and non adopters was rejected at a very high level of significance. That is SWC have a higher likelihood of being implemented on steeper slopes, which are more susceptible to erosion and which previously were highly degraded soils of a given plot. From the result obtained, the pattern of SWC adoption is thus significantly affected by plot and soil characteristics, with plots typically considered to be worse being more likely to have SWC. This supports the findings by Bekele and Holden (1999) and Birhanu and Swinton (2003).

Because of this, when a difference in yield between plots with and without SWC is observed, the underlining reason for the yield difference is not straight forward. One reason for this ambiguity could therefore be that there are differences in plot characteristics between plots with and without SWC adoption. This explains that on one hand, it is plausible that more productive plots attract SWC adoption to retain or further augment the production. On the other hand, SWC adoption may be adopted on slopes with high susceptibility to erosion, poor soil type, and on plots with high degrees of degradation. That means yield differences could also be due to differences in plot characteristics between plots with and without SWC adoption. To clearly see the impacts of each plot characteristics we are required to see the econometric model result in section 4.4.

4.4. Econometric Results

In this section, econometric results specific to the second and third objectives of the thesis is presented. Farmers in the study area have developed different coping and adaptation strategies in response to the recurrent drought and related environmental calamities. And this study uses soil and water conservation adaptation strategy among the various adaptation strategies employed by farmers during climate extreme events.

The result in section 4.4.1 focuses on identifying and analyzing the factors affecting the choice of Soil and water conservation adaptation strategy for climate change adaptation and section 4.4.2 analyzes the impact of soil and water conservation adoption on farmer's production.

4.4.1. Determinants of choice of SWC adaptation

This section presents the result of the estimated average determinant factors affecting the choice of SWC adoption decision. It also reports the two stage model estimates of the empirical analysis. In the first stage the probit results of SWC adaptation regression and the outcome equation in the second stage. The decision to employ SWC adaptation measures is a function of climatic factors (rainfall and temperature), household characteristics (i.e. gender, age, marital status, education level, and family size), and plot characteristics (soil type, quality, degree of soil degradation, slope, and susceptibility to erosion). The outcome equation is also a function of household characteristics, input variables, plot level characteristics, asset ownership related factors, and climatic factors.

The technique used in the first stage is linear panel probit while in the second stage is linear panel data estimator (FE estimator). VIF is not estimable after panel probit (first stage) or after FE (second stage). Therefore testing for multicollinearity and specification (omitted variable) tests in nonlinear and panel data models were irrelevant. However, a test for hetroskedasticity was available for the Fixed Effects model using the command xttest3. According to the modified wald test result for group wise hetroskedasticity in fixed effect regression model (the null is homoskedasticity i.e. constant variance), it indicates the presence of hetroskedasticity in both regimes (regime 1: chi2 (70) = 4.6e+30; prob>chi2=0.0000 and for regime 2: chi2 (136) = 5834.89; prob>chi2 = 0.0000). Therefore the option robust standard error command was used to control the hetroskedasticity.

Another important test for panel data analysis is panel unit root test to check whether or not observations are stationary over time and across cross-section. The Dickey-Fuller test is one of the most commonly use test for stationarity. However panel unit root tests are not required in short panels (three periods in this case), but in long (macro) panels.

The result of the first stage suggest that factors such as household head education level, farming experience, livestock holding in TLU, labour input in man days, frequency of extension contact for SWC, climatic factors such as amount of rainfall and plot level characteristics such as soil type, soil depth, plot quality, degree of degradation, plot slope, plot susceptibility to erosion tend to strongly govern farm households' SWC adoption decisions.

We found that the variables related to input such as labor in man days, household family size, and total livestock holding in TLU affect household plot level SWC adoption decision positively and significantly. Extension services also play an important role in determining farmer's decisions to adapt SWC. The variable frequency of extension contact is both positive and significant in affecting farm household SWC adoption decision. Farm households with access to extension tend to apply SWC adaptation measures on their farms than those with no access to extension.

Labour input in man days: Unit increases in the number of labour input in man days have the impact of raising the probability of adopting SWC to climate change by 1.3%. This depicts that increase in the number of labour input directly will increase the probability of SWC adoption.

Household size: According Hassan and Nhemachena (2008) the empirical literature that household size has mixed impacts on farmers' adoption of agricultural technologies. Larger family size is expected to enable farmers to take up labor intensive adaptation measures. And household size is positively and significantly related to SWC adaptation. A unit increase in the household size has an impact of raising the probability of adopting SWC to climate change by 12.1%. Therefore household size is a determinant factor in affecting the choice of SWC adaptation strategy to climate change in this study.

Household head education level: Education is the other important factor which influences SWC adoption decision. Higher level of education is believed to be associated with access to information on adoption of improved technology and higher productivity (Norris and Batie 1987). Evidence from various sources indicated that there was a positive relationship between the education level of the head of the household and adoption of improved technologies and adaptation to climate change (Maddison, 2006).

Several studies have also shown that improving education is an important policy measure for stimulating local participation in various development and natural resource management initiatives (Shields *et al.,* 1993; Dolisca *et al.*, 2006; Anley *et al.*, 2007; Tizale 2007). Better education improves awareness of potential benefits and willingness to participate in local natural resource management and conservation activities. However, Clay *et al.* (1998) found that education was an insignificant determinant of adoption decisions, while Okeye (1998) and Gould *et al.* (1989) found that education was negatively correlated with such decisions. According to the finding of this study, a unit increase in the level of household head education decreased the probability of taking SWC adaptation method to climate change by 7.2% with 5% significant level.

Farming experience: Farming experience in terms of years is one of the determinant factors in affecting the choice of SWC adaptation to climate change. Experienced farmers usually have better knowledge and information on climate change and agronomic practices that they can use to cope with changes in climate and other socioeconomic conditions (Hassean *et.al.,* 2008). However, according to the switching regression model result, the less experienced farmers are more likely to adapt SWC than the more experienced farmers. A unit increase in the farming experience in years of the household head would have the impact of decreasing the probability of SWC adoption to climate change by 3.2 %.

Frequency of extension contact for SWC: Extension education was found to be an important factor motivating increased intensity of use of specific soil and water conservation practices (Bekele, & Drake, 2003). Of the many sources of information available to farmers, agricultural extension for SWC is the most important for analyzing the adoption decision. On the other hand, (Pender *et al.*, 2006; Nakonya *et al.*, 2006; Birungi, 2007) found that extension was not significant factor affecting the adoption of soil and water conservation measures. However the result of this study identified that a unit increase for SWC extension contact will have the impact of increasing the probability of SWC adoption to climate change by 41.3%.

Livestock holding in TLU: The variable Livestock holding in TLU is the other determinant factor for the adaptation of SWC technology. The study result shows that Livestock holding is positively and significantly related to SWC adoption decision. Unit increases in the Livestock holding have the impact of raising the probability of adopting SWC to climate change by 12.7%.

Plot ownership status: A number of studies have demonstrated that security of plot ownership has a substantial effect on the agricultural performance of farmers. And the model result depicts that the likelihood of adopting SWC is less likely to be adopted on Shared out plot as compared to the base own plot ownership status.

Plot soil type, plot slope, plot erosion susceptibility, plot soil degradation: Research outputs such as this one, which accounts for plot/farm level characteristics, could reveal more information about factors dictating SWC adaptation to climate change at plot or farm level. And plot level characteristics such as plot soil type, plot slope, plot erosion susceptibility, and plot soil degree of degradation are significant determinants of SWC adaptation and the most important pre conditions to take up SWC adaptation measures in the study area.

Accordingly, plot soil type is one of the significant determinants of SWC adaptation. According to the surveyed farmers black soil type is a good one and white soil type is a poor quality one. The econometric result showed that the likelihood of adopting SWC is less likely to be adopted on dark brown plot soil type as compared to the base black soil type.

The slope of a plot is the other significant determinant of SWC adoption. In particular, the study result found that the likelihood of adapting SWC is more likely to be adopted on plots with mid hill slope as compared the base plain slopes. While the likelihood of adapting SWC is less likely to be adopted on plots with steep slope as compared to the base category plain slopes.
We also found that SWC is less likely to be adopted on plots with low erosion susceptibility as compared to the base high erosion susceptibility and SWC is less likely to be adopted on plots with none susceptibility to erosion.

With regards to plot soil degradation the econometric result indicate that SWC is less likely to be adopted on plots with degraded to no degradation plots as compared to the base highly degraded plot soil types. In general it is clear to observe from the study result that farmers tend to adapt SWC technologies when the plot level soil type gets poorer in quality. And when plot erosion susceptibility level increases, farmers tend to construct/adopt SWC structures in their plots. SWC adaptation choice decreases as there is less level of plot soil degradation experience. The same is true for the other plot characteristics degree of degradation. This also implies that, for sustainable agricultural adaptation practices to be successful, they must consider plot specific characteristics.

Rainfall plays important roles on the decision to adapt SWC strategy. More average annual rainfall is negatively correlated with SWC adaptation strategy. And farm households that experienced less rainfall than average both in the short and main rainy seasons also seem to adopt SWC strategy to climate change than others. The statistically significance of these climatic variables on the probability of SWC adaptation provide some evidence that SWC adaptation strategies undertaken by farmers are indeed correlated with climate change.

4.4.2. Impact of SWC adoption on crop production

This section of the paper presents the impact of SWC adaptation to climate change on production using parametric approaches. The central focus of this study is to measure the impact of SWC adoption on crop production. Most importantly it is to see whether farm household plots that actually did have SWC adaptation measures are indeed better off in terms of increase in plot level production in value terms. This is very central if SWC adaptation measures need to be put in place. In this section, we present and discuss the empirical results from the parametric analysis about the impact of SWC adoption on plot production.

4.4.2.1. Estimation results of the impact of SWC on crop production

When we test the production implications of SWC adoption, the simplest approach to investigate the effect of SWC adoption on production is the OLS model which includes a dummy variable equal to 1 if the farm household adopted, and 0 otherwise. This approach would lead to conclude that there is no difference in plot production in birr by farm households that adopted with respect to those farm households that did not adopted on specific plot. This approach, however, assumes that SWC adaptation to climate change is exogenously determined while it is a potentially endogenous variable. However, this assumption would yield biased and inconsistent estimates. Therefore, endogenous switching regression model was preferred instead.

Plot level SWC adoption and production data were complemented with household specific information. To empirically test for the roll of SWC adoption on production we use fixed-effect endogenous switching regression model. Estimation and inference procedures for the parameters of the endogenous switching regression model and sample selection models were developed. Random coefficients are incorporated in both the decision and regime regression models to account for heterogeneity across individual units across different times. Accordingly we test the relevance of the fixed effects using the Hausman test by rejecting the null hypothesis that jointly equal to zero. Thus, the use of fixed effect switching regression model in this thesis helps to address the potential endogeneity bias due to the inclusion of SWC adoption variable in the right hand side of the model.

To analyze the implications of SWC strategy on production we used the predicted value from SWC adoption model (first stage model). This is consistent as long as these predicted values are used in the second stage production model. Different alternative model variables have been checked and the natural logarithmic function for the endogenous switching regression model was preferred to be consistent.

Table 17: Parameter estimates of impact of SWC adoption to climate change on crop production

Model	SWC Adoption 1/0	Endogenous Switching Regression	
		Adoption = 1	Adoption= 0
Dependent Variable	SWC Adoption	Log of plot level output in birr	Log of Plot level output in birr
Male Household head	-0.151	3.107**	
Age of the household head	0.013		-0.057
Household marital status			
Married (non married)	-0.724	.	-0.247
Divorced (non married)	-0.751	.	.
Widow (non married)	-0.308	.	-1.907
Labor in person days	0.013***		0.025****
Household/Family size	0.121*	0.111	-0.024
Household head education in years	-0.072**	-0.030	-0.011
Household head farm experience in years	-0.032**	-0.057	.
Manure applied in kg	.	0.000***	0.000
Extension contact for SWC	0.413**	.	.
Nonfarm income (other source of income)	0.000	0.001****	0.000
Household livestock holding in TLU	0.127*	0.870	0.033
Average annual rainfall in mm	-0.896****	-4.430***	-2.183****
Production season	.	-0.121	0.103
Plot ownership status		.	.
Rented in Plot (Own Plot)	-0.115	.	0.139
Rented out Plot (Own Plot)	0.063	0.562	-0.182
Shared in Plot (Own Plot)	-0.260	0.390	-0.105
Shared out Plot (Own Plot)	-0.326*	0.000	-0.081
Plot size in square meters (log)	-0.000	-0.562****	-0.683****
Number of plots a farmers has in a given year	0.014	-0.143	-0.050
Plot distance from homestead in meters	.	-0.001	-0.001
Plot soil type			
Dark brown (black soil)	-0.341**	-0.600*	-0.319**
Red (black soil)	-0.274	-0.947**	-0.060
White (black soil)	-0.946	1.466	-3.328**
Sandy (black soil)	0.719	.	0.327
Plot soil depth			
Medium 30 to 60cm (base< 30 cm)	-0.054	.	.
Deep >60 cm (base< 30 cm)	0.324	.	.
Plot slope			
Tedafat/foothill (Meda/plain)	0.166	0.404	0.272

Daget/midhill (Meda/plain)	0.423*	0.765	0.253
Gedel/steep slope (Meda/plain)	-1.145**	0.367	-0.502
Plot quality			
Medium (poor quality)	0.165	0.699**	.
good quality (poor quality)	-0.052	0.638*	.
Plot erosion susceptibility			
Medium (high susceptibility)	-0.182	0.080	-0.513*
Low (high susceptibility)	-0.484**	0.161	-0.320
None (high susceptibility)	-1.319****	0.101	-0.877*
Plot soil degradation			
Degraded (high degradation)	-0.433**	0.181	-0.676**
Moderately degraded (high degrad)	-0.756****	-0.400	-0.425
No Degradation (high degradation)	-1.155****	-0.835	-0.674
Pesant Association			
Gununo 02 (Demba Zamine)	0.587		
Doge Shakisho (Demba Zamine)	1.197		
Doge Meshido (Demba Zamine)	0.547		
	(1.00)		
Constant	8.910****	51.147***	39.076****
Predicted value of SWC (swchat)	0.2927	-0.671	-0.540*
R-squared: within		0.4702	0.2923
between		0.4595	0.4380
overall		0.3836	0.3486
sigma_u	1.655	2.931	1.120
sigma_e		0.968	1.166
rho (ρ)	0.733	0.902	0.480
Prob > chi2	0.000	0.000	0.000
Number of Obs.	2502	354	1013

* p<0.10, ** p<0.05, *** p<0.01, **** p<0.001

Note: Switching regression Model with Panel Endogenous switching estimated by Full Information Maximum Likelihood Method (FIML). Model 1: Panel Probit Model and Model 2: Panel switching regression model with Sigma_u and sigma_e represents the standard deviation of the individual effect α_i and the standard deviation of the idiosyncratic error ε_{it}. The output result, ρ (rho) denotes the proportion of the total variance contributed by the panel level variance component. I found also that ρ denotes the correlation coefficient between the error term n_i of the selection equation (SWC) and the error term ε_{ji} of the outcome equations in the two regimes. The missing variable value (the dots) in the table result due to the given variable has a very small number of observations from the three survey periods. And the model will drop the value of the specific variable.

Source: Model result obtained from survey data in 2005, 2007 and 2011.

Our second interest in this part of the analysis was to look at the impact of SWC on farm household plot level production. Column 3 and 4 in Table 17 report the estimated production function results with panel fixed effect model. The natural logarithmic functional form specification was employed as it was found more robust.

The difference in the plot level crop production equation coefficient between the farm household plot that have SWC structure and those farm household plots that did not have SWC also illustrate the presence of heterogeneity in the two group of samples (Table 17, columns (3) and (4). The plot level crop production function of those plots that have SWC physical structures is significantly different (Pr (T > t) = 0.0001, t = -3.8061, Std. Err.= .0221868) from the plot level crop production function of the those plots that did not have SWC. In general, there were significant differences in determinants of the log of plot output in value terms across the two groups of plots.

Farm households plot level production depends on whether or not they are adopters and non-adopters of SWC to climate change. For plots which have SWC structures, the significant explanatory variables for plot production are inputs such as manure applied in kg, plot size in hectare, average annual rainfall amount in mm, nonfarm income. Variables related plot level soil characteristics, plot soil type being dark brown (10%), soil type being red (5%), plot soil quality being medium (5%), good plot soil quality (10%) affect plot level crop production significantly. And farm household head being male also affect the plot level production of plots which have SWC structures in the study area (Table 17, column 3).

For farm household plots which do not have SWC structures, the factors significantly influencing plot level production are labor in man days, plot size in hectare, average annual rainfall, plot soil type being dark brown, soil type being white, plot soil being degraded, estimated plot level SWC adoption decision, plot being medium susceptibility to erosion, and plot being non susceptible to erosion (Table 17, Column 4).

For farm household plots that adapted SWC, the effect of plot size on log value of yield was negative and consistent with much of the literature on farm size production effects (Benjamin, 1995, Helberg, 1998). This held for farm household plots without SWC too. Our result suggests that smaller plot size attain higher plot level production compared with large plot size.

Medium and good plot quality had a positive and significant impact on the log value of output, particularly for household plots with SWC. Whereas soil color being dark brown and being red have a negative and significant impact on the log value of plot production as compared to the base black soil color for the case of households plots with SWC.

We found that the variables related to plot level characteristics such as plot size, plot soil color being dark brown and being white as compared to the base black plot soil color, soil being medium to erosion susceptibility, and being non susceptible to erosion as compared to the base high plot susceptibility to erosion and soil being degraded have a negative and significant impact on the log value of plot production for the case of household plots without SWC. The variable labour in man days, however is the only variable which have a positive and significant impact on log value of plot production for the case of plots without SWC.

Adoption of SWC measures as an adaptation strategy to climate change increases plot level household production in value terms. Moreover, the fact that the estimated SWC adoption variable is negative and significant in the case of plot level production function that do not have SWC structure indicates the declining of plot production and is negative in terms of minimizing the effect of the risk to climate change.

From the last part of Table 17 it is observed that the covariance of the errors (sigma_u and sigma_e values) from SWC adoption decision model and the production regime errors are positive for both plots with and without SWC. Both plots with and without SWC base their decision on a latent utility maximizing criterion. However, only the covariance for plot without SWC is significantly different from zero at the 5% level although the covariance's for plot with SWC are almost significant. The same signs of $\sigma_{n\varepsilon 1}$ and $\sigma_{n\varepsilon 2}$ indicate hierarchical sorting. This implies that farm household plots with SWC have above average production weather the farm households choose to adapt SWC or not to adopt on the specific plot. But the plots are more productive if the farm households opt to adapt SWC rather than not to adopt. On the other hand, farm household plots which do not have SWC structures have below average production whether they have adopted SWC or not. However, their production is higher from not having SWC structure.

Consistent with predictions of economic theory and other related research done by scholars such as (Di Falco *et al.*, 2011, Menale *et al.*, 2011) inputs such as manure and labour in man days are observed to be associated with an increase in production per hectare in value terms by the farm households that adapted and not adapt SWC to climate change respectively. However, we found the variable fertilizer used highly correlated with the other explanatory variables in both regime's and excluded from the production analysis.

The result so far appeared inconclusive with regards to the exact impact of plot level SWC adoption on crop production. And it was also observed that there were systematic difference in plot level characteristics and input quantities between farm household plots with and without SWC. The interest of this work was to know and quantify the percentage of value of production with and without SWC. Answer to this question may be useful to better understand the role of SWC to climate change and production.

Therefore actual and counterfactual treatment and heterogeneity effect are conducted to explore the difference between plots with and without SWC adaptation to climate change. Table 18 presents the expected total quantity of crops produced per plot in value terms under actual and counterfactual conditions. Cells (a) and (b) represent the expected quantity of crops produced per plot by farm households that adapted SWC is about birr 5039, while it is about birr 3979 for the groups of farm households that did not adapt SWC. This simple comparison, however, can be misleading and leads to conclude that on average farm household plots which have SWC produced about birr 1060 (i.e. 27 percent) more than the farm household plots that did not adapt SWC.

The last column of Table 18 presents the treatment effects of adaptation of SWC to climate change on plot level production in value terms as described in section 3.4.2.2. In the counterfactual case (c), farmers plots who actually adapted SWC would have produced about birr 264 (i.e. about 5.5 percent) more than farmer's plots that did not adapt SWC.

Table 18: Average expected production per plot in value terms; treatment and heterogeneity effects

	Decision Stage		
Sub Samples	To Adapt	Not to Adapt	Treatment effects
Farm households that adapted	(a) 5039.212	(c) 4774.908	TT=264.3039
Farm households that did not adapt	(d) 4738.842	(b) 3978.822	TU=760.0199
Heterogeneity effects	BH1= 300.3704	BH2= 796.0864	TH= -495.716

In counterfactual case (d) that farmers plot that did not adapt adapted SWC, the plots would have produced about birr 760 (i.e. 19.1 percent) more than if the plots did not adapt SWC. This result implies that SWC adaptation to climate change increases farmers plot level production in value terms. However, the transitional heterogeneity effect is negative (TH= - 495.716), that is the effect is smaller for the farm household plots that actually did adapt SWC with respect to those plots that did not have SWC. In addition, the last raw of Table 17, which adjusts for potential heterogeneity in the sample, shows that farmer plots which adapted SWC tend to have benefits above the average weather they adapt SWC or not, but the plots are more productive when they are adapting SWC than not adapting.

Farmer household plots which have adopted SWC to climate change had higher crop production than those which do not adopt SWC. Based on the model estimates of the result, plots with SWC structures tend to produce about 1060 birr more to 3979 birr in production than plots which did not have such structures. This accounts for 27 percent of change in value of plot production per hectare. In other words, the effect of climate change will be reduced by such a magnitude if the farm household plots have SWC adaptation structures.

The results of the estimated average SWC adoption effects from the parametric regression model are shown in Table 17. In general, the parametric result indicate that plot level SWC adoption leads to significantly higher plot production gains in the study area where there is observed high rainfall variability and low-agricultural potential.

4.4.2.2. The impact of the different SWC structures on crop production

The different soil and water conservation practices that were frequently used in the study area include grass strips, construction of traditional ditches, stone (soil) bunds, raised boundary bunds, cut off drains, *fanya juu*, planting of banana strip, *enset*, crop-residues/trash line, and construction of artificial water-way. Among thus conservation structures, grass strips (23%), traditional ditches (15%), Banana strips (12%), stone (soil) bund 9%, and raised boundary bunds constitute the first five dominant structures found in the study area.

This study investigates the impacts of different SWC technologies on crop production to determine the implications of the different structures implemented in the study area. In this section the value of the treatment effect obtained from the econometric results for each type of SWC structure is presented.

Table 19: Plot level SWC structures used in the study area and their impact on crop production

	Group	Types of plot level SWC structures	Plot Freq.	% of usage	Impact	TU*	Rank
1	Drains/waterways & ditches	Cut of Drains	260	7.76	+	137429.14	1
		Artificial water ways	242	7.22	+	39109.94	2
		Traditional Ditches	486	14.5	+	2574.62	4
2	Strips	Banana Strips	392	11.7	+	12021.68	3
		Grass Strips	783	23.37	+	1343.61	5
3	Bunds	Raised boundary bunds	294	8.77	-	-2083.89	8
		Fanya juu[4]	72	2.15	-	-2520.72	9
		Stone/soil bunds	294	8.77	-	-1425.84	7
4	No SWC	No Application	528	15.76	-	0.0006	6
		Total plots with SWC	3351	100			

Source: Survey result in 2005, 2007 and 2011. TU*= Treatment effect on the Untreated

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[4] *Fanya juu:* Literally means “throwing of soil uphill” in Kiswahili.

As shown in Table 19, SWC technologies such as cut of drains, artificial water ways, traditional ditches, banana strips and grass strips showed positive and very highly significant impacts on crop production. Another interesting result from this study is that cut of drains and artificial waterways showed the largest impact on crop production, which supports the empirical finding by Bekele and Holden (2001) in their economic analysis of soil conservation in Ethiopia.

The result of the empirical analysis of this study have demonstrated that although most of the SWC structures investments in the study area have significant mean impacts on crop production, they do not all show a corresponding positive effects. We found that SWC structures such as stone/soil bunds, *fanya juu*, and raised boundary bunds have resulted in negative value/impact on crop production (negative treatment effect on the treated); which might explain their relatively low adoption rates in the study area (Table 19).

The finding of this result is different from similar studies made by (Menale *et al.*, 2008; Wagayehu 2005; Birhanu *et al.*, 1999). Menale *et al.*, (2008) and Wagayehu (2005) both found stone bunds to have favorable positive impacts on production in low-rainfall areas unlike the result of this study.

Moreover, at this level of the study, it is also difficult to give a specific best SWC adaptation technology that can be recommended and to be implemented or scaled up in the study area. This is because this study didn't consider the cost element on SWC investment, which is a very important factor in affecting the choice of adoption of the different types of SWC technologies.

In general, the result showed that different types of SWC technologies differ in terms of their initial investment cost and their impact on crop production, which underscores the importance of promotion of the different SWC adaptation technologies on the bases of their impact on production, investment cost and location consideration.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study was based on the analysis of sources of production risk, plot level adaptation strategies, factors influencing the choice of SWC adaptation strategy and focuses on the impact of plot level SWC adaptation strategy on production in the context of climate change. A three period panel household survey collected in 2005, 2007 and 2011 was used. A total of 204 sample farmers were randomly selected in 2005 and all subsequent surveys were applied on the same households located in four kebele's within Damot Sore district of Wolaita, SNNPR, Ethiopia.

Ethiopia is one of the most vulnerable countries to impacts of climate change. Although symptoms of the problem are widespread in many parts of the country, southern part in general and the study area in particular are most affected and expected to be affected in the future. Historical climate data and perception information of the surveyed households reveals that there has been increased rainfall variability and temperature rise in the last six decades. As a result, the people are exposed to the risks of several types of disasters such as drought, flooding, epidemics, and asset loss. There is also increased frequency and spatial coverage of hazards, existing hazards are intensifying and new types are emerging with harmful effects on people lives and resources. In the study area, resources owned by farmers are shrinking over time due to climate change and lead to the loss of human lives and property.

The main adaptation strategies of farmers to climate change identified in the study area include: SWC adoption, crop diversification, fertilizer application, planting of different varieties of the same crop, *iddir* participation, manure application, changing crop planting dates, and tree planting etc. Analyzing the different adaptations together made by all respondents revealed that mixed farming system was considered to be one of the most important adaptations in response to climatic changes.

Fixed effect switching regression model was employed to analyze the determinants of SWC adaptation choice to climate change. The analysis revealed that labor in man days, household size, household head education level, household head farming experience, frequency of extension contact for SWC, household livestock holding, average annual rainfall, and plot level variables such as plot ownership status, plot soil type, plot slope, plot erosion susceptibility and plot soil degradation are the determinant factors for on the choice of SWC adaptation strategy. Moreover, the analysis of determinants of SWC adaptation to climate change indicates that labour in man days, household size, frequency of extension contact for SWC household livestock holding, and plot slope being mid hill have positive and significant impact on adaptation of SWC to climate change. Whereas factors such as household head education level, household head farming experience, average annual rainfall, and plot level characteristics such as plot ownership being shared out, plot soil type being dark brown in color, plot slope being steep slope, plot erosion susceptibility being low and non susceptible, plot soil degradation being degraded, moderately degraded and no degradation have a negative and significant impact on the probability of adaptation of SWC to climate change.

Being in receipt of extension advice relating about SWC also strongly increases the probability of adaptation. Similarly, farmers who perceived that their lands are poor in soil quality, highly degraded and susceptible to erosion are more likely to adopt SWC adaptation technologies that help in improving land production in value terms. That is, the lower the fertility of the soil, the higher the likelihood of adopting SWC adaptation strategies.

We used fixed effect switching regression model to estimate a simultaneous equation model with endogenous switching to account for unobservable factors that influence land production in value terms and the decision to adapt SWC or not.

From the result of the three period analysis of fixed effect switching regression model we can draw three main conclusions on the impact of plot level SWC adaptation to climate change on plot level crop production (differences between the two groups of farm household plots). First, the group of farm household's plots that have SWC structures has systematically different characteristics than the group of farm household's plots that did not have SWC structures. These differences represent sources of variation between the two groups (so that OLS model cannot satisfy the model requirement). Second, plot level SWC adoption as an adaptation strategy to climate change increases plot level crop production, however, a given farm household plots that have SWC structures tend to have a plot level production above the average whether decision have been made on the plots to have SWC structure or not. Third, as the transitional heterogeneity effect is negative, the effect of the impact of SWC adoption is smaller for the farm household plots that actually did adapt SWC with respect to those plots that did not have SWC structures. This result is in line with the research findings of a strong impact of soil and water conservation physical structure on crop production by Di Falco *et al*,. 2011.

Generally, the result of the empirical analysis in this study showed that SWC adoption has significant positive impact on crop production. But given the variability of the impacts of the different types of SWC structures, differences in investment cost, differences in agro ecology and other confounding factors, projects or programs aimed at promoting SWC measures should chose SWC structures which are cost effective, location specific and moreover which have positive impact on crop production.

5.2. Recommendation

To overcome the different disastrous risks and climate change related problem to agricultural production in the study area, policies and strategies and their implementations should be credible and corrected based up on the existing real situation on the ground. Hence, the following recommendations are given on the basis of the findings of this study.

There should be identification and utilization of people's adaptation strategies to local problems. Through their long experience, farmers in the study area have a good understanding of their local problems and the different sources of production risks. Accordingly, they have important coping and adaptation strategies. Therefore, the decision makers should integrate the strategies actually adopted by farmers to the improvement of agriculture in the designing of appropriate local programs in the future.

Building local knowledge: Information provision to farmers has long been a cornerstone of agricultural development strategies, with large proven benefits to agricultural outputs. And disseminating information through extension services about the availability of new technologies and how to use it, providing information on improved farm management techniques such as soil and water conservation, optimal input use, or providing forecast information about likely short or long-run shift in climate should be targeted. Including farmers in research design and implementation can also be an important means toward successful technology adoption. Therefore, given the inadequate extension services in the district, improving the knowledge and skills of extension agents as well as farmers through trainings about climate change and management strategies is crucial. Increasing extension-farmer ration and making the extension services more accessible to farmers appear to be the key components of a successful adaptation program to increase agricultural production.

Providing credit and weather index insurance products: Expanding the availability of credit and insurance to the farmers in the study area, could help farmers finance the purchase of inputs, smooth income in the face of production shortfalls, and thus encourage diversification out of low-risk, low return crops and into higher-reward activities. Providing weather index insurance products to poor producers would overcome problems related to covariate shocks. In particular, there is widespread interest in the development of crop insurance schemes that would reimburse farmers in the event of climate-related production shortfall. Moreover, the availability of insurance could speed the adoption of new, better-adapted varieties, in addition to helping maintain incomes in bad years.

Encouraging and supporting extra non-farm activities and income diversification: Non-farm income generating schemes should be strengthened and expanded. As large scale enterprises are very scanty in the study area, small scale firms or handicrafts and business play an important role in creating employment opportunities and generating income. In areas like Wolaita, the agricultural sector is not only vulnerable to natural calamities but also it becomes unable to support the increasing population. There are many people engaging in handicrafts and small business and still many others would like to involve into these activities. However, most of them lack the skills and the initial capital to undertake. Therefore, there is a need to strengthen and expand these activities. It could be the provision of credit and training. There are emerging institutions to expand credit availabilities to rural communities. However, the rural credit lending procedures requires improvement including its high interest rate and short terms of repayment.

Taking measures against the prevailing high population growth: The study area is one of the most densely populated areas in the country. Every year there are many new claimants for farm plots in rural areas. On the other hand, the fertility of many farm lands is ever decreasing. Most people in the study area are now well aware of the problem and want to limit their family size. However, they don't use the different contraceptive services due to cultural reason and lack of access. So population pressure is a particularly urgent issue to address. All organizations should therefore have family planning on their agenda, as an increasing population will require more intensive agricultural production. Investing in women and girls education in ways that can improve their health, well-being and awareness creation is important.

Measures against environmental degradation should be strengthened: Generally, the result of the empirical analysis in this study showed that SWC adoption has significant positive impact on crop production. But there is still a need to rehabilitate the degraded agro-ecology in the highland areas. In the studied highland *kebele's* soil erosion is very severe. Some farm plots are degraded to the extent that they can’t support farm practice. The main problem is that people are using very steep mountain sides as farm plots and these mountain sides are severely eroded. Therefore, there should be a strengthened intensive natural resource conservation and rehabilitation activities. Particularly measures that conserve the environment and at the same time can generate income to support farmers are essential. For instance, eucalyptus plantation and other similar alternatives should be sought.

Introducing SWC structures which are cost effective, location specific and have positive impact on crop production: Given the variability of the impacts of the different types of SWC structures, differences in investment cost, differences in agro ecology and other confounding factors, projects or programs aimed at promoting SWC measures should chose adaptation structures which are cost effective, location specific and moreover which have positive impact on crop production.

Finally, to enhance policy towards tackling the challenges that climate change poses to farmers, it is important to identify the different sources of risks, have knowledge of farmers’ perception on climate change, different potential adaptation measures, factors affecting adaptation to climate change and their impact on farmers should be further studied in the future. In general, there should be an urgent consideration of all those above measures.

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APPENDICES

Appendix Table 1: Socioeconomic and plot characteristics of farmers (Categorical variables)

Differences for plots with and without SWC					
Chi-square comparison test					
Variable	without swc	with swc	Differences	S.DV	P-Value
Sex (Male)	1.832254	1.856181	-0.023927	0.366471	0.0045
Marital status	1.071021	1.075591	-0.00457	0.410376	0.6888
Freq. of SWC extension contact	2.832759	2.905821	-0.073062	1.60913	0.0533
Extension contact for manure	2.711708	2.815261	-0.103553	1.546505	0.0041
Extension contact for FA**	2.734478	2.718258	0.01622	1.554657	0.6549
Extension contact for ISA*	2.735163	2.736208	-0.001045	1.530646	0.9767
Land rent	0.289689	0.1466667	0.1430223	0.439595	0.0000
Credit apply	0.4332182	0.3939962	0.039222	0.493657	0.0008
Credit obtained	0.4810606	0.5658537	-0.0847931	0.500063	0.0000
Plot ownership status	1.579301	1.575988	0.003313	1.322595	0.9141
Plot soil type	1.503163	1.678379	-0.175216	0.703387	0.0000
Plot soil depth	1.995786	2.024225	-0.028439	0.772466	0.1157
Plot slope	1.479543	1.75791	-0.278367	0.667069	0.0000
Plot quality	2.131094	1.960321	0.170773	0.810088	0.0000
Plot erosion susceptibility	2.997105	2.216052	0.781053	1.137196	0.0000
Plot degree of degradation	3.292194	2.675404	0.61679	1.05821	0.0000

*ISA=improved seed application **FA=fertilizer application

Appendix Table 2: Conversion factor used to compute adult equivalent

Age Group (in years)	Male	Female
Below 10	0.6	0.6
10-13	0.9	0.8
14-16	1	0.75
17-50	1	0.75
Over 50	1	0.75

Source: Storck, et al. (1991)

Appendix Table 3: Conversion factor used to estimate total livestock holding in terms of TLU

Animal category	TLU
Calf	0.25
Weaned Calf	0.34
Heifer	0.75
Bule	0.8
Cow and Ox	1
Horse	1.1
Donkey (adult)	0.7
Donkey (young)	0.35
Camel	1.25
Sheep and Goat (adult)	0.13
Sheep and Goat (young)	0.06
Chicken	0.013

Source: Storck, et al. (1991)

Appendix Table 4: Conditional expectations, treatment and heterogeneity effects

	Decision Stage		
Sub-samples	To Adapt	Not to Adapt	Treatment effects
Farm households that adapted	(a) E ($y_{1i}/A_i = 1$)	(c) E ($y_{2i} / A_i = 1$)	TT
Farm households that did not adapt	(d) E ($y_{1i} / A_i = 0$)	(b) E ($y_{2i} / A_i = 0$)	TU
Heterogeneity effects	BH1	BH2	TH

Note (a) and (b) represent observed expected production in value terms (c) and (d) represent counterfactual expected production in value terms

swc=1 if farm households plot have SWC adaptation to climate change and swc=0 if farm households plot did not have swc structure

lny1hat : natual logarithim of plot level production in value terms if farm household adapted swc

lny0hat: natual logarithim of plot level production in value terms if farm household di not adapted swc

TT : the effect of the treatment (i.e. swc adaptation) on the treated (i.e. farm households plot that have adapted swc)

TU : the effect of the treatment (i.e. swc adaptation) on the untreated (i.e. farm households plot that did not adapt swc)

BHj: the effect of base heterogeneity for farm households plot that adapted swc (i=1) and did not adapt swc (i=2)

TH= (TT-TU), i.e transitional heterogeneity

Appendix Table 5: Livestock holding differences for farmers with and without SWC

Mean comparison test for Livestock holding					
Variable (in no.)	Without Soil and Water Conservation	With Soil and Water Conservation	Differences	S.DV	|t|-ratio/Value
Milk cow	1.159823	1.278229	-0.11841	0.69326	6.6073***
Oxen	0.962585	1.096753	-0.13417	0.691578	6.3769***
Heifer	0.938412	1.116511	-0.1781	0.668029	8.6798***
Bulls	0.626978	0.980836	-0.35386	0.642404	15.8864***
Calves	0.94807	1.141587	-0.19352	0.812254	7.7031***
Sheep	0.83085	1.045685	-0.21483	0.947996	5.5109***
Ewes	0.844355	1.101053	-0.2567	0.884308	7.6717***
Ram	0.295508	0.545788	-0.25028	0.58953	8.7707***
Lamb	0.456573	0.587549	-0.13098	0.843699	3.0908***
Goats	0.087671	0.289618	-0.20195	0.436683	8.0481***
Does	0.097561	0.542373	-0.44481	0.518795	19.0890***
Bucks	0.110482	0.074074	0.036408	0.667628	0.8852
Kids	0.008671	0	0.008671	0.083647	1.6720*
Horse	0.021368	0.030303	-0.00894	0.150163	0.9727
Mules	0	0	0	0	.
Donkeys	0.309724	0.488095	-0.17837	0.818871	4.3021***
Chicken	2.358436	2.806988	-0.44855	3.558348	3.6537***
Bee hives	0.854592	1.7	-0.84541	3.222122	4.8911***
TLU	2.674222	2.855587	-0.181365	1.710847	4.6150***

Source: own computation using 2005, 2007, 2011 survey data

Appendix Table 6: Livestock holdings by type and year

	Over all		Year 2005		Year 2007		Year 2011	
Animal Type	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Milk cow	1.20	0.69	1.02	0.78	1.22	0.53	1.34	0.67
Other cow	0.54	0.69	0.21	0.47	1.25	0.60	1.19	0.49
Oxen	1.00	0.69	0.71	0.69	1.15	0.40	1.27	0.72
Heifer	0.99	0.67	0.69	0.68	1.11	0.41	1.34	0.61
Bulls	0.74	0.64	0.41	0.61	1.13	0.33	1.19	0.43
Calves	1.00	0.81	0.67	0.89	1.24	0.75	1.28	0.52
Sheep	0.89	0.95	0.47	0.81	1.56	0.75		
Ewes	0.92	0.88	0.46	0.64			1.51	0.81
Ram	0.36	0.59	0.15	0.44			1.16	0.36
Lamb	0.49	0.84	0.30	0.75			1.46	0.56
Goats	0.13	0.44	0.05	0.28	1.34	0.65		
Does	0.22	0.52	0.01	0.10			1.23	0.51
Bucks	0.10	0.67	0.04	0.34			3.35	2.53
Kids	0.01	0.08	0.01	0.08				
Horse	0.02	0.15	0.00	0.07	1.00	0.00		
Mules	0.00	0.00	0.00	0.00				
Donkeys	0.35	0.82	0.15	0.39	1.00	0.00	1.57	1.57
Chicken	2.49	3.56	1.59	2.88	4.20	5.72	2.92	1.74
Bee Hives	1.04	3.22	0.55	2.38	3.02	2.14	4.87	6.39
TLU	2.73	1.71	2.75	1.67	2.65	1.59	2.78	1.81

Appendix Table 7: Summary of FGD report format and risk questionnaires

Survey team:_________________________ Date:

Zone: District: PA:

Village:__________________ Sub village____

GPS reading from the center of the PA: Latitude…….Longitude ……Altitude…

UMB/ CIMMYT Vulnerability, Risks and Climate Change Adaptation Strategies Assessment, Kebele/ Community Level Discussion Guide

Welcome

- We are conducting today's discussion to understand the wide range of risks that poor & low–income families' like yourself face in the course of running their business and day to day lives. We also want you to share us the impact of these risks & how you deal with these challenges.
- We will use this information for developing and disseminating drought tolerant maize varieties and micro insurance products (or developing agricultural risk management strategies) where poor & low-income households will be benefiting.

Interview Group and Village composition

				# cultivating		
	Total	Male	Female	>2ha	<2ha	Not cultivating
Interview group(no)						
Whole village (no)						

Main Questions

1. What are the biggest or most important economic stresses and risks that families face in this community? List and rank them.

1.1 What other risks do people in your community face? List and rank them based on their financial burden.

2. Which of these risks have the greatest impact on family life? Rank the risks according to their impact on family life?

2.1 Describe the level of financial pressure related to these risks?

2.2 How frequently does this risk occur? List and rank them based on their frequency

2.3 How wide spread is the risk?

2.4 Does the risk lead to other problems?

2.5 Is the impact short term or long term?

3. How do families in your community cope with when they are encountered with the most important shocks you identified above?

Preventive:

Probe: Self-insurance (borrowing, use of savings, sale of assets)

Probe: Assistance from friends and relatives, participation in the informal group based insurance system

Probe: Use of formal insurance

Probe: Precautionary measures that could be taken in the future to reduce the risks

Probe: Adopting technologies, varieties (OPV maize as *ex-ante* coping measures), using new information

Probe: Changes in timing and planting

Probe: Crop diversification

Coping:

Probe: Selling livestock

Probe: Migration

Probe: Resowing

Probe : Borrowing grains and seeds from other farmers/relative

Are there differences in risks and coping mechanisms for women and men?

Probe: Reducing consumption

4. Drought/dry spells last 10 years

4.1. How many times did you face dry spells within the last 10 years?

4.2. How many times did you face rainfall shortage within the last 10 years?

4.3. Is drought increasing, decreasing or remain the same within the last 10 years

Region ________________ Woreda ____________________ Village

Name of household head ____ Household ID:

Respondent Name______________________________________ Date of interview Enumerator

VULNERBILITY, RISK, COPING MECHNISMS AND THE DEMAND FOR MICRO-INSURANCE: NFR PROJECT: UMB/CIMMYT COLLABORATION

1	Did food shortage affect your farming activity within the last four years? 1=Yes, 0=No	Code	
2	If yes, how many times food shortages affect your farming activity within the last four years?	Code	
3	If yes, for how long did food shortage affect your family last 12 months?	months	
4	How did food shortage affect your farming activity? 1). Reduced fertilizer and seed use 2). Reduced labor use 3). Lower harvest 4. out migration 5. Others (specify)	Code	
5	If yes for Q.1, what did you do? 1=Got food aid 2=Got assistance from relatives 3. Rented out land for cash, 4= Used my savings 5. Sold animals 6. Borrowed money from *iddir* 7. Got credit from another MFI 8. Used my	Code	
6	Do you think shortage of rainfall is more common over the last six years Compared to the year before? 1= yes 0=no	Code	
7	Which one of the following more frequent in your area within the last 10 years? 1). Floods 2). Hailstorms 3) High temperature 4). Crop disease/pest	Code	
8	Has the household head been sick within the last four years 1 .yes 0.no	Code	
9	If yes, how long?	Code	
10	Did sickness affect farming/business activity? 1=Yes, 0=No	Code	
11	If sickness affected your farming, how did you manage to cope? 1. Get food aid 2. Get assistance from relatives 3. Rent out land on long-term contract for cash, 4. Use my savings 5. Sold out animals 6. Borrow money from iddir	Code	
12	What is the risk that has negatively affected your farming/business activity the most? 1= rainfall shortage 2= crop disease/pest 3= unexpected drop in price 4=bad investment (taking credit for fertilizer, improved seed, loan from microfinance, etc) 5=illness 6= sudden death of family members 7= loss of	Code	
13	What is the second most important risk (use codes in Q. 12 above)	Code	
14	What is the third most important risk (use codes in Q. 12 above)	Code	
15	If it does not rain, what do you do? 1= simply wait for rain before sowing 2= rely on food aid 3= engage in food for work 4= find non-farm job 5= sow other crops (early maturing substitutes) 6=others		
16	What other risk coping mechanisms do you use to withstand unexpected food shortage? 1= borrow money from friends or relatives 2= use my own saving 3= borrow money from iddir 4= borrow more money from MFIs 5=others (specify)	Code	

17	What is your most effective informal risk coping mechanism? 1). Reduce consumption 2).Rely on social networks such as iddir 3= No effective means 4). Rely on saving 5). Rent out land 6). rent out animals 7). Sale animals 8). Depend on locally available low cost food 9). skip meals such as breakfast or lunch	Code	
18	**Actual output vs. expected output** last 12 months: 1=Above expectation, 2=As expected, 3=Below expectation	Code	
19	If above expectation, why? 1=Good weather, 2=Good management 3=Good input supply 4=Other, specify	Code	
20	If below expectation, why? 1=Drought, 2=Pest/disease problems, 3=Too little inputs applied, 4=Poor land management 5= Illness 6=others (specify)	Code	
	POST HARVEST LOSSES		
21	Did you face storage losses for maize last 12 months? 1 yes 0: no	Code	
22	If yes, how much in kg?	Birr	
23	If no, why? 1. Do not have enough maize to store 2. I used better storage techniques such as chemicals, modern store, etc 3. Others (specify)	Code	
24	If yes to Q. 21,did you buy any chemical such as DDT or others within the last six years to protect your harvested crops against damage? 1. yes 0. no	Code	
25	If yes to Q. 21, how much did you lose each year due to current storage system for your major crops? 1. In 2001/02 E.C kg 2. In 2002/03 kg	Year 1 Year 2	
26	How much did you lose due to pests within the last two years? 1. In 200 1/02 E.C kg 2. In 2002/03 Birr	Year 1	
27	Mention two other kinds of post harvest grain losses (e.g. floods, price, etc) 1……………………... 2……………………………..		

Appendix Table 8: Household Questionnaire 16 pages (See Million Tadesse, 2010)