

88097

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
INSTITUTE OF DEVELOPMENTAL STUDIES
CENTER FOR ENVIRONMENT, WATER AND DEVELOPMENT

THE ECONOMIC IMPACTS OF CLIMATE CHANGE ON CROP
 PRODUCTION
 (A Case in Choke Mountain Watersheds of Ethiopia)



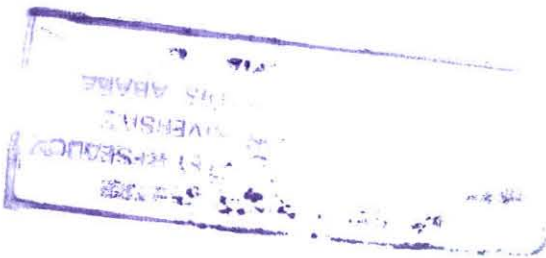
By:

Sewagegnehu Asfaw

Advisor: Belay Simane (Associate Professor)

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS
 ABABA UNIVERSITY IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS
 FOR THE DEGREE OF MASTER OF ART IN ENVIRONMENT AND DEVELOPMENT

May 2011
 ADDIS ABAB, ETHIOPIA



The
 SET
 2011

18697

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**

**INSTITUTE OF DEVELOPMENT STUDIES
(IDS)**

Title

*The Economic Impacts of Climate Change on
Crop Production: A case in Choke Mountain
Watersheds of Ethiopia.*

By

Sewagegnehu Asfaw

DEVELOPMENT STUDIES

APPROVED BY THE BOARD OF EXAMINERS:

SIGNATURE

Dr. Belay Simane
CENTER HEAD



Dr. Belay Simane
ADVISOR



Dr. Assefa Seyoum
INTERNAL EXAMINER





The
S3 E1
2011

Acknowledgements

First, I would like to thank the Almighty God and his beloved mother St. Mary for giving me the endurance, determination and inner peace throughout the ups and downs in this study. Without you, I am nothing but with you I am everything.

Next, several people have assisted me during my research work. Although it is not possible to mention all in a few sentences I would like to thank those who have been particularly important to my work. First and for most, I feel great pleasure to express my deepest appreciation and sincere gratitude to my advisor Dr. Belay Simane for his unreserved and valuable professional supports and important advices throughout my work. Moreover, his enthusiastic and compassionate natures were essential to produce this paper and unforgettable in life too.

I am indebted to express my heartfelt thanks to my brothers Dr. Teferi Gedif, Girma SHEMELES and Solomon Girma for all of their determinations and commitments in all the tracks I went through for this study. Moreover, I want to praise my sisters Tsehay Lema and Aselef Yaregal with my special and warmth thanks for their heartily thoughts and continuous material as well as moral supports for my study.

My special thanks also forwarded to Sebsib Belay and Azmeraw Ayehu for their contributions to my research particularly at proposal and data gathering stages. My sincere and special thanks also need to be forwarded to Mr. Meseret Mola and Yalemzewud for their professional assistance in analyzing the econometrics model.

Here, I also indebted to thank Sister Tsega G/Meskel, Sister Martha, Sister Sirgut and Sister Rahel for all of their contributions for this paper in writing and giving necessary information related to my paper timely.

Next, my warmest gratitude goes to those Development Agent Workers Addisu, Molla, Asratie, Animew, Nigusie, waganesh, Belesti, and Dawud for all of their effort and time in gathering the data and gathering local farmers to conduct interview and FGD for the study.

Last but not the least I am also greatly thankful of those district agricultural experts Mr. Alemu and Minyamir for their special co-oppression by giving me their office car to collect data in the nearby kebele administration and giving me the district and kebele data with your special interest.

This paper is part of the choke integrated development and research initiative coordinated by Addis Ababa University.

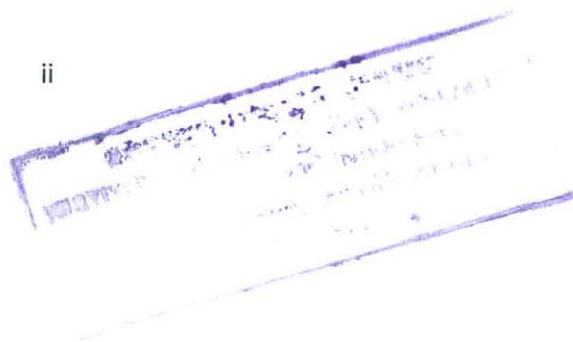


Table of Contents

Acknowledgement	ii
Abbreviations and Acronyms	vi
List of tables	vii
List of figures	viii
List of Pictures	viii
Abstract	viii
1. Chapter-one Introduction	1
1.1 Background	1
1.2 Statement of the problem	4
1.3 Objective of the study	6
1.3.2 Specific objectives	6
1.4 Basic Research Questions	7
1.5. Significance of the study.....	7
1.6 Scope and Limitation of the Study	8
1.7 Organization of the Study.....	9
2. Chapter –Two Review of Related Literatures	10
2.1 Definitions of Conceptual Terms	10
2.1.1 Climate Change	10
2.1.2 Climate variability	11
2.1.3 Sensitivity	11
2.1.4 Vulnerability	11
2.1.5 Adaptive capacity	12
2.1.6 Adaptation	12
2.1.7 Principles of adaptation	12
2.1.8 Adaptation measures to climate change	13
2.1.9 Adaptation Technologies	13
2.1.10 Types of adaptation technologies	13
2.2 Empirical literatures	14
2.2.1 Impacts Climate change on crop productivity	14

2.2.2 Marginal impacts of climate change	16
2.2.3 Estimated impact of climate change on crop production	17
2.2.4 Adaptation options against climate change	18
2.2.5 Agricultural technologies, crop production and climate change adaptation	19
3. Chapter Three Research Methodology	23
3.1 Research Design	23
3.2 Sources of Data	23
3.3 Samples, Sample Size Determination and Sampling procedures	24
3.4 Data collection instruments.....	25
3.5 Methods of data analysis	26
3.5.1 T-test and ANOVA	27
3.5.2 Descriptive Analysis	27
3.5.3 Recardian Model specification	27
3.6 Description of Dependent and Independent Variables	33
4. Chapter-Four Brief Description of the Study Area	36
4.1 Agro ecological Features of the Study Areas	38
4.2 Socio-Economic characteristics of the study population.....	42
4.3 Farming systems, cropping pattern and Landholding	46
5. Chapter-Five Results and discussion.....	47
5.1 Farmers' perception towards climate change.....	47
5.2. Whether farmers take an adjustment measures against climate change	49
5.3 Use of agricultural technologies for climate change adaptation.....	51
5.3.1 Use of chemical fertilizers.....	51
5.3.2 Use of improved seed varieties	52
5.3.3 Use of Soil conservations.....	54
5.3.4 Use of irrigation with improved technologies.....	56
5.4 Other adaptation options taken by farmers.....	58
5.4.1 Planting trees.....	58
5.4.2 Diversifying income sources.....	59
5.4.3 Crop diversification.....	59

List of tables

Table-3.1 Net revenue of crop production in CMWs	33
Table-4.1 Agro Ecological classification of CMWs	39
Table-4.2 Gender distribution in the sample household heads.....	42
Table-4.3 age of sample household heads in CMWs	43
Table-4.4 households' family size in CMWs	44
Table- 4.5 level of education of sample household heads in CMWs	44
Table-4.6 Households access to credit in CMWs	46
Table- 4.7 size of farmlands of the households in CMWs	46
Table-5.1 farmers' perception towards changes in temperature	47
Table-5.2 farmers' perception towards changes in precipitation	48
Table-5.3 whether farmer took adjustment measure to climate change	50
Table-5.4 farmers' use of chemical fertilizers for crop production	51
Table-5.5 farmers' use of improved seed varieties	52
Table-5.6 farmers use of improved soil conservation practices for crop production	54
Table-5.7 Farmers use of irrigation technologies for crop production	56
Table-5.8 Regression results of model without adaptation (climate and soil variables)	60
Table-5.9 Regression results of model with adaptation (climate, soil and Agricultural technology variables)	61
Table-5.10 Regression results of model with adaptation (climate, soil, agricultural Technologies, and socio economic variables)	63
Table-5.11 Marginal impact of climate change on net Revenue per Hectare	65
Table-5.12 Marginal impact of Temperature across agro ecological zones	66
Table-5.13 Marginal impact of precipitation across agro ecological zones	67
Table-5.14 Impact of uniform climate scenarios in choke mountain watersheds	68

List of Figures

Figure-1 Map of Choke Mountain watershed districts	37
Figure-2 Map of the selected study areas	38
Figure -3 Agro Ecological classification of CMWs.....	39
Figure-4 use of Agricultural technologies in Choke Mountain Watersheds	58

List of Pictures

Picture-1 soil erosion and soil conservation in Choke mountain watersheds	53
Picture-2 Irrigation in Choke mountain watersheds	55
Picture-3 Plantation of Eucalyptus tree in Choke mountain watersheds	57

Abstract

This paper explores the economic impact of climate change on crop production and the role of agricultural technologies as an option of adaptation in the Choke Mountain watersheds of Ethiopia. In this research Cross sectional research design was employed. Questionnaire, focus group discussion, key informant interview and field observation were the data gathering instruments used in the study. Both analytical and descriptive analysis techniques such as Recardian model, percentage and ANOVA that were used to analyze the respective quantitative and qualitative data collected for the study. The descriptive statistics of this study show that most framers in Choke Mountain have perceived the increased temperature and the reduced precipitation in their areas. In addition, based on this choke mountain watershed farmers have started to take measure to minimize its effect on crop production. Thus, farmers have used agricultural technologies as an option for climate change adaptation, though the application of different agricultural technologies varies in the six AEZs of the watershed. The paper has also identified factors that determine farmers' decision to use agricultural technologies such as problems related to price and supplies as well as dissemination of agricultural technologies and minimum access to credit service are some. On the other hand, the regression result of the econometrics models showed that there was a reduction in net revenue per hectare with an increase in winter precipitation. Increasing summer and spring temperature is damaging to crop production in choke mountain watersheds. However, the increase spring and summer precipitation benefits choke mountain farmers by boosting their crop net revenue per hectare. Nitosols were positively related to crop net revenue per hectare. Then again, the farmers' use of chemical fertilizers, improved seeds, soil conservation and irrigation agricultural technologies have increased crop net revenue per hectare of choke mountain watershed farmers. The socio economic variables such as size of farmland, access to credit, education and household size are positively correlated with the dependent variable net revenue. Nonetheless, gender and age variables were negatively related crop net revenue per hectare. The estimated marginal impact of change in temperature and precipitation indicate that the increase of winter temperature and fall temperature to a certain extent benefits farmers of choke mountain watersheds with an increase of their crop net revenue by 2,161birr and 3,877.63birr respectively . Whereas, its increase in spring and summer temperature reduces crop net revenue of choke mountain farmers by 7,513birr and 6,442.54 birr. The increase of precipitation in spring, summer, and fall seasons increases net revenue per hectare by 3,571.46, 7,105 and 2,411.91 birr respectively. While increase of winter precipitation is damaging to crop production, and reduces crop net revenue per hectare by 1,690.24birr. In a nutshell, the analysis of this paper shows the degree of the economic impact of climate change on crop farming in different AEZs of the Choke Mountain watersheds. The finding shows that the increase in temperature and decrease of precipitation highly determines crop agriculture in Choke mountain watersheds. In this case, crop farming in the very cold and cold sub moist highlands and the warm sub moist lowlands of the choke mountain watersheds are highly affected by climate change. Therefore, the government of Ethiopia should have to take imperative measures to adapt the impacts of climate change on crop production by designing policies that assist farmers to cope for the changing climate. Lifting up the current adaptation options taken by farmers, particularly use of fertilizers, improved seeds, soil conservation and irrigation practices. In line with this, capacitating farmers to buy agricultural technologies by themselves through the provision of credit services is important. Helping farmers to raise the fertility of soil especially to those farmers in the high and lowland areas through the supply of gypsum should also be given priority. Hence, this would buffer better climate change adaptation in the area.

Key words: Climate Change, crop Net revenue, adaptation, agricultural technologies, choke mountain watersheds

Chapter-One

1. Introduction

1.1 Background of the study

Agriculture plays a pivotal role in Ethiopian economy. Agricultural development is a key for the country in order to feed its growing population and to ensure food security and achieve its economic development. In the country the largest domestic products and foreign incomes are generated from this sector. As Ministry of Finance and Economic Development (MoFED) (2006), in Ethiopia the agricultural sector employs more than 80% of labour force; it also accounts 45% of GDP and 90% of the export revenue. In Ethiopia, small-scale farmers depend on low-input and low output rain-fed mixed farming with traditional technologies dominates the sector, even though large-scale commercial farms are operational in several regions (Abebe, 2008). Moreover, the present government of Ethiopia has given top priority to this sector considering it as a motor to move in to other sectors. Hence, it has taken measures to increase agricultural development in the country to solve major problem of food insecurity and to step forward for the overall economic development. As enshrined in the current development strategy of the country (Plan for Accelerated and Sustainable Development to End Poverty- PASDEP) and GTP, due emphasis is given to the role of agriculture for achieving economic growth, poverty reduction, and food security.

Though the sector is believed to play tremendous roles for the country's development, it is highly sensitive to global climate change as most farmers are small scale and use rain fed agriculture. In this regard, the National Meteorological Authority (NMA, 2007) enunciated in the climate change National Adaptation Program for Action (NAPA) of Ethiopia, the country is highly dependent on the agricultural sector for its income, foreign currency, and food security. The sector is dominated by small-scale farmers who employ largely rain-fed and traditional practices which renders Ethiopia highly vulnerable to climate variability (as seen during past persistent drought), and thus to climate change which is projected to reduce yields of the wheat staple crop by 33 %. As a result, the contribution of this sector to the total economy is challenged

by its vulnerability to climate change. It is now widely recognized that developing countries particularly, low income countries of tropical and sub-tropical regions will be disproportionately affected by the adverse impact of climate change (IOP, 2009).

Climate change has reduced the production of agricultural activities through the variations in temperature and precipitation. These variations have been taken as an advantage by mid latitude western countries, Asia and some parts of US. However, it is a big challenge for countries in the tropics especially sub-Sahara Africa which are highly crashed by the change. Accordingly, agriculture, a large fraction of the economy in sub Sahara Africa, and relies on relatively basic technologies is predicted to be highly vulnerable to climate change because it already endures high heat and low precipitation in the region (Kurukulasuriya et al. 2006; Pearce et al. 1996; McCarthy et al. 2001). To reduce the sensitivity of agriculture, taking a measure for better adapting the sector with climate change is indispensable action to uphold the previously exposed population from poverty and high food shortage and to exceed its economic growth. Incidentally, some adaptation measures were taken by farmers including the use of improved agricultural technologies to enhance agricultural productivity in Ethiopia.

Improving agricultural productivity is the key for the development of agriculture in Ethiopia because productivity growth is the most sustainable mechanism to increase production in the highland areas, though Ethiopia could also potentially increase agricultural production by putting marginal and vast lowlands into cultivation. The major factors for the poor performance of the agricultural sector in the country have been identified as limited use of improved production technologies, insufficient infrastructure and institutions, ill-devised policies, drought and environmental degradation (Berhanu and Befekadu 2000; Haward *et al.* 1995). Among these constraints, limited access to improved agricultural technologies received the greatest attention.

Under the general framework of Agriculture-Led Industrialization Development Strategy (ALIDS), the country implemented an agricultural extension program called “Participatory Demonstration and Extension Training System” (PADETS) in 1994/95 E.C. The focus of the extension program had been the promotion of improved agricultural technologies such as high yielding (improved) seed varieties, fertilizers, and chemicals for the control of diseases, insects

and weeds (Bekabil and Rashid, 2006). Hence, agricultural technologies like improved seeds and fertilizer have given a central place in enhancing agricultural productivity. Ethiopian government regards these agricultural inputs as crucial elements to increase productivity. Consequently, the fertilizer application rate improved from less than 5kg/ha in 1983 to around 36kg/ha in 2007 (Belay, 2006).

Despite the considerable attention given to the sector and its role in effecting broad-based development, low productivity remains the main challenge of Ethiopian agriculture. The productivity of cereal crops is estimated around 1.5 tons per hectare, far below the world average of about 3.1 tons per hectare, which is too low against the rate of fertilizer application (36kg/ha) (Belay, 2006). The level of agricultural technology adoption among small-scale farmers is still low in Ethiopia. The proportion of farmers adopting improved seed varieties is less than 5% and of those farmers using fertilizer is not more than 45%.

The recommendation for balanced and sustainable solutions following the incidence of soaring food prices in Ethiopia (FAO, 2008) embraces the need for increased agricultural production among small-scale farmers by assisting them through different forms of interventions. The interventions would be better informed if supported with credible evidence on the current quantity, quality, availability, and affordability and utilization rate of modern technologies such as improved seeds, fertilizer, water harvesting and irrigation, soil conservation technologies and on the cultural practices and efficiency levels of farmers' use of these technologies.

Hence, this study was intended to assess the vulnerability of crop production to climate change by measuring farmers' crop net revenue and to see the role of agricultural technologies like fertilizers, improved seed varieties, soil conservation practices and irrigation as an option of adaptation for crop production. At the end, endeavours were made to look for ways of solving problems manifested.



1.2 Statement of the problem

Climate change has become a solemn issue for all nations of the world because of its direct and indirect harming effects on human life. It has tremendous adverse ecological, social and economic impacts. Climate change seriously impairs the agriculture sector, particularly crop agriculture. According to Downing and Watson et al. (1996), discussed in Meseret (2009), Global and regional climate change will affect all economic sectors to some degree, but the agricultural sector is perhaps the most sensitive and vulnerable economy since agricultural production remains highly dependent on elements of climate.

Both the extreme events causing drought and flood, high temperature and variable precipitation in addition to lower soil and water conservation and management cause the reduction of crop production in Ethiopia. Chiotti and Johnson (1995), explained that the combined effects of increased temperature, elevated atmospheric CO₂ concentrations, increased probability of extreme events (droughts, floods, frosts, etc.) and reduced crop water availability are expected to cause significant changes in crop yields, cropping systems, scheduling of field operations and pest conditions. Thus, the lower crop production in turn hampers food security in developing tropical countries of Africa. Higher temperatures, more variable precipitation, and changes in the frequency and severity of extreme climate events will have significant consequences for food production and food security.

Quoting Kurukulasuriya and Rosenthal (2003) Meseret (2009) also argued that, many research findings had indicated that climate change have significant impacts on tropical regions, particularly poor countries like Ethiopia having high sensitivity to climate change and thus the vulnerability of these poor countries is due to their technological, resource and institutional constraints.

Improved agricultural technologies can play prominently to adapt the sector with the global and regional climate changes. Thus, adaptation technologies are the application of technology in order to reduce the vulnerability, and enhance the resilience, of a natural or human system to the impacts of climate change (Used in UNFCCC seminar on technologies on adaptation in Trinidad

and Tobago in 2005). The reality about agricultural technology intervention for crop production in Ethiopia is a recent phenomenon apart from the traditional means used by farmers to enhance crop production. Though the supply/provision and effective application as well as awareness of farmers towards agricultural technologies is under several constraints, agricultural technologies play prominent roles to enhance resilience to climate change by increasing crop productivity. Therefore, using improved agricultural technologies such as improved seeds, fertilizers, soil conservation and irrigation are significant for climate change adaptation and mitigation by facilitating the growth of crops within a short period and helps to cope up the shortage of water and high temperature for plant growth. Since, climate change has an effect to shorten the growing time of crops by shortening the rainy season in tropical countries like Ethiopia. In line with this, this research is conducted to see the vulnerability of crop production and the significance of agricultural technologies to adapt climate change in Choke Mountain Watersheds of Ethiopia.

In Choke Mountain watersheds, similar studies were not yet done except the research done by Meseret (2009) on Nile Basins of Ethiopia on irrigated and dry farming and another research done by Deressa (2006) at country level to observe the economic impact of climate change on agriculture. This is to the best knowledge of the researcher. With regard to Meseret's research, it was done on crop agriculture by comparing the impact of climate change on irrigated and non-irrigated (dry farming). Though in his research he was indicated the adaptation options taken by farmers in the Nile basin of Ethiopia, he did not show what kind of adaptation options were taken in the different agro ecological zones and which adaptation measures were effective in which AEZ. Furthermore, the researcher did not see how agricultural technologies were effective to increase crop productivity and reduce farmers' sensitivity. On the other hand, Deressa's study was mainly focused on the impact of climate change on agriculture in several AEZs of Ethiopia. In the first place, the research was not showed how farmers could adapt climate change in each AEZs of the study and his research was only emphasized farmers' vulnerability to climate change. Second, his research did not clearly specify which system of agriculture whether livestock or crop farming or whether farmers who used irrigation or rain fed agriculture were more vulnerable to climate change.

However, this research has tried to see the marginal impact of climate change by taking crop farming as a specific component in different Agro Ecological Zones (AEZs) of Choke Mountain watersheds (CMWs). It has also been conducted in the dry land or farmers who were using rain fed agriculture since production of the chosen crops by irrigation is not commonly done by a number of farmers. With the irrigation practice in the area local farmers have usually grow vegetables including potato and other fruits. Therefore, classifying sample farmers as those who have practiced irrigation and rain fed agriculture might reduce the credibility of the research. Therefore, to see the impact of climate change on agricultural crop farming at AEZ level was found important for this research, which has been done in CMWs. Furthermore, this study has examined the local adaptation measures taken by farmers particularly the role of agricultural technologies for better adaptation of to climate change in the study area. In this regard, the study observes the implementation, practice and effectiveness of fertilizer application, improved seed varieties, irrigation and soil conservation technologies.

1.3 Objectives of the Study

The general objective of the study is to examine the vulnerability of crop production to climate change by measuring its impact on crop net revenue per hectare and assessing the role of agricultural technologies as an option of adaptation in Choke Mountain Watersheds of Ethiopia.

Specific objectives

The specific objectives of this paper:

- ❖ To determine the marginal impact of temperature and precipitation on agricultural crop production.
- ❖ To predict the range of impacts of climate change on crop production under various climate scenarios by using the estimated model.
- ❖ To examine the effects of agricultural technologies on crop productivity to enhance its resilience for climate change in Choke Mountain watersheds of Ethiopia.

- ❖ To inform policy-makers on proper adaptation options to counteract the effects of climate change in various agro ecological zones.

1.4 Basic Research Questions

- ↓ What is the perception of farmers towards climate change?
- ↓ What are the marginal economic impacts of changes in climate elements (temperature and precipitation) on agricultural crop productivity?
- ↓ What measures of adaptation are taken by the local farmers particularly those agricultural technologies to enhance the resilience of crop production against climate change?

1.5. Significance of the study

Global climate change has brought severe impact on agricultural practices likewise it reduces productivity of crop farming which results in an increased food shortage and increased poverty in developing countries particularly in sub-Saharan Africa. In response to this, different agricultural technologies are used by farmers. Therefore, conducting this research is important to explore the economic impact of climate change on crop farming in the Choke Mountain Watersheds of Ethiopia. The study is also vital to investigate the relevance of different improved agricultural technologies such as improved seed varieties, chemical fertilizers, irrigation, and soil conservations that are significant to cope with climate variability and change in Choke Mountain watersheds.

Local level analysis of farmers' net revenue per hectare from crop production and identifying effectiveness of different agricultural technologies such as improved seed varieties, chemical fertilizers, irrigation, and soil conservations to adapt climate change would bring an insight for local administrators and agricultural experts to evaluate the vulnerability status of crop farming and the effectiveness of use of those agricultural technologies in their particular area. The study would further help local administrators and agricultural experts to sort out the very basic problems in their area regarding the application of several agricultural technologies and to search for the solutions.

Furthermore, the end result of this research will serve as an additional vital source of information to those planners and policy makers in designing better climate change resilient agricultural and rural development policies, strategies and programs related to crop production enhancement, food security as well as poverty reduction at kebele, district, zonal, regional as well as national levels.

1.6 Scope and Limitation of the Study

- This research did not consider panel or time series data, which could better explain the long-term effects of climate change in order to see the trend of crop productivity in accordance with the long-term variation and changes in climate. This was mainly because the study was conducted at household level that the respondent could not easily remember the statistics of what they have been produced, hectare coverage of production of each crop, quantity of production e.t.c. This was not only at household level this time series data (a minimum of 30 years) could not be found but not also available either at the district or Kebele Administration levels.
- Cross sectional data is one bottleneck to conduct household level study on climate change. This is particularly true in this study area where one meteorological station covers wider geographic area. Even to partially fill this gap, the study was not able to employ the Thin-Plate Spline method of spatial interpolation and impute the household specific rainfall and temperature values using latitude, longitude, and elevation information of each household due to shortage of finance as well as instruments and technical capability.
- Another limitation of this study was unable to see the impact of climate change for each crop which has been considered in this research as each variety of crops require climate scenarios and different adaptation options. Therefore, observing the impact of climate change and its adaptation options for each particular crop was not a part in this research though it was important.
- The data did not include exact figures of each household's cost of transportation and labor force. This was mainly because most farmers in all selected agro ecologies used animals (Donkeys, horses, mules) as a means of transportation and they got these animals by their

Chapter -Two

2. Review of the Related Literature

2.1 Conceptual Literatures

2.1 Definitions of Conceptual Terms

This section of the research defines concepts and terms related to climate change and agricultural crop productivity.

2.1.1 Climate Change

The Intergovernmental Panel on Climate Change (IPCC), an authoritative voice on climate change issues, refers to climate change as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC,2007). As USAID (2007), it is shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer). Climate change may be due to natural changes or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

The United Nations Framework Convention on Climate Change (UNFCCC) Article 1, however, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Scientific evidence indicates that due to increased concentration of greenhouse gases in the atmosphere, the climate of the Earth is changing; temperature is increasing and the amount and distribution of rainfall is being altered (Houghton et al. 1996).

According to Houghton (1996) cited in Kinfе Hailemariam (1999), the IPCC Scientific Assessment suggests that global average temperature may increase between 1.5 and 4.5°C, with a 'best estimate' of 2°C, in the next century with a doubling of the CO₂ concentration in the atmosphere. Climate change that reduces either the overall quantity of water or the timing of when water is available for use will have important effects on agriculture and industrial and urban development.

2.1.2 Climate variability

Climate variability is variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forcing (external variability) (IPCC, 2001). According to Abebe (2008) stated in Yohannes and Mebratu (2009) Climate variability is the fluctuation in climatic parameters from the normal or baseline values, where as climate change is a change in the long-term mean value of a particular climate parameter.

2.1.3 Sensitivity

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (IPCC, 2001).

2.1.4 Vulnerability

Vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects 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, 2007b).

Vulnerability is conceptualized in different ways across different disciplines. Liverman (1990) noted that vulnerability has been equated to concepts such as resilience, risk, marginality, adaptability, and exposure. This diversity of conceptualization is due to the fact that the term vulnerability has been used in different policy contexts, referring to different systems exposed to different hazards.

As stated in Kelly and Adger (2000) and Brooks (2003) and cited in Yohannes and Mebratu (2009) indicates that the climate change literature provides two main distinct epistemological approaches to conceptualizing vulnerability. One approach views vulnerability as the “end point,” in terms of the amount of (potential) damage caused to a system by a particular climate-

related event or hazard. The second approach considers vulnerability as the “starting point,” i.e. as a state that exists within a system before it encounters a hazard event.

2.1.5 Adaptive capacity

IPPC defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007a). Adaptive capacity describes the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches. It requires amongst many other things, the flexibility to experiment and adopt novel solutions (Marshall, et al., 2010, Gunderson 2000; Levin et al. 1998). Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards (Adger, 2006; Adger et al. 2005; Rapport et al., 1998).

2.1.6 Adaptation

Adaptation focuses on reducing negative effects of climate change by modifying systems to take into account new/anticipated climatic conditions.

According to Yohannes and Mcbratu (2009), adaptation as applied to climate change is a very broad concept. The concept is defined differently in the literature; some literatures define it adaptation to climate change as the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides (Burton et al., 1992). Other literatures define the term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv et al., 1993).

2.1.7 Principles of adaptation

Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of changes in conditions (IPCC, 1996). From these concepts, the following major principles of adaptation to climate can be extracted:

- Adaptation is a continuous and learning process.

- Adaptation is a response to actual or expected risks; in other words, adaptation can occur before, during or after any external stimulus or threat.
- Adaptation integrates prevention or mitigation in its process.
- Adaptation can be spontaneous and planned.
- Adaptation can be a practice, management practice or process.
- Climate change has both challenges and opportunities (Yohannes and Mebratu, 2009).

2.1.8 Adaptation measures to climate change

According to Burton et al (1993), the term adaptation measures covers eight categories: bearing losses (doing nothing), sharing losses, modifying the threat and thus preventing effects, changing use, changing location, accessing new research based technologies, disseminating knowledge through education to change behavior, and restoration.

Others have classified the different forms of adaptation as anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001).

2.1.9 Adaptation Technologies

In the climate change context, adaptation has been defined as the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm or exploits beneficial opportunities.” **Technology** has been defined as “a piece of equipment, technique, practical knowledge or skills for performing a particular activity.”

Adaptation technologies can thus be defined as “the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change” (used in UNFCCC seminar on technologies on adaptation in Trinidad and Tobago in 2005 from CIDS 2009).

2.1.10 Types of adaptation technologies

At the broadest level of classification, adaptation technologies can comprise hard technologies, such as seawalls, irrigation technologies, fertilizer, and improved varieties of crops and soft technologies such as crop rotation patterns, knowledge, know-how and organizational capacity.

A successful adaptation strategy will in general utilize both hard and soft technologies, which, rather than applied in a one-off activity, will involve the application of a combination of these technologies in an ongoing interactive process (CIDSI, 2009).

2.2 Empirical literatures

2.2.1 Impacts of Climate change on crop productivity

Global scale changes in climate will manifest as changes in average climate conditions, changes in variability at daily, seasonal, inter annual, decadal, and other time scales, and changes in extremes, all of which will exhibit substantial spatial variation. The temporal and spatial patterns of change will be critical determinants of climate risks, critically as regards exceedence of thresholds of vulnerability (IPCC, 2007). Climate change has an effect on different sectors of the economy but its effect on agricultural sector is very severe. This is mainly because the activity is highly dependent of climate elements particularly precipitation and temperature. Likewise, crop production is extremely susceptible to climate change. It has been estimated that climate changes are likely to reduce yields and damage crops in the 21st century, although, notably, effects are expected to differ widely in different parts of the world (IPCC, 2007).

Research on climate change impacts, adaptation, and vulnerability requires information about past and current social and economic conditions, correlated with climatic and environmental data, to investigate empirically the causes of vulnerability to climate stress, the consequences of exposures, and the efficacy of adaptive strategies that have been used in the past. Information about future social and economic conditions, or socioeconomic scenarios, is needed to examine future impacts, adaptation, and vulnerability. Mitigation research is also dependent on past data and future scenarios of social and economic conditions (IPCC, 2007).

However, in Africa for many regions there is no available surface water so that warming scenarios with reduced rainfall are particularly deleterious. On the other hand, mild scenarios with increased rainfall may not be harmful at all (kurukulasuriya and Mendelson, 2006).

Accordingly, there are also literatures done on the impact of climate change on crop productivity shows that, global climate change reduces farmers' net revenue of crop production. This effect is sounder to African agriculture. Africa net farm revenues are highly sensitive to changes in

climate. The sensitivity is relatively high for changes in temperature. Further warming and drying have severed adverse effects on farm net revenue. Variations in sensitivity to climate based on farm type and whether the farm is dry land or irrigated. Dry land and specialized crop or livestock farms suffer most from further increases in warming and drying compared to irrigated and mixed crop livestock farms. Therefore, farming systems found in dry and semi dry arid lowland areas will suffer most with the increase of temperature.

In Africa, both land value and net revenue are sensitive to temperature and precipitation. The land value and net revenue of farms have hill shaped relationships with temperature. Farmers at moderate temperature earn more profits compared to farmers at extreme tropical temperature. (Seo and Mendelson, 2007). Other literatures indicate that African farms are sensitive to climate and especially temperature. It finds that farm net revenues are lower in places with higher temperatures. Specifically, the temperature elasticity with respect to the net revenue of African farms is estimated to be -1.3. That is, a 10% increase in temperature will lead to a 13% decline in net revenue. The precipitation elasticity is estimated to be 0.4. African farms are more sensitive to changes in temperature than changes in precipitation. The sensitivity is the greatest for dry land farms with a temperature elasticity of -1.6 and a precipitation elasticity of 0.5. Irrigated farms, by contrast, are resilient to temperature changes and may actually increase in value (partly because of their location in temperate regions of Africa). These results are similar to preliminary analyses using the same data (Kurukulasuriya et al., 2006). Similar results were also found for US farms (Mendelsohn et al., 1994; Mendelsohn and Nordhaus, 1999; Mendelsohn et al., 2001; Mendelsohn and Dinar, 2003).

On the other hand, South American agriculture is highly vulnerable to climate change. If global warming is mild, the impact will be small. However, if severe warming scenarios come to pass, farmers could lose up to 50% of their net revenue by the end of this century. This would be a stunning blow to the agricultural sector in South America. The impact would be even more devastating to the hottest most vulnerable regions in South America (Seo and Mendelsohn, 2007).

There are also literatures expressing the economic impact of climate change on agriculture in general and crop production in particular in several countries of Africa. For instance, the net crop

revenue of Kenyan farmers gets changed with the variation of temperature and precipitation in different seasons. Climate affects Kenyan agricultural productivity. Increased winter temperatures increase net crop revenue, while high summer temperature decreases it. Increased precipitation increased crop net revenue. There is no linear relationship between temperature and crop revenue on the one hand and between precipitation and crop revenue (Mariara and Karanja, 2007). In the same token that Deressa, and Reshid (2009), have tried to show how the change in climate elements in place and season affect Ethiopian, farmers net crop revenue. Increasing precipitation during spring increases the net revenue per hectare by us\$ 225.08, whereas increasing precipitation during winter significantly reduces net revenue by us\$464.76. Marginally increasing precipitation in summer and the fall also reduces the net revenue per hectare by us\$18.88 and US\$64.19, respectively, even though the level of reduction is not significant. Increasing annual precipitation marginally will reduce the net revenue per hectare. This is mainly because of the high intensity precipitation in some of the seasons that is more than that of crop requires.

2.2.2 Marginal impacts of climate change

In Africa, rain fed farms and irrigated farms have different responses to climate. The elasticity of land value or net revenue to summer temperature was -2.8 for small and -1.7 large rain fed farms but the elasticity for irrigated farms was zero for small farms and +0.9 for large farms. Furthermore, large farms have high values in places with more precipitation but large irrigated farms have high value in dry places (Seo and Mendelson, 2007). Unlike this in US temperature and precipitation, effects can be to some extent separated by comparing the effects of the climate scenario over both rain fed and irrigated production the latter is being sensitive to precipitation changes. Using US corn as an example when the averaged across sites and scenarios rain fed production increased 11% in 2030s but irrigated production decreased by 6%. In 2090s rain fed production was 15% higher than present, while irrigated production decreased to 8% (according to the US national assessment technical report, effect of cc on us crop production (Tubiello et al., 2005). Dry farms in the Nile basin of Ethiopia are most likely affected by climate change and farmers in these areas are highly vulnerable for an increase in temperature and decrease of precipitation than irrigated farmers (Meseret, 2009).

African agriculture is sensitive to climate change. Many farmers in Africa will experience net revenue losses from the warming. Any reduction in precipitation will be especially deleterious to dry land farmers, the poorest segment of the agriculture community. Irrigation is an effective adaptation against loss of rainfall and high temperatures provided there is sufficient water available. However, for many regions there is no available surface water so that warming scenarios with reduced rainfall are particularly deleterious. On the other hand, mild scenarios with increased rainfall may not be harmful at all (kurukulasuriya and Mendelson, 2008).

The sensitivity to climate change is the greatest for dry land farms with a temperature elasticity of -1.6 and precipitation elasticity of 0.5. Irrigated farms, by contrast, are resilient to temperature changes and may actually increase in value (partly because of their location in temperate regions of Africa. The dry land analysis alone provides a biased forecast of the overall effect of climate change on all farms. Irrigated farms are much more robust to warming than dry land farms (kurukulasuriya and Mendelson, 2008).

2.2.3 Estimated impact of climate change on crop production

The estimated marginal impacts of climate variables (temperature and precipitation) revealed that global warming is harmful for agricultural productivity i.e. the temperature component of global warming is much important than precipitation for crop agriculture in Kenya. The result from prediction of the impact of climate change on Kenyan crop agriculture net revenue based on the two GCMs CCC and GFDL which predicts 3.5 °C and 4°c changes in temperature by the year 2030 respectively and a 20% change in precipitation over the sample periods. The predictions show that long-term changes in temperatures and precipitation will have a substantial impact on net revenue, and that the impact will be more pronounced in medium and low potential zones than in high potential zones. The latter are expected to receive some marginal gains from mild temperature increases, holding precipitation constant (Mariara and Karanja, 2007).

The study done on Latin American agriculture estimated the future impact of climate change on the sector by using the climate model CCC, CCSR, and PCM. Whereby the CCC scenario predicts the largest damage, the PCM scenario predicts the smallest damage, and the CCSR scenario predicts a moderate damage in between. The result explains that in Latin America For

both small and large farms CCC predicts a gradual increase in damage from about 16% in 2020 to 33% in 2060, to 61% in 2100. In contrast, the CCSR model predicts damage of about half that size and PCM model about one fourth at large (Seo and Mendelson, 2007).

2.2.4 Adaptation options against climate change

There are a number of adaptation options taken by both farmers and concerned stakeholders to reduce the sensitivity of agriculture sector and to increase farmers' resilience. From them use of irrigation practice in addition to the rain fed agriculture is one. Irrigation is one of the most important adaptation options used to overcome heat stress (Helmy *et al.*, 2007).

In Africa, Irrigated farms will benefit slightly across all scenarios. The fate of dry land farms depends on the scenario. Mild climate scenarios will probably benefit dry land farmers. Harsh scenarios will lead to large losses. Impacts are expected to be evident as early as 2020 and to become larger over time as warming increases (kurukulasuriya and Mendelson, 2008). The same author says that in Africa, Irrigated farms will benefit slightly across all scenarios. The fate of dry land farms depends on the scenario. Mild climate scenarios will probably benefit dry land farmers. Harsh scenarios will lead to large losses. Impacts are expected to be evident as early as 2020 and to become larger over time as warming increases. On the other hand, in the Nile basin of Ethiopia irrigated farms are more resistant to changes in climate which indicates irrigation is an important adaptation option for reducing the impacts of changes in climate and used to overcome heat stress (Meseret, 2009).

The other social adaptation to climate change is education. That is educating farmers would help them to easily adopt agricultural technologies and for better adaptation to climate change. This education might include both formal education at school and non-formal like different short term and long-term trainings. In Nigeria Access to education promotes climate change adaptation in. This implies that education to improve awareness of potential benefits of adaptation is an important policy measure for future adaptation and mitigation strategies (Apata, et al., 2010).

Crop diversification or a change in the crop mix is the common adaptation measure particularly in the high potential zones, while water conservation and irrigation of crops are the main adaptation measures in drier regions (Kabubo and Karanja, 2007).

2.2.5 Agricultural technologies, crop production and climate change adaptation

Climate change exacerbates the already daunting challenges facing the agricultural sector, and this is particularly the case in developing countries. Climate has obvious and direct effects on agricultural production. Crop production is extremely susceptible to climate change. It has been estimated that climate changes are likely to reduce yields and/or damage crops in the 21st century (IPCC, 2007), although, notably, effects are expected to differ widely in different parts of the world.

According to FAO (2007), Climate change affects agriculture related to the microbial population of the macro-environment (soil, air and water) and the population of pests or other vectors. It is, therefore, a contributing factor to the occurrence and gravity of biotic diseases attributable to (micro) organisms such as fungi, bacteria, viruses and insects. Abiotic factors such as nutrient deficiencies, air pollutants and temperature/moisture extremes also affect plant health and productivity. While the impact of biotic and abiotic factors on crop production and food security are more obvious, it is important to note that these factors may also have significant impact on the safety of food crops.

The climate change implications of agricultural production and practices have broadened the agricultural agenda over recent years to include responses to climate issues, and the climate change agenda has similarly subsumed agricultural production as both a contributor to climate change and, through adjustment in practices, a potential mitigating force. Innovative agricultural practices and technologies can play an important role in climate change mitigation and adaptation.

Increasing agricultural productivity for better climate change adaptation requires technological advances in crop yields. In contrast to developed countries, which have seen dramatic yield gains in the past century through investments in agricultural innovation and operate close to the technological frontier, in most of developing countries agriculture is far from this frontier. The greatest latent productivity potential, therefore, resides in developing countries generally and in Sub-Saharan Africa in particular. In these places, profitable adaptation and farmer adoption of suitable varieties and crops could spark substantial yield gains (ICTSD, 2010).

Agricultural production involves a number of activities ranging from land preparation, planting, weeding, irrigation, harvesting, processing and preservation or storage. Each stage of the production process demands particular types of scientific and technological inputs with environmental implications. The majority of African farmers use obsolete and poorly developed science and technology in their production endeavors. Planting, weeding and harvesting are done using mostly poorly developed technologies. Use of poor science and technology limit the amount of land available for cultivation, as well as the efficiency of carrying out the production and storage processes. However, there is high potential and need for increasing output and productivity through improved practices (ECA, 2003).

In supporting this idea, Schultz's approach argues about the important dimension that the process of agricultural development can be accelerated through provision of new and improved inputs and technologies (particularly improved seeds, fertilizers, pesticides, and irrigation systems). In developing countries what farmers need are new high-payoff inputs and technologies to increase their productivity (Allam, 2004).

On the other hand, the existence of acute poverty and hunger, exacerbated by unstable and sometimes very high food and fertilizer prices, cries out for an immediate response. "Smart" Fertilizer Subsidy Programs in Africa are potentially attractive because they can raise food production and thus reduce hunger in the short run. Income gains transferred to farmers through the subsidy are expected to result in greater savings and investments in productive assets, contributing to longer-run growth. In addition, income transfers to farmers address the social and political objectives of poverty alleviation and improved equity (COMESA). Therefore, utilization of fertilizer in developing countries can reduce vulnerability to climate change and impacts on their agricultural crop productivity.

However, the issue of CO₂ fertilization has given rise to much debate. Some scholars in the field argue that, increasing CO₂ fertilization could make a major contribution to solving the problems created by climate change for agriculture; however, others feel this contribution may be overestimated. It is worth noting the differential impacts of CO₂ fertilization, with crops such as wheat, rice and soybeans known as C₃ crops responding positively to increased CO₂, whilst other major staples, such as maize, sorghum, sugarcane and millet C₄ crops do not benefit. As C₄ crops

are those grown in the tropics, this factor alone shows the possibility of differential climate change effects and points to the fact that only agricultural production in more temperate zones, will be partially compensated by the beneficial effects of CO₂ enrichment (Claire *et al.*, 2002).

Furthermore, applying improved variety of crops is important to cope up climate change through agricultural productivity enhancement. In addition to increasing productivity generally, several new varieties and traits offer farmers greater flexibility in adapting to climate change, including traits that confer tolerance to drought and heat, tolerance to salinity and early maturation in order to shorten the growing season and reduce farmers' exposure to risk of extreme weather events. These promising new traits and varieties, which are mostly still in development, can emerge from traditional breeding techniques that leverage existing varieties that are well suited to vagaries of the local production environment, as well as from more advanced biotechnology techniques such as marker assisted selection and genetic modification.

Improvements in crop yields per unit of land are crucial as an alternative to extensive conversion of grassland and forestland to crops. Therefore, technologies with potential to increase the intensity of land use can yield mitigation benefits. This may even include application of additional fertilizer, or pesticide inputs, where the "first round" Green House Gas implication may not look favorable. However, there are other amendments like biochar, a charcoal soil amendment that brings both improved soil fertility and serve as a carbon sink (Lehmann *et al.*, 2006). Similarly, herbicides and other inputs that reduce competition from weeds can improve productivity and thereby serve to mitigate Green House Gas emissions associated with bringing additional land under cultivation. Furthermore, since potential cropland in different regions has very different capacities to sequester carbon, shifting crops to the land with the least negative carbon implication may have net Green House Gas benefits. This may mean that, farming dry regions under irrigation, which allows use of land that otherwise, would not contribute to mitigation (Lybbert and Sumner, 2010).

Moreover, the midst of increasing urban and environmental demands on water, agriculture must improve water use efficiency generally. Adding climate change to this mix only intensifies the demands on water use in agriculture. With hotter temperatures and changing precipitation patterns, controlling water supplies and improving irrigation access and efficiency will become

increasingly important. Climate changes will burden currently irrigated areas and may even outstrip current irrigation capacity due to general water shortages, but farmers with no access to irrigation are clearly most vulnerable to precipitation volatility. Since Africa only irrigates 6% (13.6 million hectares) of its arable land in contrast to 20% worldwide (FAO, 2007), African farmers are in desperate need of techniques, technologies and investments that improve water management efficiency, access to irrigation or to find ways to improve incomes with less secure and more variable water availability (Lybbert and Sumner, 2010).

Therefore, creating the necessary agricultural technologies and harnessing them to enable developing countries to adapt their agricultural systems to the currently varying and changing climate conditions will require utilization of improved agricultural technologies such as fertilizers, improved variety of seeds, irrigation and water harvesting technologies and improved soil conservation techniques. Further, innovations in policy and institutions are very significant for better implementation. In sum, this would result in, good agricultural and environmental development including food security and improved livelihoods at different levels in the country.

Chapter-Three

3. Research Methodology

3.1 Research Design

This research uses both descriptive and cross sectional research design to see the impact of climate change on crop production and to assess the types and effectiveness of adaptation measures taken by the local farmers. The study adopts the cross sectional Ricardian approach to measure the vulnerability of crop production by estimating the economic impact of climate change on its net revenue in Choke Mountain Watersheds of Ethiopia. The approach has also been used to measure the marginal value of agricultural technologies to see its significance for climate change adaptation. For this study, cross sectional data and econometric analysis to estimate the impact of climate elements, soil, use of agricultural technologies and other important socio-economic factors were used to see their impact on crop net revenue.

Thus, cross-sectional approach examines farmers' performance across climate zones (Mendelsohn *et al.*, 1994; 1996; Mendelsohn and Dinar, 1999; Sanghi, 1998; Sanghi *et al.*, 1998; Kumar and Parikh, 1998a). The approach has been named Ricardian method because it draws heavily from an observation by David Ricardo that land values would reflect land productivity at a site (under competition).

The approach has been used to value the contribution environmental measures make to farm income. By regressing land value or net revenue on a set of environmental inputs, one can measure the marginal contribution of each input to farm income. The approach has been applied to the United States (Mendelsohn *et al.*, 1994; 1996; 1999) and Brazil (Sanghi, 1998). The approach has also been used in India where annual net revenue was substituted for land value (Sanghi *et al.*, 1998; Kumar and Parikh, 1998).

3.2 Sources of Data

This study uses both primary and secondary sources of data:

Primary data were collected through several data gathering techniques including questionnaire (structured and semi structured), key informant interviews and Focus Group Discussion (FGD) from the selected households in each Kebele Administrations. On the other hand, the data have been taken in to account agricultural experts and administrators in each selected districts and KAs as key informants to obtain vital information for the study.

On the other hand, secondary Data was gathered mainly recorded precipitation and temperature data of the study areas, soil data of each selected agro-ecologies and this was helpful to buffer the primary data collected through questionnaire, interview or focus group discussion.

3.3 Samples, Sample Size Determination and Sampling Procedures

The data for this study was collected from five major districts with varied agro ecologies in the CMWs such as Sinan, Debre Elias, Gozamen, Enemay and Dejen which were selected with purposive sampling technique from the nine districts in the watershed. From these seven representative Kebele Administrations having similar agro ecologies with their corresponding districts were chosen purposefully to get a wide representation of farmers across several climate conditions in the study areas. Accordingly, Dangulie and Gedamawit KAs from Sinan, Enerata KA from Gozamen, Guay KA from Debre Alias, Mahibere Birhan KA from Enemay and Gelgelie and kurar KAs from Dejen districts were selected. These represents the six Ago ecologies of Very cold sub-moist mid highlands, Cold sub-moist mid highlands, Cool sub-moist mid highlands, Cool-Moist Mid highlands, Tepid moist mid highlands and Warm sub-moist lowlands of Choke Mountain Watersheds respectively (see table 4.1).

However, the study uses households as major units of analysis. The researcher has employed stratified simple random sampling techniques to select representative sample households from the selected Kebele Administrations. This has been done based on standard statistical formula called Raosoft Sample Size Calculator (<http://www.raosoft.com/samplesize.html>). This formula has considered the margin of error, confidence level, response distribution and the total household population size of each selected Kebele Administrations such as Dangulie, Gedamawit, Enerata, Mahibere Birhan, Guay and Gelgelie & Kurar with the total household

population of 6944, 6983, 5243, 6923, 8688 and 10988 respectively (CSA, 2008). So that, the total sample size obtained from the calculation was 276 households (refer Chart-1 in the annex to see the samples from each AEZs). The number of sample households chosen in each KAs or AEZs was varied from 35 to 47 in accordance with the total count of their respective population. From these chosen household heads, data was collected about the farming activities and crop production, adaptation options they have used and other socio economic condition of households during the period from January 2009 to January 2010. However, not all the sample households were used for the study because some of the surveys contained incorrect information and some others have exaggerated figures about farmer as the researcher crosschecked through interview and focus group discussions. Therefore, from the total surveys only 258 were used.

In addition to the survey conducted by administering questionnaires, Focus Group Discussions and Key informant interviews were carried out with the participation of 12 and 7 household heads respectively from each AEZ in consultation with the local administrators and Development Agents (agricultural experts) by considering gender, age, education status and use of agricultural technologies, wealth and others.

3.4 Data collection Instruments

Both primary and secondary data were gathered through the following instruments: Questionnaire both open ended and close-ended questions were prepared and administered for each sample household heads in the study area. Most of these questions were related to farmers' socio economic conditions, their perceptions towards climate change, the adaptation options they were taking, the agricultural technologies they have used for crop production, and how they use agricultural technologies to produce crops, the major constraints and most determinant factors in utilizing agricultural technologies, productivity of their farmland, and their cost of production.

Key Informant Interview was conducted with different concerned individuals at different levels. At the household level, it was conducted with some knowledgeable, experienced, communicative as well as aged household heads. At the Kebele Administration level, it has been takes placed with development agents and administrator. At the district level, it was carried out with different

experts in the agricultural and rural development offices particularly crop and agricultural technology experts.

Focus Group Discussion was also conducted as a supplementary for the data collected through questionnaire to understand the perception of different individuals from various social strata/groups on the issues of climate change and variability, impact of climate change on crop production and agricultural technology interventions in the area and major constraints.

Field Observation was another instrument and undertaken in the form of transect walks with the guidance of local administrator or development agents and with the participation of voluntary local farmers.

Pre-testing of data Gathering instruments

Before the final administration of the questionnaire, the data collection instruments were commented by the research advisor, colleagues, and the experts who had abundant knowledge and experience in the area. Then pilot testing was commenced in the two nearby Kebele Administrations of Enerata and Gelgelie in Gozamen and Dejen districts respectively with 20 randomly selected individuals. This was done to establish the reliability of the proposed questionnaires and interview as well as Focus Group Discussion guides in order to ensure its clarity of language, length and wording of sentences, necessity, ambiguity and redundancy of questions. As a result, few problems were found in the pilot test like missing of words in a sentence, numbering error, ways of expression of words (inclusion of jargons) were some of the problems explored and edited.

3.5 Methods of data analysis

The data collected through the aforementioned techniques has helped to obtain both quantitative and qualitative data, which requires corresponding quantitative and qualitative data analysis methods. Since the study was heavily depend on quantitative data, which needs quantitative methods of data analysis such as descriptive statistics (percentage, cross tabulation or frequency tables), one way ANOVA and Recardian model. For these statistical determinations, application

of a statistical software package called STATA had tremendous importance. Apart from this qualitative data collected through interview, Focus Group Discussion and observation was analyzed through the method of triangulation with results obtained from the statistical tests or model estimations.

3.5.1 ANOVA

One way ANOVA was employed to see whether there was any statistical significance in the farmers' socio economic conditions and households' perception towards climate change among different agro ecological zones in the Choke Mountain watersheds.

3.5.2 Descriptive Analysis

Descriptive statistics of percentages and frequency tables were among the methods used to analyze the data for this study. Qualitative data collected through interviews and Focus Group Discussions were analyzed through the method of triangulation with the results obtained from the descriptive statistics such as percentage and frequency tables.

3.5.3 Ricardian Model Specifications

The Ricardian method is a cross-sectional approach to studying agricultural production. It is based on land rent, which is seen as the net revenue from the best use of land. The land rent would reflect the net productivity of farmland. Farm value (V) consequently reflects the present value of future net productivity. The principle is captured by the following equations based on the works of Deressa (2006) and Meseret (2009):

Assuming the existence of a set of well-behaved (twice continuously differentiable, strictly

Quasi-concave and positive marginal products) production function of the form:

$$Q_i = Q_i(K_i, E), i=1, 2, \dots, n \dots \dots \dots (1)$$

Where: Q_i is the quantity of the product of good i

$K_i=(k_{i1},k_{i2},\dots,k_{ij},\dots,k_{iJ})$ is a vector of all purchased inputs j used to produce Q_i , $k_{ij} =$ the purchased input j (1, 2,..., J) in the production of good i .

$E=(E_1,E_2,\dots,E_m,\dots,E_M)$ is a vector of site specific exogenous environmental factors such as climate(temperature and precipitation) and soil.

Given a set of factor prices W_j , E and Q , cost minimization provides the cost function of the form

$$C_i = C_i(Q_i, W, E) \dots\dots\dots (2)$$

Where: C_i is the cost of production of good i and $W (w_1,w_2,\dots.w_n)$ is a vector of factor prices. Using the cost function C_i at a given market prices, the profit maximization by farmers on a given site can be specified as

$$\text{Max}(\pi) p = P_i Q_i(K_i, E) - C_i(Q_i, W, E) - P_L L_i \dots\dots\dots (3)$$

Where: P_L is the annual cost or rent of land at that site, L_i is the land in hectare.

Under perfect competition all profits in excess of normal returns to all factors (rents) are driven to zero i.e

$$P_i Q_i^*(K_i, E) - C_i^*(Q_i^*, W, E) - P_L L_i = 0 \dots\dots\dots (4)$$

If the production of good i is the best use of the land given E , the observed market rent on the land will be equal to the annual net profits from the production of the good. Solving equation (4) for P_L gives the land rent per hectare to be equal to net revenue per hectare.

$$P_L = (P_i, Q_i^*(K_i, E) - C_i^*(Q_i^*, W, E))/ L_i \dots\dots\dots (5)$$

The present value of the stream of current and future revenues gives the land values,

$$V_L = L \int_0^{\infty} P_L e^{\sigma t} dt = \dots\dots\dots (6)$$

$$= \int_0^{\infty} [(P_i Q_i^*(K_i, E_i) - C_i(Q^*, W, E)) / L_i] e^{-\rho t} dt \dots \dots \dots (7)$$

The farmer is assumed to choose K to maximize net revenues given the characteristics of the farm and market prices.

The Ricardian model is based on a set of explanatory variables such as climate, soils and socio-economic variables that affects farm value. The model uses actual observations of farm performance in different agro-climatic zones (Mendelsohn et al., 1994). The standard Ricardian model relies on a quadratic formulation of climate:

$$V = \beta_0 + \beta_1 F + \beta_2 Z + \beta_3 G + u \dots \dots \dots (8)$$

Where:

F = vector of climate variables

Z= set of soil variables

G= set of socio-economic variables

u= an error term

F and F² capture linear and quadratic terms for temperature and precipitation. The introduction of quadratic terms for temperature and precipitation reflects the non-linear shape of the response function between net revenue and climate. From past studies one expects that farm revenues will have U-shaped or hill-shaped relationship with temperature. When the quadratic term is positive, the net revenue function is U-shaped, but the quadratic term is negative, the function is hill shaped. For each crop, there is known temperature where that crop grows best across the seasons though the optimal temperature varies from crop to crop (Mendelsohn et al., 1994).

Given equation (8), one can derive the marginal impact of climate variables (f_i) on crop revenue evaluated at the mean as follows:

$$\begin{aligned}
& \frac{dv}{df_i} = E[\beta_{1,i} + 2\beta_{2,i} * f_i] \\
& = \beta_{1,i} + 2 * \beta_{2,i} * E(f_i) \dots \dots \dots (9)
\end{aligned}$$

The change in economic welfare, ΔW , resulting from an environmental change from A to B, which causes environmental inputs to change to E_B can be measured as follows (Kurukulasuriya and Mendelsohn, 2006). Here one can analyze the impact of exogenous changes in environmental variables on net economic welfare (ΔW). The net economic welfare is the change in welfare induced or caused by changing environment from a given state A to B, which causes environmental inputs to change from E_A to E_B . The change in annual welfare from this environmental change is given by:

$$\Delta W = W(E_B) - W(E_A)$$

$$= \int_0^{Q_B} [(P_i Q_i(K_i, E_B) - C_i(Q_i, W, E_B)) / L_i] e^{\sigma t} dQ - \int_0^{Q_A} [(P_i Q_i(K_i, E_A) - C_i(Q_i, W, E_A)) / L_i] e^{\sigma t} dQ \dots \dots \dots (10)$$

If market prices do not change because of the change in E, then the above equation reduced to:

$$\Delta W = W(E_B) - W(E_A)$$

$$= [P_{QB}(K_i, E_B) - \sum_{i=1}^n C_i(Q_i, W, E_B)] - [P_{QA}(K_i, E_A) - \sum_{i=1}^n C_i(Q_i, W, E_A)] \dots \dots \dots (11)$$

(Substituting for $P_L L = P_i Q_i - C_i(Q_i, W, E)$ from (5))

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^n (P_{LB} L_{Bi} - P_{LA} L_{Ai}) \dots \dots \dots (12)$$

Where P_{LA} and L_A are at E_A and P_{LB} and L_B are at E_B .

The present value of welfare change is thus

$$\int_0^{\infty} \Delta W e^{\alpha t} = \sum_{i=1}^{\infty} (V_{LB}L_{Bi} - V_{LA}L_{Ai}) \dots\dots\dots (13)$$

The Ricardian model takes either (12) or (13) depending on whether data are available on annual net revenues or capitalized net revenues (land values, V_L). The model in (12) was employed for this study to measure the impact of climate change in choke mountain Watershed of Ethiopia, as data on land prices for the selected samples were not available.

This approach have been applied also by Sanghi et al. (1998) and Kumar & Parikh (1998) for India, Deressa (2006) for Ethiopia, Ouedraogo et al. (2006) for Burkina Faso, Molua & Lambi (2006) for Cameroon, Kabubo-Mariara & Karanja (2006) for Kenya ,Eid et al.(2006) for Egypt, Benhin (2006) for South Africa, Sene et al. (2006) for Senegal, Jain (2006) for Zambia and Mano & Nhemachena (2006) for Zimbabwe1 and Meseret (2009) for the Nile Basin.

The empirical models developed for this study follow the works of Mendelsohn et al. (1994), Sanghi et al. (1998), Ouedraogo et al. (2006) and taking into account the climate in the Choke Mountain watersheds of Ethiopia. The models examine how long-term farm profitability varies with climate (temperature and precipitation) and soils while controlling for other factors. Agricultural technology variables and other socio economic are also assessed to see the extent to which they control or worsen the adverse impacts of climate change on crop agriculture. Two main models are formulated: ‘without’ adaptation and ‘with’ adaptation. The former include only climate and soil variables. While the latter in addition to these variables include only agricultural technologies such as, use of chemical fertilizers, improved seeds, soil conservation and irrigation technologies. The other with adaptation model includes climate and soil variables agricultural technologies with other relevant socio-economic variables such as farm size, access to formal credit, household size, education status of the household head and female dummy. These three models estimated for sample farms that represent Choke Mountain Watersheds of Ethiopia (here after called full sample model or entire farm model to assess any significance difference in the impacts of climate change on the dry land farming system.

The model without adaptation options includes only the physical variables (temperature, precipitation and soils):

$$NR_1/ha = \beta_0 + \beta_1 ST + \beta_2 WT + \beta_3 SPT + \beta_4 FT + \beta_5 SP + \beta_6 WP + \beta_7 SPP + \beta_8 FP + \sum_{i=1}^n \Delta_i soil_i + E^1_k$$

The model with adaptation includes the previous variables and farms characteristics:

$$NR_1/ha = \beta_0 + \beta_1 ST + \beta_2 WT + \beta_3 SPT + \beta_4 FT + \beta_5 SP + \beta_6 WP + \beta_7 SPP + \beta_8 FP + \sum_{i=1}^n \Omega_j Y_j \Delta_i soil_i + E^3_k$$

$$NR_1/ha = \beta_0 + \beta_1 ST + \beta_2 WT + \beta_3 SPT + \beta_4 FT + \beta_5 SP + \beta_6 WP + \beta_7 SPP + \beta_8 FP + \sum_{i=1}^n \Omega_j X_j Y_j \Delta_i soil_i + E^4_k$$

Where: ST, WT, SPP and FT are the mean long-term weather temperature for the summer, winter, spring, and fall season respectively, and SP, WP, SPP, and FP are the mean long-term weather precipitation for summer, winter, spring, and fall season respectively. The variables $X_j Y_j$ are set of socio-economic and agricultural technology variables and the B, Δ , and Ω are coefficients of the seasonal temperature & precipitation, soils, agricultural technology and socio-economic variables respectively. E^1_k, E^2_k , and E^3_k , are the random disturbance term for the first and second model respectively.

It is not obvious how to represent monthly temperature and precipitation data when Ricardian regression model is applied (Kurukulasuriya and Mendelsohn, 2006). The correlation between adjacent months is too high to include every month. This study explored several ways of defining three-month average seasons. Comparing the results, defining summer (the average for June, July and August), winter (the average for December, January and February), spring (the average for March, April and May) and fall (the average for September, October and November) provided the most robust results for Choke Mountain Watershed of Ethiopia. This study has used only the non-squared and linear temperature and precipitation variables due to multi-co linearity problem.

3.6 Description of Dependent and Independent Variables

Net crop revenue per hectare

In this study net revenue is gross crop revenue (which is the product of total harvest and price of crops grown in the selected agro ecological zones of choke mountain this includes wheat, maize, teff, barley, sorghum and engido) minus total cost of production. Since the farmers in these areas used to grow more than one crop on the same land then it is the sum of the products of the crop harvested and their prices minus their associated cost of production. Total harvest of crops includes harvest used for household consumption, livestock feed and harvest sold. The cost element is mainly total variable costs (TVCs), which in this case include expenditure on, marketing, storage, post-harvest losses, fertilizer, pesticide, and seeds, . What is excluded from the estimation of the cost is household labor because of the possibility of overestimation. We control for this by using household size as a proxy for household labor in the model. On the other hand, cost of transportation is not considered since most of sample households use animal back as a means of transportation of harvest to storage and market by which these animals were their own or their relatives as well as neighbors.

Average Net Revenue is the dependent variable that is explained by the variables indicated above.

Table-3.1 Net revenue of crop production in CMWs

AEZs	Mean net revenue per hectare
Choke mountain watersheds	8,633.54
Very cold sub-moist mid highlands	4,229.01
Cold sub-moist mid highlands	7,338.27
Cool sub-moist mid highlands	9,452.59
Cool -Moist Mid highlands	11,604.88
Tepid moist mid highlands	13,249.05
Warm sub-moist lowlands	5,927.41

Climate variables: temperature and precipitation

The data on climate was gathered from the Ethiopian National Meteorological Agency (NMA). The Agency was given both the temperature and precipitation data, which is a measurement,

result of about 32 to 25 years from the spot of the selected districts as well as kebeles administrations. According to Kurukulasuriya (2006), there are many ways of that one could represent monthly temperature and precipitation data in Recardian regression model. It is not also advisable to include all monthly temperature and precipitation data because there is high correlation between the adjacent months. Therefore based on this, the study used the mean seasonal temperature and rainfall data of 32/25 years.

The long-term mean temperature and precipitation for each chosen agro ecological zones of Choke Mountain Watersheds are presented in table-D and table-E in the annex. These tables indicate that spring is the hottest season with the average temperature of 21.9⁰C. Summer season have relatively lower temperature of 7.8⁰C. From the sample KAs or districts Dangulie (Sinan) was the coldest and Kurar(Dejen) was the hottest areas. Their average long-term minimum temperature was 4.2⁰C and 12.3⁰C respectively. In these the maximum mean temperature was found in Kurar by having 28.5⁰C and the maximum long term mean temperature of Dangulie was 14.5⁰C (see table-D from the annex).

In the study area, the maximum long-term mean precipitation was 473.2mm in Dangulie and the minimum was 6.7mm in Kurar. Here all AEZs receive the highest mean precipitation in summer from all seasons whereas winter receives the lowest (see Table E from the annex).

Soils

The soil data was gathered from the surveys collected of each of sample farmer household heads by asking the type of soil they used to grow crops. The survey have also been asked farmers whether the soil of their farmland fertile or not. Then the data of soil gathered from each individual sample farmers was referred to the soil experts from Debre Markos Soil Experiment Center based on their preliminary data of each chosen AEZs

Both sources of data indicates that in choke mountain watersheds there are various soil types but the dominant ones are Nitosols, Vertisols, Cambisols, Lithosols (See table B from the annex). The table indicates that Nitosols soil is the dominant in Tepid moist mid highlands agro ecology of Guay and Lithosols and Vertisols are dominant in the Warm sub-moist lowlands agro ecology of Gelgelie and the other soil type Cambisols cover large areas of Cold sub-moist mid highlands



of Gedamawit. The impact of these soils was tested to see their contribution of natural conditions for total net revenue of crop production.

Agricultural technology utilization

Agricultural technology variables were also included for the study to see their adoption, use as well as distribution. In addition, these variables were also importance to notice their role on climate change adaptation by estimating the marginal impacts on farmers' net revenue of crop farming. These improved agricultural technologies include improved agricultural inputs of chemical fertilizers of dap and urea as well as improved seed varieties and use of irrigation (by using irrigation technologies of motor pump, water pump, geo-membrane) and practice of improved or modern soil conservation practices such as use of soil bund, stone bunds...etc. Therefore, the data collected from each Agro ecological zones of study population indicates that there were users and non-users of these agricultural technologies. The extent of implementation of these technologies has also varied from one agro ecology to another.

Socio-economic factors

These variables tested in the models include total land under crops, livestock ownership, gender or female as dummy, access to credit, household size used as proxy for household labor and Educational level of the household head used as a proxy for literacy rate.

Chapter-Four

4. Brief Description of the Study Area

The Choke Mountain range is the most important source of water for the Blue Nile river system in Ethiopia. The area extends between 10° to 11°N and 37°30' to 38°30'E, the highest peak is located at 10°42'N and 37°50'E. It is situated in the south of Lake Tana, in the central part of the Amhara National State of Ethiopia. Its elevation extends from 810m.a.s.l to 4050m.a.s.l. The mean annual rainfall varies between 995mm and 1864mm based on data from 13 stations for the years 1971-2006. The mean annual temperature ranges from 7.5°C to 28°C (BCEOM, 1998a).

There is no longer significant natural forest cover in this mountain range. The major remaining natural habitats are moisture moorland, sparsely covered with giant lobelias (*Lobelia* spp.; Jibara/Jibbra), lady's mantle (*Alchemilla* spp.), Guassa grass (*Festuca* spp.) and other grasses. There is very little natural woody plant cover; heather (*Erica* spp.; Asta) and Hypericum (*Hypericum revolutum*; Amijja) are found in patches. Bamboo or Kerkeha (*Arundinaria alpina*) is found as homestead plantation as well as part of the natural vegetation cover in the area, albeit very sparsely. Korch (*Erithrina brucei*) is commonly grown as border demarcation plant in the area. *Eucalyptus globulus* is extensively grown in plantation, and some of the residents have become dependent on it for their livelihoods (Belay Simane, 2006).

Though all the above descriptions about the mountain watershed are facts, it is highly threatened due to both human and natural pressures. In the area, there is critical and extensive cutoff tree for farming and grazing land as a result, the mountain is currently hosting extensive erosion, which has a significant impact on agricultural activities in the area. Due to this, large sizes of the farmlands in the area are becoming unproductive and facing soil acidity problem because of the continuous removal of soil minerals and nutrients from the top soil by erosion.

The mountain is the source of major rivers like; Chemoga, Cheye, Suha, Gedeb, Muga, Temcha, Bir, Bogena, Lah and Streams such as Sedie, Teme, Azuari, Teza, Dechet, Yeda ...etc. Hence, the local communities called it “*Yewuha Gan*” (*the water tower*). These streams and number of rivers flows across several districts. Though there are various rivers and streams flow

across these districts, the practice of irrigation was very low or it seems at the stage of startup. according to the local authorities, farmers and agricultural experts in the area irrigation was not yet extensively implemented because of lack of expertise support, lower awareness of local farmers, the land escape (topography of the area because of its natural steepness), shortage of irrigation technologies (for the last several years), expensive price of modern irrigation technologies.

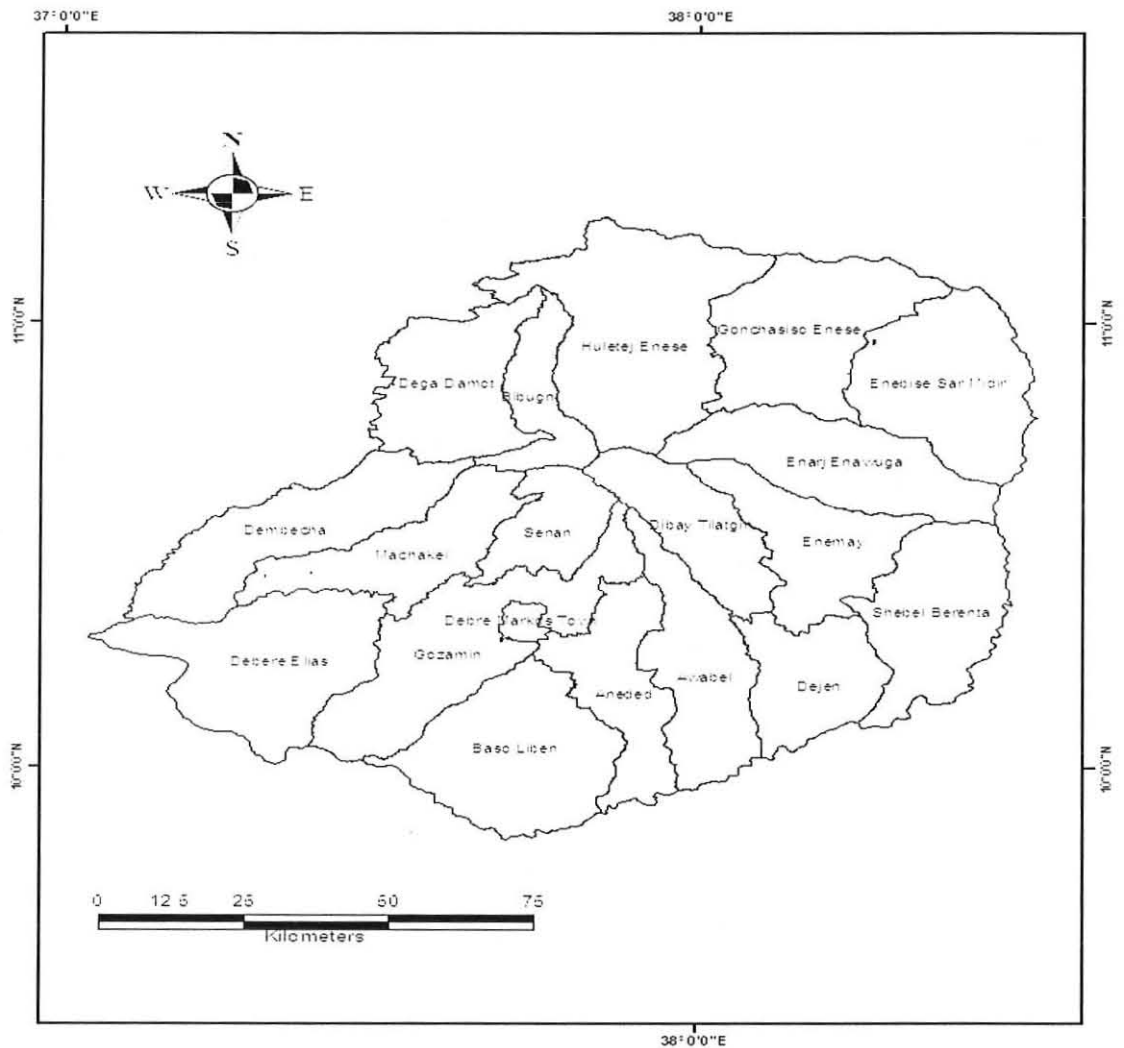


Figure-1: Map of Choke Mountain watershed districts

vegetations, animals, crops, and livestock. There have also different rainfall amount and degree of temperature. This is also true for choke mountain watersheds.

Table 4.1: Agro Ecological classification of Choke Mountain Watersheds

AEZs	District	Kebele Administration
Very cold sub-moist mid highlands	Sinan	Dangulie
Cold sub-moist mid highlands	Sinan	Gedamawit
Cool sub-moist mid highlands	Gozamen	Enerata
Cool -Moist Mid highlands	Enemay	Mahibere berhan
Tepid moist mid highlands	Debre Elias	Guay
Warm sub-moist lowlands	Dejen	Kurar and Gelegelie

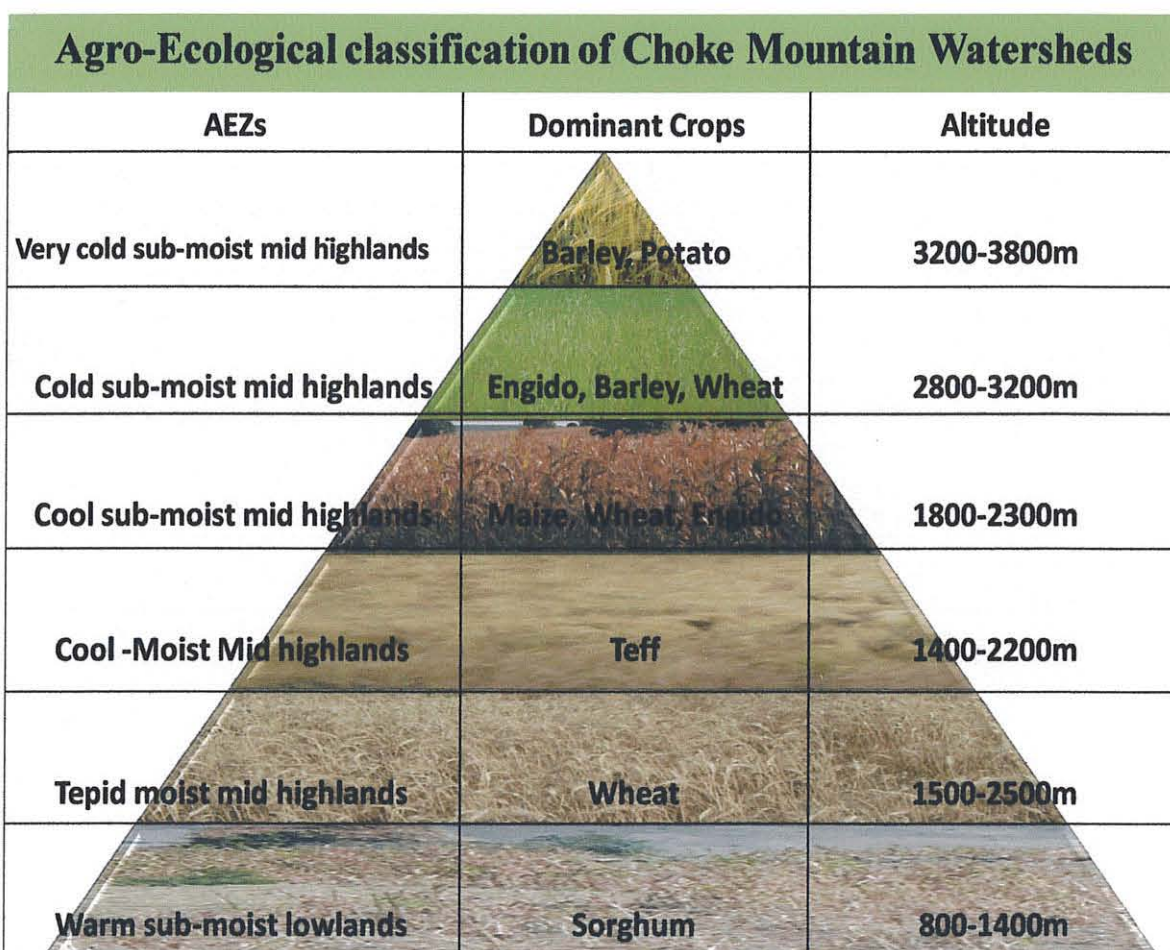


Figure 3: Agro-Ecological classification of the study area

1. Very cold sub-moist mid highlands

In the watersheds, this AEZ is represented by Dangulie Kebele Administration of Sinan district. The altitude varies between 3200 and 3,800 m.a.s.l. The annual temperature is $<7.5^{\circ}\text{C}$. The growing period varies between 61 and 120 days. The dominant crops grown in the area includes barley, potato and wheat. The dominant vegetation covers are *Juniperus procera*, *Erica arborea*, *Hagenia abyssinica*, *Hypericum revolutum* and *Olea europae*. The dominant soil types are Cambisols, Vertisol and Andosols. The zone has potential for biodiversity reserve. Very cold temperature and deforestation are constraints of the sub zone.

2. Cold sub-moist mid highlands

This zone represents the cool sub moist Sinan District in the watershed particularly Gedamawit kebele administration. Its altitude varies between 2800 and 3200m.a.s.l. The annual temperature varies between 7.5°C and 10°C and the growing period is between 61 and 120 days. The major crops grown in the area are potato, wheat, barley and other pulses. The dominant plant tree species are the *Juniperus procera*, *Erica arborea*, *Hagenia abyssinica*, *Hypericum revolutum* and *Olea europae*. The dominant soil types are Cambisol, Humic Andosols and Nitosols. The zone has high potential for afforestation and low potential for agriculture. The major constraints of the sub zone are low temperature, soil erosion and deforestation.

3. Cool sub-moist mid highlands

In the Choke Mountain Watershed, this zone is represented by Gozamen district of Enerata kebele administration. The elevation ranges from 1400 to 2200 m.a.s.l. The annual temperature varies between 11°C - 15°C and the growing period between 61-120 days. The soil types found in this zone are Nitosols and Cambisols. *Accacia* and *Balanities* are the dominant plant species. Shallow soil depth and rugged landforms are constraints for crop production. The main crop types produced are wheat, maize, teff, and pulses.

4. Cool -Moist Mid highlands

In the Choke Mountain Watershed this zone is particularly represent Enemay district of Mahibere Berhan kebele Administration. It has an elevation ranges from 1800 to 2300 m.a.s.l. The annual temperature varies between 11 and 15 °C. The growing period is between 121 and 180 days. Vertisols and Leptosols are dominant soil type. Hagenia, Olea, Ficus, Croton, Cordia etc species are dominant vegetation types. The zone is potential for teff production. The highly rugged landform is the major constraint for crop production.

5. Tepid moist mid highlands

This zone is represented by Debre Elias District Guay Kebele Administration in the Choke mountain watershed areas. The elevation varies between 1500 and 2500 m.a.s.l. The annual temperature varies between 16 and 21°C. The growing period is between 121-180 days. Nitisols and Cambisols are dominant soil types. Cereal production; wheat production in particular is the dominant farming system in the area. However, the Zone also produces maize and teff crops. The zone has potential for agriculture and livestock production.

6. Warm sub-moist lowlands

This zone is found in Dejen district and it mainly includes the lowland areas of the Abay Gorge such as Kurar and Gelgelie. Its elevation ranges from 800 to 1400 m.a.s.l. The annual temperature falls between 21°C and 27.5°C. The growing period ranges between 61 and 120 days. The dominant soil types are Lithosols, Gypsisols, Vertisols, and Cambisols. *Oxytenathera abyssinica* and *Accacia species* are the dominant natural growing trees. The zone has potential for sorghum and sesame production. Malaria and tse tse fly infestation are the major constraints in this zone of agro ecology.

4.2. Socio-Economic characteristics of the study population

Gender of household heads

Productivity of crops can be determined by gender due to the disparities in physical and human capita, originating from economic and socio-cultural differences (Aly, Hassan et al., 2010). From the selected households in the Choke Mountain Watersheds 91.1% were male household heads and the remained 8.9% were female household heads.

Table 4.2: Gender distribution in the sample household heads

AEZs	Female (%)	Male (%)	Analysis of variance	
			F-value	Sig.
Choke Mountain watersheds	8.5	91.5	2.1	0.09*
Very cold sub-moist mid highlands	11.8	88.2		
Cold sub-moist mid highlands	7.3	92.7		
Cool sub-moist mid highlands	14.3	85.7		
Cool –Moist Mid highlands	2.5	97.5		
Tepid moist mid highlands	8.5	91.5		
Warm sub-moist lowlands	13.5	86.5		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Age of household Heads

The age of the household head was one of the explanatory variables, which is expected to influence net revenue, and on the implementation of different adaptation options including adoption of several technologies in the study population. This variable was characterized as youth (15-24), prime working population (25-44), old working population (45-64) and ages ≥ 65 years old as old population category. Accordingly, from the total sample households of those chosen study areas 0.8% was found to be under the age group of 15-24, which is characterized as youth group however, 58.9% were found as prime working populations (25-44) and 35.3% were fall under old working population (45-64) but the remained 5% were under the old age population category. In general, from the total sample population about 94.2% were categorized under prime and old working population groups. On the other hand, the rest percentage covers the youth and old population groups.

The average age of sample households was 42.87 years old and the minimum and maximum age distribution of the sample household heads in Choke Mountain Watershed areas was 22 years old

and 88 years old respectively. The t-test result showed that there is significant difference among age groups in each agro ecological zones as well as total sample population.

Table 4.3: Age of sample household heads in CMWs

AEZs	15-24 (%)	25-44 (%)	45-64 (%)	≥65 (%)	Analysis of variance	
					F-value	Sig.
Choke Mountain watersheds	0.8	58.9	35.3	5	9.20	0.07**
Very cold sub-moist mid highlands	0	64.7	32.4	2.9		
Cold sub-moist mid highlands	0	34.1	63.4	2.4		
Cool sub-moist mid highlands	3.6	71.4	17.9	7.1		
Cool –Moist Mid highlands	0	65	30	5		
Tepid moist mid highlands	2.1	70.2	23.4	4.5		
Warm sub-moist lowlands	0	43.2	45.9	10.8		
Warm sub-moist lowlands	0	67.7	29	3.2		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Family Size of the Household

Size of the household is one of the determinants for crop net revenue. Therefore, in the Choke Mountain watersheds of Ethiopia 71.3% had the family members between 5-9, however the remaining other 22.5% and 6.2% represent family size of ≤ 4 and ≥ 10 respectively. In the Very cold sub-moist mid highlands of Dangulie about 20.6% of household have the < 5 family size but the remaining 70.6% and 8.8% have 5-9 and ≥ 10 family size respectively. However in the Cold sub-moist mid highlands of Gedamawit about 7.3% of farmers had family size of < 4 but the rest 80.5% and 12.2% had a family size 5-9 and ≥ 10 respectively. The minimum family size was 2 and the largest family size was 12 with the mean of 6.2 and standard deviation of 2.27.

Table 4.4: Households' family size in CMWs

AEZs	1-4	5-9	≥ 10	Analysis of variance	
				F-value	Sig.
Choke Mountain watersheds	22.5	71.3	6.2	1.01	0.839
Very cold sub-moist mid highlands	20.6	70.6	8.8		
Cold sub-moist mid highlands	7.3	80.5	12.2		
Cool sub-moist mid highlands	32.1	64.3	3.6		
Cool –Moist Mid highlands	22.5	72.3	6.4		
Tepid moist mid highlands	21.3	72.3	6.4		
Warm sub-moist lowlands	22.6	74.2	3.2		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Level of Education of Household Heads

The level of education of household heads was also considered in the study. The maximum education level of sample household heads was higher education level and the minimum was illiterate. From the total sample population of the study 30.2% of household heads were illiterate, 38.8 %were able to read and write. 25.2% have attended elementary school. In addition to this, the household heads who has completed secondary education and who attended higher education were 5% and 0.8% respectively. In general larger sample populations of the study 69% were not attended formal education except some of them who could able to read and write.

Table 4.5: Level of education of sample household heads in CMWs

AEZs	Illite rate	Able to read & write	Elemen tary school	Second ary school	Higher educati on	Analysis of variance	
						F-value	Sig.
Choke Mountain watersheds	30.2	38.8	25.2	5.0	0.8	2.8	0.08*
Very cold sub-moist mid highlands	47.1	29.4	23.5	0	0		
Cold sub-moist mid highlands	24.4	48.8	22	4.9	0		
Cool sub-moist mid highlands	39.3	35.7	17.9	7.1	0		
Cool –Moist Mid highlands	30	35	27.5	5	2.5		
Tepid moist mid highlands	34	36.2	17	10.6	2.1		
Warm sub-moist lowlands	29.7	32.4	37.8	0	0		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Households Access to Credit

Access to credit is another important variable which is expected to have an impact on farmers' net revenue. It is important for local farmers to buy for different agricultural technologies including fertilizer, improved seeds and other important technologies used for irrigation practice in their farming activities. Therefore, from the total respondents 58.5% have got access to credit and the rest 41.5% didn't have access for credit to enhance their crop production.

Table 4.6: Households access to credit in CMWs

AEZs	Credit		Analysis of variance	
	Yes	No	F-value	Sig.
Choke Mountain watersheds	58.5	41.5	4.32	0.04**
Very cold sub-moist mid highlands	61.8	38.2		
Cold sub-moist mid highlands	39	61		
Cool sub-moist mid highlands	75	25		
Cool –Moist Mid highlands	82.5	17.5		
Tepid moist mid highlands	55.3	44.7		
Warm sub-moist lowlands	37.8	62.2		

* Significant at 10%, ** significant at 5%, *** significant at 1%

4.3 Farming systems, cropping pattern and Landholding

Mixed farming consisting of crop and livestock is the main farming system practiced by farmers in all sample AEZs of Choke mountain watersheds. The livelihood is mainly depending on rain fed agriculture and livestock rearing. Thus in the area irrigation agriculture is practiced only by few farmers. With the exception of maize, barley, and wheat, which are grown in both, irrigated and rain fed conditions other cereal crops: teff, sorghum, engido and other pulse crops are grown under rain fed condition.

The land tenure arrangements and farm size have significant effect on the value of crop production (Prada et al., 2003). From the study sample households 86.8% were farming/cultivating their own land (owner operator) and the rest 13.2% were not cultivating theirs but they got their farmland by land rent, tenant sharecropper, and through contract.

Farmers with more land and farm tools are also more likely to adopt new technologies (Quisumbing and Agnes, 1995). In Choke mountain watershed areas, largest numbers of the population household heads have small-scale farms. For instance, from the total sample households 70.5% have small scale farm which is the land holding less than 2ha but the remaining 29.5% are medium scale farmers with medium scale farm which ranges from 2-8ha. In this study area there is no large-scale farmer having ≥ 8 ha of land. In this regard, the size of the land that farmers have, could determine the amount of net revenue per hectare that the farmer gets from crop production. As table 4.7 shows that, the agro ecological distribution of size of farmland in choke Mountain watersheds in the Very cold sub-moist mid highlands of Dangulie 97.1% and the cold sub-moist mid highlands of Gedamawit 95.1% of householders have small scale farming which is < 2 ha. In the warm sub-moist lowlands of Gelgelie and Kurar 83.8% of farmers, have small-scale farms. However, in the Tepid moist mid highlands of Guay about 80.9% of farmers have medium scales of land. In the Choke Mountain watershed areas the smallest farm size hold by the household was 0.125ha in the Cold sub-moist mid highlands of Gedamawit and the largest was 4.75ha in the Tepid moist mid highlands of Guay. The average farm size was 1.6ha and the standard deviation was 0.89.

Table 4.7: Size of farmlands of households in CMWs

AEZs	Size of farmland			Analysis of variance	
	Small scale (%)	Medium scale (%)	Large scale (%)	F-value	Sig.
				25.59	0.002***
Choke Mountain watersheds	70.5	29.5	0		
Very cold sub-moist mid highlands	97.1	2.9	0		
Cold sub-moist mid highlands	95.1	4.9	0		
Cool sub-moist mid highlands	67.9	32.1	0		
Cool –Moist Mid highlands	85	15	0		
Tepid moist mid highlands	19.1	80.9	0		
Warm sub-moist lowlands	83.8	16.2	0		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Chapter-Five

5. Results and discussions

5.1 Farmers' perception towards climate change

Adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them (Maddison, 2006). The frequency table-5.1 indicates that about 89.5 %of the respondents were having the opinion that, there has been an increase of the day temperature in their locality for the last 20 and 30 years. However, 1.9% and 2.3% of the total sample population perceived that there is a decrease and no change in the day temperature in their areas respectively. The perception of farmers towards temperature has a little bit varied in the selected AEZs. In the warm sub-moist lowlands of Gelgelie and Kurar all of the sample household heads perceived that there is an increase in the day temperature over the past 20 and 30 years and in the very cold sub moist mid highland of Dangulie 73.5% of farmers have a perception that temperature has been increasing in their area. In the cool sub moist mid highlands of Enerata and the cool moist mid highlands of Mahiber Birhan Kebele Administrations 85.7% and 90% of the total sample population of each areas respectively has perceived that the day temperature has increased for the past 20 and 30 years. However, in the tepid moist mid highlands of Guay only 34% of the total sample population in the area perceived that there is an increased temperature.

Table 5.1: Farmers' perception towards changes in temperature

AEZs	Perception towards temperature (%)				Analysis of variance	
	Increase	Decrease	No change	I don't perceive	F-value	Sig.
Choke Mountain watersheds	89.5	1.9	2.3	6.2	17.45	0.00***
Very cold sub-moist mid highlands	73.5	11.8	11.8	2.9		
Cold sub-moist mid highlands	78	2.4	0	19.5		
Cool sub-moist mid highlands	85.7	10.7	3.6	0		
Cool -Moist Mid highlands	90	7.5	0	2.5		
Tepid moist mid highlands	34	23.4	2.1	38.3		
Warm sub-moist lowlands	90.3	0	3.2	6.5		

* Significant at 10%, ** significant at 5%, *** significant at 1%

With regards to farmers' perception towards precipitation over the last 20 and 30 years is depicted in table-5.2. As indicated by the table, from the total population 65.7% of farmers said there is a reduction and 9.4% of sample households said there is an increase but the rest of 20.6% and 4.3% of the household heads respond that they don't perceive the change and they is no change in precipitation over the last several years respectively.

On the other hand, the table also shows that farmers' perception towards changes in precipitation across various agro ecological zones of CMWs 58.8% and 97.6% of farmers in the very cold sub moist mid highlands of Dangulie and cold sub moist mid highlands of Gedamawit respectively have perceived that there was a reduction in precipitation in their areas. In addition to this in the warm sub moist lowlands of Gelgelie and Kurar about 78.4% of sample farmers perceived that there was a reduction in precipitation. However in Cool sub-moist mid highlands of Enerata, Cool -Moist Mid highlands of Mahibere Birhan and Tepid moist mid highlands of Guay 39.3%, 35%, and 85.1% of the total sample household heads respectively had the perception that precipitation in their area was changed to a negative direction.

Table 5.2: Farmers' perception towards changes in precipitation

AEZs	Perception towards precipitation (%)				Analysis of variance	
	Increasing	decreasing	No change	I don't perceive	F-value	Sig.
Choke Mountain watersheds	9.4	65.7	4.3	20.6	37.89	0.00***
Very cold sub-moist mid highlands	17.6	58.8	14.7	8.8		
Cold sub-moist mid highlands	2.4	97.6	0	0		
Cool sub-moist mid highlands	25	39.3	10.7	25		
Cool -Moist Mid highlands	5	35	0	60		
Tepid moist mid highlands	6.4	85.1	0	8.3		
Warm sub-moist lowlands	0	78.4	0	21.6		

* Significant at 10%, ** significant at 5%, *** significant at 1%

Table 5.3: Whether farmer took adjustment measure to climate change

AEZs	Yes (%)	No (%)	Analysis of variance	
			F-value	Sig.
Choke Mountain watersheds	74.4	25.6	4.45	0.075*
Very cold sub-moist mid highlands	69	31		
Cold sub-moist mid highlands	90	10		
Cool sub-moist mid highlands	85.7	14.3		
Cool -Moist Mid highlands	85	15		
Tepid moist mid highlands	58.3	41.7		
Warm sub-moist lowlands	78.3	21.7		

* Significant at 10%, ** significant at 5%,*** significant at 1%

5.3 Use of agricultural technologies for climate change adaptation

5.3.1 Use of chemical fertilizers

Chemical fertilization is a major factor in increasing crop production and a response for high demand through agricultural input/output for crop production (Bhattacharjee, 2006).

Therefore, in response to the less productivity of crops in the Choke Mountain Watersheds farmers used chemical fertilizers of dap and urea to increase the productivity. Chemical fertilizers were not commonly used for all crops but farmers in CMWs used them mainly for wheat, barley, maize, teff and seldom for sorghum and Engido crops. As the table below depicts, the use of chemical fertilizer varies with regard to the variations of different agro ecological zones. In broad expression, the application of chemical fertilizers in each chosen AEZs showed differences. For instance, in the very cold and cold sub moist mid highlands of Dangulie and Gedamawit as well as in the warm sub moist lowlands of Gelgelie and Kurar use of chemical fertilizers was relatively lower as compared to its application in the mid altitude AEZs of cool sub moist mid highlands of Enerata, Cool sub-moist mid highlands of Mahibere Berhan and Tepid moist mid highlands of Guay. Since these areas were high potentials of wheat and teff production in the watershed.

Table 5.4: Farmers' use of chemical fertilizers for crop production

AEZs	Fertilizers (%)	Analysis of variance	
		F-value	Sig.
Choke Mountain watersheds	75.2	69.10	0.00***
Very cold sub-moist mid highlands	0		
Cold sub-moist mid highlands	52.9		
Cool sub-moist mid highlands	96.4		
Cool -Moist Mid highlands	97.5		
Tepid moist mid highlands	97.9		
Warm sub-moist lowlands	49.7		

* Significant at 10%, ** significant at 5%, *** significant at 1%

As the table-5.4 indicates, 75.2% of the sample surveys have applied chemical fertilizer for crop production. However, this percentage is not the same in every agro ecological zone of the watershed. For instance in the Very cold sub-moist mid highlands of Dangulie none of the sample households were used chemical fertilizers. In the warm sub-moist lowlands of Gelgelie and Kurar 49.7% of households were applied chemical fertilizers to grow crops. Those farmers who have applied chemical fertilizers to enhance the production of crops in the Cool sub-moist mid highlands of Enerata, Tepid moist mid highlands of Guay and Cool -Moist Mid highlands of Mahibere berhan were 96.4%, 97.9% and 97.5% respectively.

In general farmers' application of chemical fertilizers in the midland agro ecologies of Cool sub-moist mid highlands, Cool -Moist Mid highlands and tepid moist mid highlands was higher than the two extreme high and lowlands agro ecological zones of Very cold sub-moist mid highlands and Warm sub-moist lowlands of Choke Mountain watersheds in Ethiopia.

5.3.2 Use of improved seed varieties

In response to long term perceived changes, farm households had undertaken a number of adaptation measures. Changing crop varieties, adoption of soil and water conservation measures, and tree planting were major forms of adaptation strategies followed by the farm households in our study sites (Salvatore, 2007).

To be able to adapt to less predictable rainfall patterns and a shortened rain season, subsistence farmers requires improved crop varieties with shorter production cycles and increased drought resistance to guarantee the necessary production in less time (Christian, 2010).

The summary statistics of table-5.5 indicates that from the total sample households 63.6% of the respondents have used improved seed varieties. However, the use of improved seeds for crop agriculture varies in the chosen agro ecologies of the study area. For instance, in Tepid moist mid highlands of Guay all the respondents have used improved seed varieties whereas, in the Very cold sub-moist mid highlands of Dangulie only 5.9% of the total sample households were used improved seed varieties and that was for barley crop. On the other hand, in the Cold sub-moist mid highlands of Gedamawit, cool sub-moist mid highlands of Enerata, and Cool-Moist Mid highlands of Mahibere Berhan about 78%, 67.9%, and 75% of respondents respectively have used improved seeds for their crop agriculture. When we see this in the Warm sub-moist lowlands of Gelgelie and Kurar 40.5% of respondents were used improved seed varieties.

In general utilization of improved seed varieties in the midland agro ecologies of Cool sub-moist mid highlands, Cool -Moist Mid highlands, tepid moist mid highlands is better than the two extreme Very cold sub-moist mid highlands and Warm sub-moist lowlands of Choke Mountains.

Table 5.5: Farmers' use of improved seed varieties

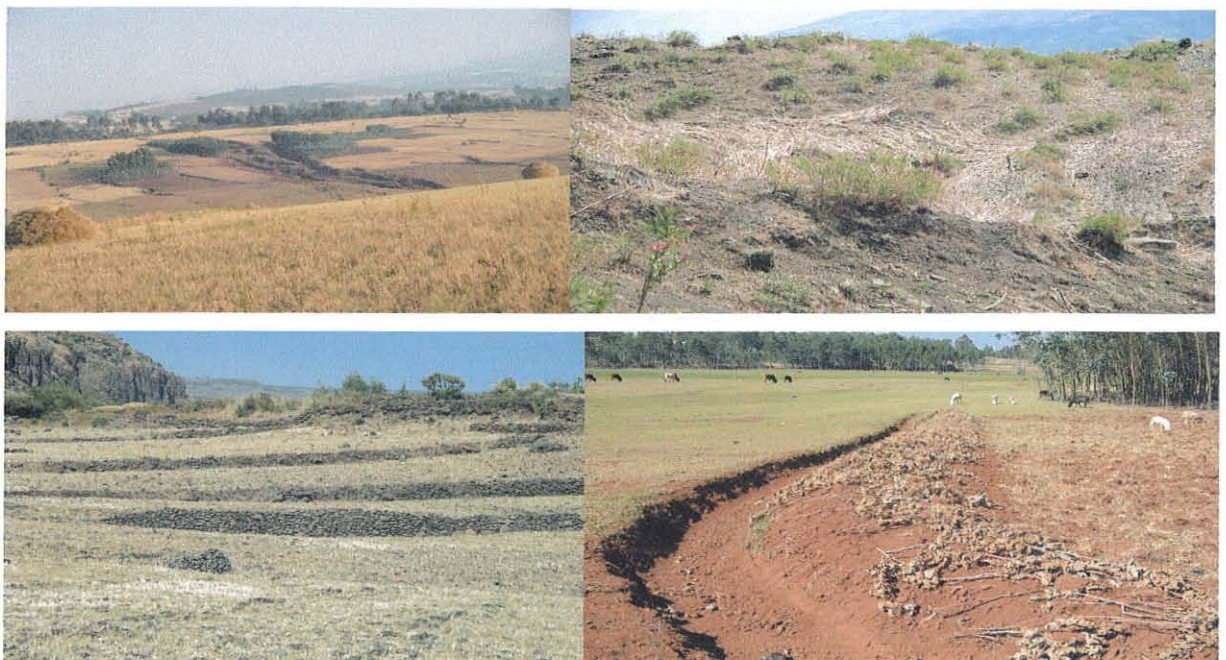
AEZs	Improved seed (%)	Analysis of variance	
		F-value	Sig.
Choke Mountain watersheds	63.6	64.85	0.00***
Very cold sub-moist mid highlands	5.9		
cold sub-moist mid highlands	78		
Cool sub-moist mid highlands	67.9		
Cool -Moist Mid highlands	75		
Tepid moist mid highlands	100		
Warm sub-moist lowlands	40.5		

* Significant at 10%, ** significant at 5%, *** significant at 1%

5.3.3 Use of Soil conservations

In response to the increased variability as well as change of temperature and precipitation Choke Mountain watershed farmers have adopted various soil conservation practices such as stone bunds, soil bunds, biological terracing and trenches over gullies in order to maintain and improve as well soil moisture and fertility for better crop productivity.

Soil conservation technologies have been suggested as a key adaptation strategy for developing countries, particularly those in Sub-Saharan Africa, in light of increased water shortages, drought, desertification, and worsening soil conditions. In Nile Basin of Ethiopia, more than 30 percent of farmers adopted soil and water conservation measures in response to perceived long-term changes in temperature and rainfall (Edward, *et al.* 2009). Thus, in the Choke Mountain Watersheds, which are the major source of Nile basin in Ethiopia 66.7% of farmers, have used to practice soil conservation in their crop agriculture. Nevertheless, this doesn't mean that the practice is uniform in all agro ecologies of the area. In the Very cold sub-moist mid highlands and Very cold sub-moist mid highlands agro ecologies of Dangulie and Gedamawit about 67.2% and 80.5% of farmers used to implement Soil conservation practices in their crop farmland.



Picture 1: Soil erosion and soil conservation in Choke mountain watersheds

While this number was lower in the mid land agro ecologies of choke mountain such as Cool sub-moist mid highlands Enerata Cool -Moist Mid highlands Mahibere berhan and Tepid moist mid highlands Guay, since only 57.1%, 14.9% and 17.5% of the total sample farmers in each respective agro ecologies practice soil conservation. However, different from this and since the problem of soil erosion in the lowland of Choke Mountain Watersheds particularly in the Warm sub-moist lowlands of Abay Gorge is more severe than the midland agro ecologies it has better implementation that 87.1% of local farmers were implement soil conservation practices for crop agriculture.

In a nutshell, the use as well as practice of Soil conservation in the two extreme highland and lowland agro ecologies is better than the midland agro ecologies of Choke mountain watersheds. Based on the results obtained from own observation and Key Informant Interview this was because of the serious soil fertility problems that farmers of the two extreme agro ecologies encountered and the relatively less constraints on soil fertility in the midland agro ecologies.

Table 5.6: Farmers' use of improved soil conservation practices for crop production

AEZs	Soil conservation (%)	Analysis of variance	
		F-value	Sig.
Choke Mountain watersheds	66.7	1.89	0.09*
Very cold sub-moist mid highlands	67.6		
Cold sub-moist mid highlands	80.5		
Cool sub-moist mid highlands	57.1		
Cool -Moist Mid highlands	17.5		
Tepid moist mid highlands	14.9		
Warm sub-moist lowlands	87.1		

* Significant at 10%, ** significant at 5%, *** significant at 1%

5.3.4 Use of irrigation with improved technologies

In Choke Mountain, there are several rivers and streams, which are spring from the mountain and flow across various districts. The chosen districts as well as kebele administrations do also share these rivers and stream. However, implementation of irrigation in all agro ecological zones is not satisfactory.

As the table-5.7 indicates that, the use of irrigation for crop production by farmers in the CMWs was 24.6% from the total sample population considered for this research. Nevertheless, the utilization varies throughout the seven Agro ecological zones. In the Very cold sub-moist mid highlands of Dangulie there are very few numbers of households who have used irrigation and they were about 5.9%. However, the number of farmers using improved irrigation was increased in the Cold sub-moist mid highlands of Gedamawit to 43.3%. In the midland Agro ecologies of Cool sub-moist mid highlands of Enerata, Tepid moist mid highlands of Guay and Cool -Moist Mid highlands of Mahibere Berhan there were about 14.3%, 17% and 10% of farmers have been practiced irrigation respectively. On the other hand, in the Warm sub-moist lowlands agro ecology of Choke Mountain Watersheds particularly in the Abay Gorges of Gelgelie and Kurar there were about 40.5% farmers were used irrigation agriculture.



Picture 2: Irrigation in Choke mountain watersheds

In general the use of irrigation agriculture in the Cool sub-moist mid highlands, Cool -Moist Mid highlands and tepid moist mid highlands was lower. Since these areas are potential areas of wheat and teff crops and the soil relatively fertile than the lowland and highland areas of CMWs and the farmers are satisfied with their net revenue of crop production. However, there is a

relatively better practice in the Warm sub-moist lowlands since they are less productive which attributed from the infertile and eroded soil as well as the very hot climate. Therefore, as a way out from this challenge, local farmers chose to implement irrigation activity. In the highland part of this area farmers also used to grow crops like potato, barley and different fruits like highland apple by irrigation agriculture and the practice is also better than the midland agro ecological areas.

Table 5.7: Farmers' use of irrigation technologies for crop production

AEZs	Irrigation (%)	Analysis of variance	
		F-value	Sig.
Choke Mountain watersheds	24.6	2.55	0.05**
Very cold sub-moist mid highlands	5.9		
Cold sub-moist mid highlands	43.9		
Cool sub-moist mid highlands	14.3		
Cool -Moist Mid highlands	17		
Tepid moist mid highlands	10		
Warm sub-moist lowlands	40.5		

* Significant at 10%, ** significant at 5%, *** significant at 1%

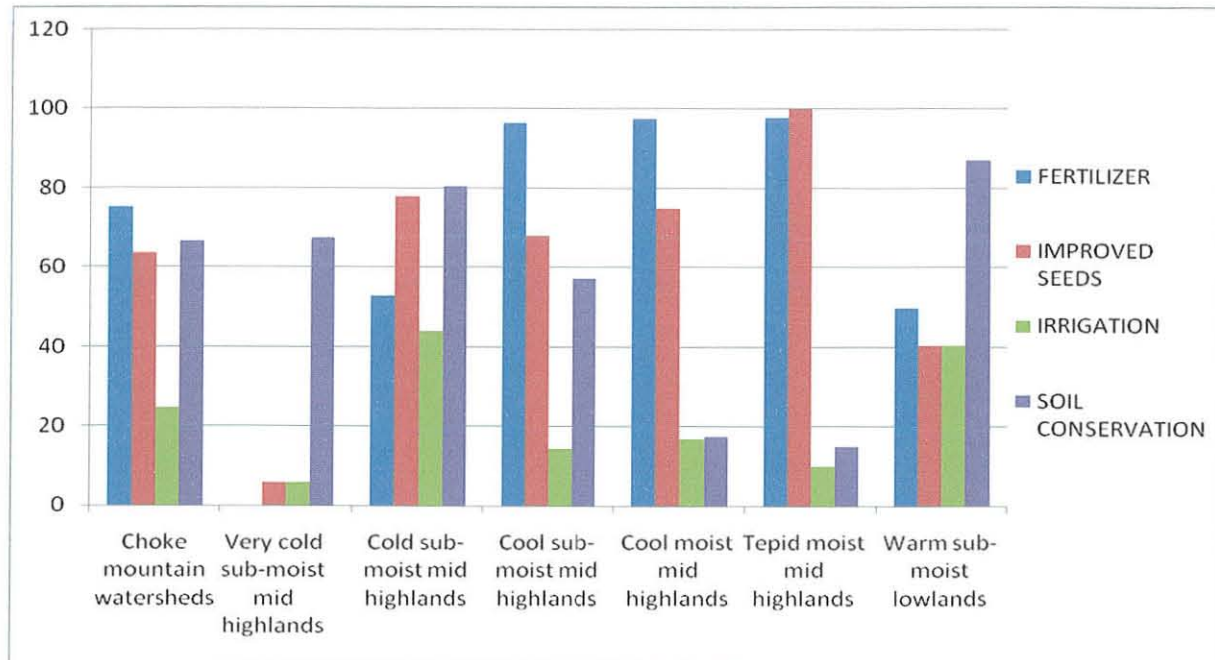


Figure 4: Use of Agricultural technologies in Choke Mountain Watersheds

5.4 Other adaptation options taken by farmers

5.4.1 Planting trees

In the study area Farmers were planting trees especially eucalyptus tree as a means of adaptation to climate change on their farmlands. In with this, 62.5% the sample household heads has planted trees around their homesteads and their crop farmlands and they did it deliberately to use it as another source of income to cope the impacts of changes on their crop farming. Moreover, this is common in the Very cold sub-moist mid highlands and Cold sub-moist mid highlands AEZs.



Picture 3: Plantation of Eucalyptus tree in Choke mountain watersheds

For instance, according to participants of focus group discussion in Dangulie and Gedamawit planting eucalyptus tree in place of their farmland has helped them to diversify their income. Some of them said since most of the soil of their farmlands is infertile and couldn't give them enough and productive outputs and due to this reason recently most of the farmers were covered their croplands with this fast growing tree. On the top of this, some others of the participants in the focus group discussion and key informant interviewees said that the return that farmers get from eucalyptus tree is becoming better than that farmers get from crop farming. Therefore, most farmers in the area turn their face to this plantation instead of crop agriculture.

5.4.2 Diversifying income sources

In the study areas, 45% of sample farmers have created other sources of incomes to cope up the impacts of climate change. They were participated in other sources of incomes such as shopping, trading of crops, trading of animals, and working as a laborer to harvest and wedding of crops in the nearby potential wheat and teff productive areas of Enerata, Guay and Mahibere berhan. This was also confirmed by participants of the focus group discussion and key informant interviewees. Both of the participants in the focus group discussion as well as key informant interview said that, they themselves as well as other farmers who lived in their area were diversifying their income sources because of the change and variability of precipitation and the increased intensity of temperature in their areas, which brought direct impacts on their crop agriculture.

5.4.3 Crop diversification

Crop diversification was also another means to adapt climate change in study area. From the sample household heads, 60% have used crop diversification as an option of adaptation and the remaining 40% didn't use it. Most farmers particularly in the two extreme high and lowland agro-ecologies have used to diversify the crops they grown in the year to alleviate the risk of crop failure due to different reasons. In this regard, the selected participants of Focus Group Discussion and Key Informant interviewees in most of the selected AEZs confirmed that crop diversification could reduce the uncertainties of crop production. The focus group discussion participants and key informant interviewees in the cold sub-moist mid highlands of Gedamawit and Tepid moist mid highlands of Guay said, in the year 2001/2002 E.C. there was a reduction in wheat production due to fungus infection. As a result, those farmers who have planted their farmland with the diversity of crops such as teff, barley as well as maize has got an advantage to cope this impact.

5.4.4 Use of natural fertilizer:

In Choke Mountain Watersheds, application of natural fertilizer takes placed in the selected AEZs. In this case, almost all farmers were aware about its importance to increase crop

productivity. This can be buffered by the result obtained from the focus group discussion and key informant interview. Participants of focus group discussions and key informant interviewees said that, natural fertilizer application was significant to enhance crop productivity as compared to chemical fertilizer. They said, one-year application of Natural Fertilizer would make their farmland productive for the next two and three years whereas the application of chemical fertilizer in a certain year could make the land productive for only that particular year. However, the major problems that forced them to use chemical fertilizer were they could not easily get enough production raw materials. Hence, they have produced small amount of natural fertilizer and they used it for the crops they produced around their homesteads mainly maize and potato crops.

5.6 Analysis and Discussion of results of the econometrics model

The Ricardian model regress farm values/net revenue on climate, soils, and other control variables such as socio economic variables, which are expected to have an impact on net revenue or land value. The research explores two main sets of the Ricardian model equations. The first is the model without adaptation and it includes climate and soil variables. The second model is a model with adaptation and this helped to assess the level to which the addition of these variables increase or decrease the effect of climate elements temperature and precipitation on crop production. These adaptation variables consists of agricultural technologies such as fertilize, improved seeds, soil conservation and irrigation on the one hand and agricultural technology variables with other socio economic variable on the other. These socio-economic variables are also possible policy instruments for policy makers to explore as tools for controlling or taking advantage of climate effects (Benhin, 2006). Therefore, based on these Models of Ricardian we examine the effect of climate on choke mountain watersheds. It also helped to assess whether there are significant differences among different agro-ecological zones of the watershed. This in turn would help to see the effect of various adaptation variables in several AEZs of choke mountain watersheds for better adaptation of climate change.

5.6.1 without adaptation models: climate and soil variables only

In this model, climate variables have significant impact on crop net revenue. Besides, the soil variables of Nitosols, Vertisols and Cambisols have significant influence on crop net revenue per hectare of farmers in the crop farming of the watershed. The model shows that, the coefficients of fall and winter temperature; spring, summer and fall precipitation indicated that, they have a positive effect on crop net revenue per hectare in the choke Mountain watershed areas. Whereas, spring and summer temperature and winter precipitation in the area has negative effects on crop net revenue.

In addition to this, the result of table-5.8 indicated that Nitosols, Vertisol and Cambisol were significant soil variable and both cambisols and Lithosols have negative impact on crop agriculture in CMWs. However, Nitosols and vertisols have positively affect crop net revenue per hectare in the study areas.

Table 5.8: Without adaptation Model (climate and soil variables)

Variable	Coefficient
Winter temperature	101.43***
Spring temperature	-296.21*
Summer temperature	-235.59***
Fall temperature	139.74**
Winter precipitation	-242.91***
Spring precipitation	153.97***
Summer precipitation	36.3***
Fall precipitation	21.23***
Nitosols	556.57***
Vertisol	269.4*
Cambisol	-164.47**
Lithosols	-425.72
Constant	-12,344.88***
N	258
R ²	0.53
F	19

* Significant at 10%, ** significant at 5%, *** significant at 1%

5.6.2 With adaptation Models (climate, soil and agricultural technology variables)

The model includes those climate variables of temperature and precipitation, soil variables and agricultural technology variables of farmers' use of chemical fertilizers, improved seeds, soil conservation practices and irrigation. In this model, the estimated coefficients of climate variables except for spring temperature and the soil variables such as Nitosols and Lithosols the rest of climate and soil variables were statistically significant. Besides to this, use chemical fertilizers, improved seeds, soil conservation practices and irrigation variables were statistically significant (table-5.9). Accordingly, all the agricultural technologies included in the model indicate that, they positively affect crop net revenue per hectare and benefits farmers of CMWs.

Table 5.9: With adaptation model (climate, soil and agricultural technology variables)

Variable	Coefficient
Winter temperature	131.22**
Spring temperature	-420.43
Summer temperature	-435.17***
Fall temperature	254.24*
Winter precipitation	-86.91**
Spring precipitation	40.50**
Summer precipitation	23.82***
Fall precipitation	12.876***
Nitosols	763.90***
Vertisol	69.63
Cambisol	-442.427
Lithosols	-362.209
Use of chemical Fertilizers	532.46**
Use of Improved seeds	934.92 ***
Use of Soil conservation	378.31 *
Use of Irrigation	849.25 **
Constant	-8,473.84***
N	258
R ²	0.55
F	17.08

* Significant at 10%, ** significant at 5%, *** significant at 1%

5.6.3 With adaptation model (climate, soil, agricultural technologies, and Socio economic Variables)

In addition to the climate and soil variables, this model also consists of variables of different agricultural technologies such as use of chemical fertilizer, improved seeds, soil conservation practices and irrigation practices as well as other important socio-economic variables like age, female dummy, education status, family size of the household, size of farmland and access to credit.

The inclusions of these agricultural technology variables and other relevant socio economic variables are indispensable for explaining crop net revenue per hectare in CMWs. According to the regression result indicated in table 5.10, the agricultural technology variables such as farmers' uses of, chemical fertilizers, improved seeds and irrigation have significant impact on the net revenue of crop production. In addition to this, the socio economic variables such as land size, access to credit and female dummy variables have significance in the model. From the socio economic variables age of the household head and female household head as a dummy variable have negative impact on crop net revenue in the study area. On the other hand, both farm size, access to credit, education and family size have positive impact on crop net revenue per hectare. In other literatures such as Deressa (2009) and Meseret (2009) livestock ownership of farmers was a significant socio economic variable. However, in this model it is not significantly affect net revenue of crop production since almost all the sample households' in the chosen AEZs practiced mixed farming systems.

Table 5.10: With adaptation (climate, soil, agricultural technologies, and socio economic variables)

Variable	Coefficient
Winter temperature	339.84***
Spring temperature	-763.61***
Summer temperature	-802.96**
Fall temperature	471.06**
Winter precipitation	-156.97*
Spring precipitation	269.00***
Summer precipitation	12.76***
Fall precipitation	4.01**
Nitosols	907.40**
Vertisol	73.98
Cambisol	-490.31
Lithosols	-426.75
Use of chemical Fertilizers	457.04*
Use of Improved seeds	793.28***
Use of Soil conservation	268.77
Use of Irrigation	773.18**
Access to Credit service	568.26*
Land size	541.01**
Female dummy	-15.98*
Education status	5.71
Age of the household head	-4.14
Family Size of the household	0.7
Constant	-4,561.24**
N	258
R ²	0.56
F	14

* Significant at 10%, ** significant at 5%, *** significant at 1%

5.7 Marginal impacts of climate variables on crop net revenue

The marginal impact analysis was undertaken to observe the effect of changes in temperature and rainfall on Choke mountain watershed areas. The estimated marginal impacts of both temperature and precipitation variables are discussed below in table 5.10 and 5.11 respectively. Following the works of Kurukulasuriya *et al.* (2006), Deressa *et al.*(2009) and Meseret (2009), the marginal impact of climate variable (f_i) on the net revenue evaluated at the mean that variable is given as:

$$E\left[\frac{dv}{df_i}\right] = \beta_{1,i} + 2\beta_{2,i} * [f_i]$$

As table-5.11, shows the marginal effects of 1°C temperature increase on net revenue of crop production for the farmers in choke mountain watersheds in accordance with different farming seasons of the year. Therefore, the result obtained from the econometrics model indicates that the increase in summer and spring temperature would have a negative impact on crop net revenue of CMWs farmers. On the other hand, increases in temperature in the winter and fall seasons would have a positive impact on crop net revenue until a certain point. When we see the net effect of the increase of 1°C temperature each seasons of the year.

The marginal impact of changes in temperature and precipitation has an effect on the net revenue of crop farming in the Choke Mountain Watershed areas. The increase of 1°C on the mean temperature of winter season has an advantage to increase the farmers' net revenue per hectare by 2,161birr nonetheless the increase in 1°C of summer and spring season temperature would result in a reduction of net revenue of crop production by 6,441.54birr and 7,513birr respectively. Nevertheless, in the case of fall season temperature it will create an advantage of increasing farmers' net revenue of crop production by 3,877.63birr.

Apart from this, the marginal impact of precipitation on the net revenue of crop production in the choke mountain is different for several seasons of the year. As table-5.11 indicates during winter season, the increase in precipitation would results in 1,690.24birr reduction in the crop net revenue of choke mountain farmers. However, in spring, summer and fall seasons 1mm increase in precipitation has a positive impact on net revenue of crop farming. For instance, increment of precipitation in spring and fall would raise farmers' crop net revenue to 3,571.46birr and 2,411.91birr respectively. Likewise, the increase in summer precipitation would in turn benefits Choke Mountain farmers by increasing their net revenue of crop production by 7,105birr.



Table 5.11: Marginal impact of climate change on net Revenue per Hectare (Birr)

Seasons	Winter	Spring	Summer	Fall	Annual
Temperature	2,161.00*	-7,513.00***	-6,442.54***	3,877.63**	-1,979.23**
Precipitation	-1,690.24	3,571.46**	7,105.00***	2,411.91*	2,849.53**

* Significant at 10%, ** significant at 5%, *** significant at 1%

The marginal impact of temperature and precipitation is different in several agro ecological zones of the study area. The increment of temperature of winter and fall to a certain degree in all agro ecological zones benefits choke mountain farmers. Nonetheless, the marginally increase of winter and fall is highly increases the net revenue farmers of the tepid moist mid highlands and warmer sub moist lowlands than farmers of the very cold and cold sub moist mid highlands in the choke mountain watershed areas. The marginal impact of the increment of the already highest spring and summer temperature of the warm sub moist lowlands of Kurar and Gelgelie and the tepid moist midlands of Guay highly reduces farmers' crop net revenue per hectare. The very cold sub moist mid highlands of Dangulie and the cold mid highlands of Gedamawit have relatively cooler spring and summer temperature thus the net revenue of crop production per hectare is relatively small.

Generally, the marginal increase of temperature in all agro ecological zones of Choke Mountain Watersheds regardless of seasonal variations reduces net revenue of crop farming per hectare though the amount differ for each AEZs. In the very cold and cold sub moist mid highlands, the annual marginal increase in temperature reduces crop net revenue by 1,002.18birr and 1,660.38birr per hectare respectively. However, in the tepid moist mid highlands and warm sub moist lowlands the increase of temperature marginally decreases net revenue of farmers by 2,387.64birr and 2,429.32birr per hectare respectively. While in the cool sub moist mid highlands and cool-moist mid highlands, the increase of temperature marginally reduces net revenue by 1,938.58birr and 2,020.54birr per hectare of land respectively.

Table 5.12: Marginal impact of Temperature across agro ecological zones (Birr)

AEZs \ seasons	Winter	Spring	Summer	Fall	Annual
Very cold sub-moist mid highlands	1,023.48	-3,994.09	-2,741.57	1,703.44	-1,002.18
Cold sub-moist mid highlands	1,758.29	-6,348.5	-5,178.52	3,127.21	-1,660.38
Cool sub-moist mid highlands	2,178.19	-7,693.88	-6,179.41	3,940.79	-1,938.58
Cool -Moist Mid highlands	2,138.83	-7,735.92	-6,527.55	4,042.49	-2,020.54
Tepid moist mid highlands	2,571.84	-8,618.83	-7,876.58	4,373.01	-2,387.64
Warm sub-moist lowlands	2,742.42	-9,207.43	-8,311.75	5,059.47	-2,429.32

The marginal effect of the annual increase of precipitation at different AEZs of Choke Mountain watershed areas benefits all though the benefit varies according to different AEZs. The marginal impact of temperature of winter season negatively benefits all agro ecological zones in Choke Mountain. Like most areas of Ethiopia, this season is the time for crop harvesting which requires enough temperature and very small precipitation. Therefore, the increase of winter temperature in the area raises the marginal impact on crop net revenue. However, its increase in spring, summer and fall seasons raises crop net revenue of all the selected AEZs in the choke mountain watershed areas.

As table 5.13 depicts that, increase in winter precipitation highly affects the very cold sub moist mid highlands of Dangulie and the cold sub moist mid highlands of Gedamawit and it reduces crop net revenue by 5,399.11birr and 2,707.25birr per hectare respectively. Whereas, in the tepid moist mid highlands of Guay and the warm sub moist lowlands of Gelgelie and Kurar the marginal impact of an increase of winter precipitation is relatively small which is the reduction of 661.43birr and 515.3birr of farmers net revenue per hectare from their crop production. The increase in precipitation of spring and summer seasons benefits all choke mountain farmers in all AEZs, since these seasons are very important to plant as well as for the growth different crops. The planting and growing of crops in these seasons require enough precipitation. The increase of precipitation in the fall season also increases net revenue of choke mountain farmers found in different AEZs but the increase is limited to a certain extent because this season is the time for crop maturation and ready for harvesting which needs optimum amount of precipitation and temperature as well.

Table 5.13: Marginal impact of precipitation across agro ecological zones (Birr)

AEZs \ Seasons	Winter	Spring	Summer	Fall	Annual
Very cold sub-moist mid highlands	-5,399.11	7,220.55	11,275.22	6,110.18	4,801.711
Cold sub-moist mid highlands	-2,707.25	4,385.78	7,939.35	3,708.2	3,331.52
Cool sub-moist mid highlands	-1,169.04	2,765.92	6,033.15	2,335.64	2,491.42
Cool -Moist Mid highlands	-7,10.652	2,692.22	8,068.74	1,486.71	2,884.25
Tepid moist mid highlands	-6,61.43	3,122.29	7,801.15	3,346.76	3,402.19
Warm sub-moist lowlands	-5,15.3	2,194.92	5,732.92	1,715.7	2,282.06

5.8 The impact of forecasted climate scenarios

The Recardian results above estimate how net revenues vary across existing climates on the Choke Mountain watersheds. However, in this projection, we also predict that how future climate might affect future net revenue of crop farming. This projection assumes that all other conditions hold constant and that the results of the cross section can be used for long-term inter temporal analysis Deresa (2005) and Meseret (2009).

The impact of climate change on crop net revenue per hectare was also analyzed by uniform climate scenarios through the use of uniform change of temperature and precipitation levels for the coming 2050 and 2100. The uniform climate scenario assumes that only one aspect of climate change and that change is uniform across the study area. These scenarios are increase temperature by 2.5⁰C and 5⁰C and reduction of precipitation by 7% and 14%. These scenarios of temperature and precipitation are in line with the expectations that increasing temperature and reducing precipitation is damaging to agriculture in Africa, indicating a need for policy intervention targeting adaptation through technology such as irrigation, and the use of drought tolerant and early maturing crop varieties (Deressa, 2006).

The impact of changing temperature and precipitation on crop net revenue per hectare is given by:

$$\Delta NR_i = NR_{i,t} - NR_{i,t-1} \quad \text{Where;}$$

$NR_{i,t}$ is $NR_i (T_t, P_t)$

$NR_{i,t-1}$ is $NR_i (T_{t-1}, P_{t-1})$

And $T_t = T_{t-1} + \Delta T$, and, $P_t = P_{t-1} + \Delta P$

ΔNR_i is the change in net revenue per hectare of a given district

NR_{it} is the forecasted value of net revenues per hectare under a new climate scenario

$NR_{i,t-1}$ is predicted value of net revenue per hectare of the base climate scenario

T_t, P_t is temperature and precipitation under the new climate scenario

T_{t-1}, P_{t-1} is temperature and precipitation for the base climate scenario

$\Delta T, \Delta P$ is change in temperature and precipitation.

The average of ΔNR_i gives the impact of a given climate change scenario.

Accordingly, table-5.14 showed that the increased temperature by 2.5⁰C and 5⁰C has reduced farmers' crop net revenue per hectare by 6,377.05birr and 7,119.407birr respectively. On the other hand, the 7% and 14% reduction of precipitation in the Choke mountain watersheds might reduce net revenue by 12,573.1birr and 13,748.4birr respectively.

Table 5.14: Impact of uniform climate scenarios in choke mountain watersheds (birr)

Impacts	Temperature		Precipitation	
	+2.5 ⁰ C warming	+5 ⁰ C warming	7% reduction in precipitation	14% reduction in precipitation
CHANGE IN NET REVENUE PER HECTARE (Birr)	-6,377.05	-7,119.407	-12,573.1	-13,748.4

Chapter Six

6. Summary, Conclusions and policy implication

The study has revealed that choke mountain farmers have noticed the change in temperature and precipitation. The analysis indicated that, farmers' perception about climate change (change in precipitation and temperature) varies in different agro ecologies of CMWs. Accordingly, farmers in the cold sub-moist mid highland and the warm sub-moist lowland have better perceived the change than the tepid sub-moist mid highland farmers. The paper also explores that several adaptation options that were taken by local farmers in each Agro ecologies. Thus, farmers in these watershed areas used agricultural technologies as an option of adaptation, though the extent and effective utilization varies across AEZs of the watershed.

The results of this study also showed that, climate variables of temperature and precipitation are vital for crop agriculture and have an impact on its production in the Choke Mountain watersheds of Ethiopia. The result confirmed that, crop production is sensitive to climate change. Increased summer and spring precipitation has enhanced farmers' crop net revenue per hectare. The increased precipitation has reduced crop net revenue. The result from the econometrics model regression further demonstrated that, net revenue per hectare was increased with the increased temperature in winter season since it is the season for crop cultivation and harvesting. In both summer and spring season net revenue per hectare has reduced with the increased temperature. However, in the season of fall the increment of both precipitation and temperature benefits choke mountain watershed farmers to a certain degree.

The empirical research also suggests that, the use of agricultural technologies such as improved seeds, chemical fertilizers, soil conservations and irrigation are important adaptation options used to overcome the impact of climate change on crop farming. The study further explores that, all the agricultural technologies used in the regression were significant and has a positive impact on net revenue of crop farming per hectare in Choke Mountain watersheds of Ethiopia.

The result of this study proved that, there were constraints that prohibit farmers from using agricultural technologies to enhance crop productivity. The constraints include expensive price, supply problems, limited credit service and quality problems of agricultural technologies. In addition to this the socio economic variables such as size of land and education were significant to raise net revenue per hectare for farmers in the watershed. However, the female dummy variable reduces net revenue per hectare.

The study also predicts the impact of different climate change scenarios on crop farming in the Choke Mountain watersheds of Ethiopia. For this purpose, uniform climate scenarios were applied to predict crop net revenue per hectare in the future. The uniform climate scenarios assume only one aspect of climate change and that change is uniform across the study area. These scenarios are increase temperature by 2.5⁰C and 5⁰C and reduction of precipitation by 7% and 14%. The prediction shows that long-term changes of temperature and precipitation in the study area might have considerable negative impacts on crop net revenue per hectare if the trend of adaptation kept constant. The impact is more prominent in the warm sub-moist lowland agro ecology.

In line with this, the result obtained from this study enunciated that in all the study areas farmers have noticed that there was climate change which seriously affect their crop agriculture. This indicates that it urgently requires policy and planning implications. Therefore, the government of Ethiopia in general and the regional state of Amhara in particular should consider this in their design and implementation of agricultural and rural development plans which emphasize appropriate adaptation options so as to tackle the impact of the variability and change of climate in the watersheds of Choke Mountain. Particularly, the current adaptation options taken by the local farmers of the study area and thus, agricultural technologies should be given the highest priority.

Priorities that should be given to each specific AEZs of Choke Mountain watersheds in the future for better climate change Adaptation.

- ❖ In the Cold sub-moist mid highland and Warm sub-moist lowland parts of the watershed the farmland is infertile due to incessant erosion and land slide which also cause soil acidity. Hence, crop production requires the use of several agricultural technologies to recover the fertility of the soil and enhance productivity. However, large numbers of farmers in these AEZs yet did not have the capacity to buy for these technologies particularly fertilizers and improved seed varieties. So, it is important to capacitate these farmers in different ways like through the provision of credit services with minimum interest and by assisting them to diversify their income sources to help them to buy for those agricultural technologies so as to increase their resilience to climate change.
- ❖ Moreover, in the Cold sub-moist mid highland agro ecology of Gedamawit soil acidity was the serious problem which highly reduces crop productivity. On the top of this, agricultural experts of the district and FGD discussants mentioned that there were trials like distribution of gypsum but transportation cost and the price didn't allow them to use per the recommendation in improving the fertility of the soil. Therefore, experts should take this in to account in their agricultural planning to distribute this gypsum with fair and affordable price and to arrange transportation of the material for free or lower price.
- ❖ On the other hand, Soil conservation has spectacular function to adapt climate change by reducing sensitivity. In the Cold sub-moist mid highlands, Warm sub-moist lowlands and Cool -Moist Mid highlands AEZs of watershed areas of Choke Mountain Watersheds there was a relatively good trial of soil conservation practices, though this has happened after the problem has already occurred. However, the practice is less in the Cool sub-moist mid highlands of Enerata and Tepid moist mid highlands of Guay. Therefore, agricultural experts as well as administrators at Zonal, district as well as kebele level should give priority to maintain and improve soil fertility.
- ❖ In all AEZs of Choke Mountain watersheds the use of irrigation is less than the water potential of the area and this is highly attributed to farmers less awareness and lack of improved irrigation technologies for better utilization. So, the local agricultural experts

need to give emphasis for it, since it has tremendous role to adapt the increasing temperature and reduced precipitation in the area which would in turn increase productivity of crops.

- ❖ Even though there are strengths on the part of agricultural experts as well as development agents in inculcating the importance of agricultural technologies, they should also enhance it more and should also find solutions to solve the problems of farmers in utilizing agricultural technologies for crop production especially problems related to price, quality and supply.
- ❖ Plantation of eucalyptus tree was one of the means to diverse farmers income sources to tackle the impact of climate change and this was mainly true in most AEZs particularly in the very Cold sub-moist mid highlands of Dangulie and the Cold sub-moist mid highlands of Gedamawit. But it has reduced the cropping land which might in turn affect the supply and price food crops in the area. In addition to this it also damages the fertility of soil. So that, this plantation should be done with some sort of expertise advice where to plant it. Moreover, how to help these farmers to reduce their practice should be taken in to account.
- ❖ As this study indicated that, the family led by female household head received less net crop revenue as compared to male headed households. Therefore weight should be given for them to unleash their economy and reduce their vulnerability especially by giving them an advantage of credit service to buy for agricultural inputs of chemical fertilizers and improved seeds and giving them short term skill training which help them to diversify their income sources.
- ❖ Furthermore, the researcher recommends that, it is important if further detailed studies done on the impact of climate change on livestock production and soils of Choke Mountain Watersheds of Ethiopia.

References

- Abebe, K., 2008. *Assessment of Agricultural Information Needs in East Africa, Caribbean & Pacific (ACP) Country Study*: Ethiopia Technical Centre for Agricultural and Rural Cooperation (CTA) Final Report Project: 4-7-41-255- 7/d 2008.
- Alemayehu, M., 1985. *Grass Land Ecology Study* MoA Animal and Fishery Resource Development. Addis Ababa, Ethiopia.
- Allam, A., 2004. Challenges of agricultural technology transfer and productivity Increase in the Sudan *Int. J. Technology, Policy and Management, Vol. 4, No. 2, 2004* Inderscience Enterprises Ltd.
- Aly, H. et al., 2010. Gender and Agricultural productivity in a surplus labor, Traditional Economy: Emperical evidence from Nepal. *Journal of Development Areas*.
- Apata, T.G. et al., 2010. Effects of Global Climate Change on Nigerian Agriculture: An Empirical Analysis. The 84th Annual Conference of the Agricultural Economics Society Edinburg.
- Bekabil, F., Hassan, Rashid M., 2006. *Income Risk and Crop Production Patterns of Small-Scale Farmers in Eastern Oromiya Region of Ethiopia*. Eastern Africa Social Science Research.
- Belay S., 2006. The Choke Mountain research and development initiative: *sustaining the Ecosystem of the Blue Nile basin; a concept paper*.
- Benhin, J.K.A., 2006. *Climate change and South African Agriculture: Impacts and adaptation options. CEEPA Discussion Paper No. 21. Centre for Environmental Economics and Policy in Africa, University of Pretoria*.
- Brooks, N. et al., 2005. Determinants of vulnerability and adaptive capacity at the national and the implications for adaptation. *Global Environmental Change* 15 (2005): 151–162.
- CIDSE, 2009. The Importance of Adaptation Technologies For the post-2012 Climate Agreement. Report by CIDSE and Caritas Internationalize.
- Claire, Mc.G et al., 2002. *Poverty and Climate Change: Assessing Impacts in Developing Countries and the Initiatives of the International Community*. London School of Economics Consultancy Project for the Overseas Development Institute.
- COMESA (Common Market for Eastern and Southern Africa), 2010. African Agricultural Markets Program. Fertilizer Subsidies in Eastern and Southern Africa. *Policy Synthesis #2*.
- Deressa, T., 2006. *Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach*. CEEPA Discussion Paper No. 25.
- Deressa, T. et al., 2008. *Analyzing the determinants of farmers' choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethiopia*. IFPRI Discussion Paper No. 00798. International Food Policy Research Institute, Washington, DC.

- ECA, 2003. Emerging Issues in Science and Technology for Food Security and Sustainable Development in Africa. Sustainable Development Division.
- Edward K. et al., 2009. *Are Soil and Water Conservation Technologies a Buffer Against Production Risk in the Face of Climate Change? Insights from Ethiopia's Nile Basin*. International Food Policy Research Institute. IFPRI Research Brief 15–17.
- EIAR, 2007. *Focusing Agricultural Research to Address Development Needs*.
- FAO (Food and Agriculture Organization of the United Nations), 2007. *Adaptation to climate change in Agriculture, forestry and fisheries: Rome*.
- FAO (Food and Agricultural Organization), 2008. *Expert Meeting on Climate Change Adaptation and Mitigation Options for Decision Makers Headquarters, Rome*.
- Tubiello, F.N. et al., *U.S. National Assessment Technical Report Effects of Climate Change on U.S. Crop Production Part I: Wheat, Potato, Corn, and Citrus* NASA-GISS and Columbia University. University of Florida.
- Gerald C. N. et al., 2010. *Development and Climate Change. The Costs of Agricultural Adaptation to Climate Change Discussion Paper Number 4*. The International Bank for Reconstruction and Development / THE WORLD BANK 1818 H Street, NW Washington, DC 20433, U.S.A.
- IATF/DR (Inter-Agency Task Force on Disaster Reduction), 2006. *Inter-Agency Task Force on Disaster Reduction On better terms: A Glance at Key Climate Change and Disaster Risk Reduction Concepts*.
- IFPRI (International Food Policy Research Institute), 2007. *Climate Change Pro-Poor Adaptation, Risk Management, and Mitigation Strategies 2020*.
- IFPRI (International Food Policy Research Institute), 2009. *Agriculture and Climate Change: An Agenda Focus Brief on the World's Poor and Hungry People I* Washington, DC USA International Food Policy Research Institute Gary Yohe, Ian Burton, Saleemul Huq, and Mark W. Rosegrant for Negotiation in Copenhagen FOCUS 16.
- IOP, 2009. *Climate change and Ethiopia: Global Risks, Challenges and Decisions* IOP Publishing Conf. Series: Earth and Environmental Science 6 322009 doi:10.1088/1755-1307/6/2/322009.
- IPCC (Intergovernmental Panel on Climate Change), 1996. *Climate change 1995 – The science of climate change: contribution of the WGI to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. In Houghton JT, Meira Filho LG, Callender BA, Harris N, Kattenberg A & Maskell K (eds), *The science of climate change* (Cambridge: Cambridge University Press, UK).
- IPCC (Intergovernmental Panel on Climate Change), 2001. *IPCC third assessment report – climate change 2001: impacts, adaptation and vulnerability*. Published for the Intergovernmental Panel

- on Climate Change by UNEP/GRID Arendal, 1032pp. Retrieved from <http://www.ipcc.ch/>
- IPCC, 2007. Intergovernmental Panel on Climate Change Working Group I (AR4,1.2007) [6], Summary for Policymakers, Footnote.
- IPCC (Intergovernmental Panel on Climate Change), 2007a. Impacts, Adaptation and Vulnerability Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Summary for policymakers, Brussels.
- IPCC (Intergovernmental Panel on Climate Change), 2007b. Climate Change impacts, adaptation and vulnerability: the Working Group II contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Cambridge. Cambridge University Press.
- Mariara, K.J. and Karanja, F., 2006. The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach. CEEPA Discussion Paper No. 12. Centre for Environmental Economics and Policy in Africa, University of Pretoria.
- Kinfe, H.M., 1999. Impact of climate change on the water resources of Awash River Basin, Ethiopia. *Climate Research Clim Res.* Vol. 12: 91–96.
- Kurukulasuriya, P and Mendelsohn, R, 2006. A Ricardian analysis of the impact of climate change on African cropland. CEEPA Discussion Paper No. 8. Centre for Environmental Economics and Policy in Africa, University of Pretoria.
- Kurkulasuriya, P. and Mendelsohn, R., 2008. A Ricardian analysis of the impact of climate change on African cropland *AfJARE* Vol 2 No 1.
- Maddison, D., 2006. *The perception of and adaptation to climate change in Africa*. CEEPA Discussion Paper No.10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.
- Kumar, R., 1996. *Research Methodology: A step-by-step for beginners*, SAGE publication, London.
- Liverman, D.M., 1990. Vulnerability to global environmental change. In *Understanding global environmental change: The contributions of risk analysis and management*, R.E. Kasperson, K. Dow, D. Golding, and J.X. Kasperson, eds. Worcester, MA: Clark University.
- Mendelsohn, R, Nordhaus, W. and Shaw, D., 1994. The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review* 84: 753–771.
- Meseret M., 2009. “Climate Change and Crop Agriculture in Nile Basin of Ethiopia: Measuring Impact and Adaptation Option.” (unpublished MA theses) Addis Ababa: Addis Ababa University.
- Michael, 2006. *Climate Change Impacts on East Africa a Review of the Scientific Literature* Gland, Switzerland WWF-World Wide Fund for Nature (formerly World Wildlife Fund).
- MoA (Ministry of Agriculture), 2000. *Agroecological Zonations of Ethiopia*. Addis Ababa, Ethiopia.

- MoFED (Ministry of Finance and Economic Development), 2006. Survey of the Ethiopian economy. Addis Ababa, Ethiopia.
- Marshall, N.A. et al., 2010. A Framework for Social Adaptation to Climate Change Sustaining Tropical Coastal Communities and Industries IUCN (International Union for Conservation of Nature) Rue Mauverney 28, 1196 Gland, Switzerland IUCN Climate.
- Seo, N. and Mendelsohn, R., 2007. A Ricardian Analysis of the Impact of Climate Change on Latin American Farms World Bank Policy Research Working Paper 4163.
- NMA (National Meteorological Agency), 2007. Climate Change National Adaptation Program of Action (NAPA) of Ethiopia. Addis Ababa, Ethiopia.
- Bhattacharjee, P.K., 2006. *Sustainable Fertilizer and Crop Production from Energy Security Perspective* An Overview to be presented at the annual AIChE (Central Florida) Clearwater Convention at Sand Key, Clearwater, Florida.
- Sands, 1986. Technology Adoption by Small-Scale Farmers in Ghana. The International Development Research Centre.
- Salvatore D.F., 2007. On Adaptation to Climate Change and Food Production in the Nile Basin, Ethiopia. London School of Economics and University of Kent, UK.
- Lybbert, T. and Sumner, D., 2010. Agricultural Technologies for Climate Change Mitigation and Adaptation in Developing Countries: *Policy Options for Innovation and Technology Diffusion* Issue Brief No.6 by Centre for Trade and Sustainable Development (ICTSD) International Environment House 27 chemin de Ballexert, 1219 Geneva, Switzerland.
- UNFCCC, 2007. Climate Change Impacts, Vulnerabilities and Adaptation in Developing Countries. Bonn, Germany.
- USAID, 2007. Adapting to Climate Variability and Change. A Guidance Manual for Development Planning. (United States Agency for International Development).
- Yohannes G.M. and Mebratu, K., 2009. Local innovation in climate-change adaptation by Ethiopian Pastoralists' Final report of PROLINNOVA–Ethiopia.

APPENDICES

Appendix 1

Table-A Average land size owned by the household in Choke mountain watersheds

AEZs	Average size of land owned by the household
Choke mountain watersheds	1.615
Very cold sub-moist mid highlands	0.82
Cold sub-moist mid highlands	1.08
Cool sub-moist mid highlands	1.56
Cool -Moist Mid highlands	1.46
Tepid moist mid highlands	2.78
Warm sub-moist lowlands	1.63

Table-B Soil types of crop farmlands in the study area

Crop type	Nitosols (%)	Vertisol (%)	Cambisol (%)	Lithosols (%)
Choke Mountain watersheds	56.2	56.6	23.6	11.6
Very cold sub-moist mid highlands	0	11.8	97.1	2.9
Cold sub-moist mid highlands	85.4	29.3	73.2	12.2
Cool sub-moist mid highlands	100	0	3.6	0
Cool -Moist Mid highlands	100	0	0	0
Tepid moist mid highlands	0	97.5	32.5	7.5
Warm sub-moist lowlands	6.5	15.6	25.8	67.7

Table-C Total land size used per crop types (per hectare)

Crop type	Wheat	Barley	Teff	Maize	Sorghum	Engido
Total sample	119.88	44.65	119.75	43.13	40.52	27.975
Very cold sub-moist mid highlands	4	15.13	0	0	0	0
Cold sub-moist mid highlands	12	5.87	0	2.076	0	12.235
Cool sub-moist mid highlands	10	3.62	9.15	3.625	0	15.27
Cool -Moist Mid highlands	9.51	10.4	29.8	5.86	0	0
Tepid moist mid highlands	84.13	9.38	21.87	16.87	0	0
Warm sub-moist lowlands	0	0	29.37	6.87	21.27	0

Table-D Mean temperature

AEZs	Winter	Spring	Summer	Fall	Annual
Choke Mountain watersheds	16.9	18.4	15.6	15.8	16.68
Very cold sub-moist mid highlands	7.8	9.5	6.3	6.7	7.6
Cold sub-moist mid highlands	13.4	15.1	11.9	12.3	13.2
Cool sub-moist mid highlands	16.6	18.3	14.2	15.5	16.1
Cool -Moist Mid highlands	16.3	18.4	15	15.9	16.4
Tepid moist mid highlands	19.6	20.5	18.1	17.2	18.8
Warm sub-moist lowlands	20.9	21.9	19.1	19.9	20.4

Table-E Mean precipitation

AEZs	Winter	Spring	Summer	Fall	Annual
Choke mountain watersheds	20.65	78.9	298.2	105.4	125.79
Very cold sub-moist mid highlands	70.2	178.3	473.2	267.1	247.2
Cold sub-moist mid highlands	35.2	108.3	333.2	162.1	159.1
Cool sub-moist mid highlands	15.2	68.3	253.2	102.1	109.7
Cool -Moist Mid highlands	9.24	66.48	338.63	64.99	119.83
Tepid moist mid highlands	8.6	77.1	327.4	146.3	139.8
Warm sub-moist lowlands	6.7	54.2	240.6	75	94.1

Appendix 2

Variance Inflation Factor (VIF) test for multicollinearity among Explanatory Variables included in the model with adaptation (climate + soil + agricultural technologies + socio economic variables)

Variable	VIF
Winter temperature	4.02
Winter temperature square	14.51
Spring temperature	2.64
Spring temperature square	39.00
Summer temperature	1.30
Summer temperature square	14.80
Fall temperature	1.17
Fall temperature square	31.22
Winter precipitation	2.16
Winter precipitation square	24.10
Spring precipitation	5.50
Spring precipitation square	33.66
Summer precipitation	6.47
Summer precipitation square	28.50
Fall precipitation	6.99
Fall precipitation square	27.80
Nitosols	1.65
Vertisol	2.09
Cambisol	1.48
Lithosols	1.35
Use of chemical Fertilizers	2.61
Use of Improved seeds	1.72
Use of Soil conservation	1.48
Use of Irrigation	1.20
Access to Credit service	2.39
Land size	1.59
Female dummy	1.18
Education status	1.12
Age of the household head	1.13
Family Size of the household	1.15
mean VIF	8.86

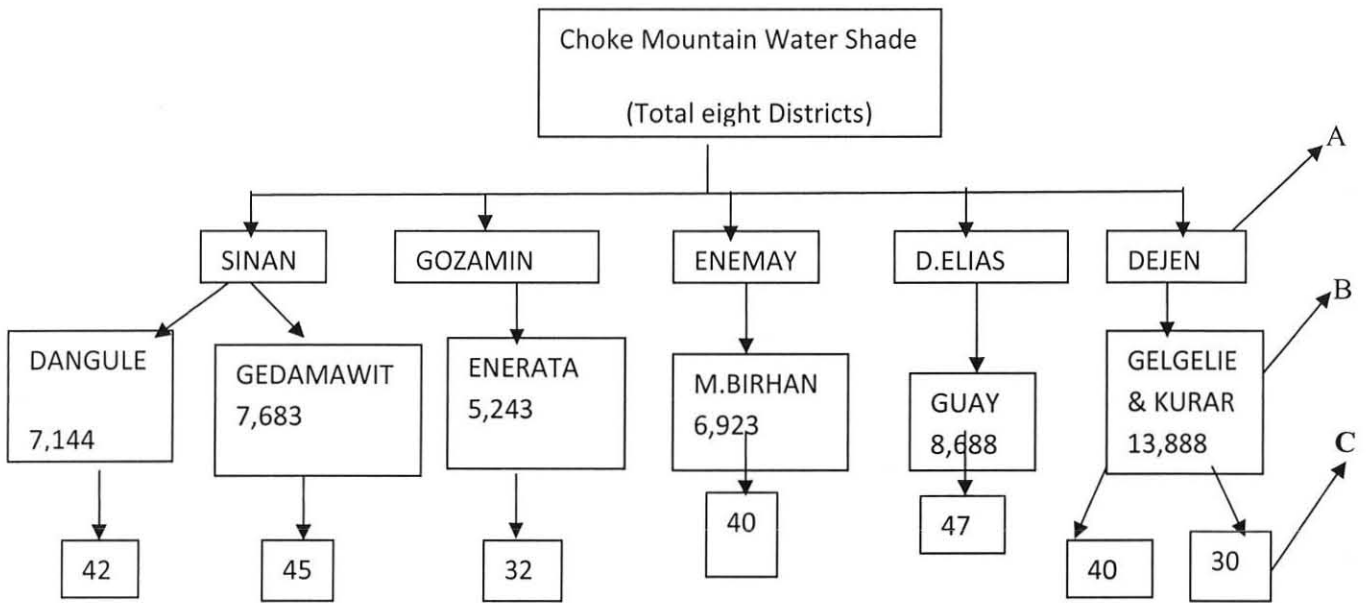
Variance Inflation Factor (VIF) test for multicollinearity among Explanatory Variables included in the model with adaptation (climate + soil + agricultural technologies variables)

Variable	VIF
Winter temperature	3.21
Winter temperature square	15.33
Spring temperature	4.24
Spring temperature square	25.83
Summer temperature	1.05
Summer temperature square	14.95
Fall temperature	1.47
Fall temperature square	21.52
Winter precipitation	3.28
Winter precipitation square	26.39
Spring precipitation	7.57
Spring precipitation square	23.2
Summer precipitation	7.97
Summer precipitation square	19.11
Fall precipitation	7.00
Fall precipitation square	23.82
Nitosols	2.08
Vertisol	3.01
Cambisol	1.89
Lithosols	2.65
Use of chemical Fertilizers	1.9
Use of Improved seeds	1.28
Use of Soil conservation	1.77
Use of Irrigation	1.2
Mean VIF	9.30

Variance Inflation Factor (VIF) test for multicollinearity among Explanatory Variables included in the model without adaptation (climate + soil variables)

Variable	VIF
Winter temperature	4.93
Winter temperature square	15.12
Spring temperature	2.88
Spring temperature square	48.83
Summer temperature	1.57
Summer temperature square	14.95
Fall temperature	1.47
Fall temperature square	37.52
Winter precipitation	3.28
Winter precipitation square	28.00
Spring precipitation	7.57
Spring precipitation square	23.20
Summer precipitation	9.97
Summer precipitation square	39.00
Fall precipitation	7.20
Fall precipitation square	36.82
Nitosols	3.06
Vertisol	2.72
Cambisol	1.56
Lithosols	1.36
Mean VIF	14.55

Appendix 3



A. 5 districts were selected using Purposive sampling

B. 7 Kebele Administrations were selected using Purposive sampling

C. 276 sample Households were selected using stratified Simple random sampling

Appendix 4

QUESTIONNAIRE

Questionnaire for Agricultural productivity study

NOTE: Questions raised refer to *meher* production for the 2001 E.C

PART I. Socio economic characteristics

1. Woreda _____ Potential status of the Woreda _____
 Kebele _____ Village _____ Household ID _____

2. Household characteristics

2.1 Household head's Age _____

2.2 Household head's Gender a) Female b) Male

2.3 Marital status 1 = married 2= never married 3 = divorced 4= widowed 5= separated

2.5 Household head's education level (refer to the alternatives in question number (2.3))

2.3 No. of household members

Age category	Sex (in number)		Level of education ^a	Occupation(see code) ^b	
	Male	Female		Main	Secondary
≤ 14 years					
Between 14 and 65 year					
≥ 65 years					

a-Educational status 1. Illiterate 2=Read and write 3= Primary level 4=Secondary level 5= Tertiary

b-Major occupation 1=crop production 2=livestock rearing 3=government employee 4= other, specify _____

3. Does the farm plot you cultivate belong to you?

a) Yes b) No

3.1 If the answer for question number 3 is No, is it

a) Rented b) Shared c) Other (specify) _____

4. What is the size of the total land owned by the household under (ha)?

a) Cultivation: _____.

b) Grass and woodland: _____.

c) Parcels/homestead: _____.

5. What type of agriculture do you practice? 1. Rain-fed 2. Irrigated 3. Mixed

6. What do you grow most on the major portion of your farm? (Rank in decreasing order)

1. Barley _____ 'Ingido' _____

2. Sorghum _____ Teff _____

3. Wheat _____ Maize _____

4. Others _____

7. What is the average land size allocated to the production of:
(Where possible use Ha or estimate and convert the local units in to Ha)

Barley	sorghum	Wheat (ha)	Ingido(ha)	Maize (ha)	Teff (ha)	Others, Specify

8. What is the major objective in producing the aforementioned crops for:-

	Barley	sorghum	Wheat (ha)	Ingido(ha)	Maize (ha)	Teff (ha)	Others, Specify
Consumption							
Market							
Both market and consumption							
Other							

9. How do you see the trend of food supply stock in your household for the last 10 years?
1. Increasing 2. Decreasing. 3. No change 4. I don't know

9.1 If your answer to question no 10 is 1, 2, or 3, what do you think is the reason?

10. Do you rear animals? 1. Yes 2. No

11. Does the household head engage in major non-farm income generating activity?

1. Yes 2. No

12. Would you tell your household source of cash income and its amount (in Birr)?(Check yes if it is your source of income, or no if otherwise)

13. How do you see the trend of average income level in your household for last 10 years? 1. Increasing 2. Decreasing. 3. No change 4. I don't know

If your answer to question no 18 is 1, 2, or 3, what do you think is the reason? _____

13.1 What is the color of the major soil type of your farm plot under the following crops? (Put '✓')

	Barley	Sorghum	Wheat (ha)	Ingido(ha)	Maize (ha)	Teff (ha)
Gray						
Brown						
Red						
Black						
Other						

PART 11. Fertilizer use and application

14. Do you use fertilizer for your crop production? 1. Yes 2. No

15. If your answer for question number 15 is no, why?

1. High price 2. Less trust 3. Less availability 4. other _____

16. If your answer for question number 27 is yes, where do you get it?

1. From the woreda agricultural office
2. From the kebele Agricultural office
3. From the office of the kebele farmers association
4. By buying from private owners

17. Is it available and sufficient to improve your food crop production? 1. yes 2. No

18. If your answer is No, what do you think are the reasons? _____

32. Which fertilizer do you use most under the following crops?

	Barley	sorghum	Wheat	Ingido	Maize	Teff
1.The white /Urea/						
2.The brown/ DAP/						
3.Both						
4.None						
5.Other						

32.1 If the answer is "other" write the type of "other" fertilizers. _____,

32.2 If the answer is 1, 2 or 3, how many kg/quintals of DAP and UREA do you use under the following crops?ⁱ

	Barley	Sorghum	Wheat	Ingido	Maize)	Teff	Others, Specify
DAP							
UREA							
Other							

33. Which factor affects most of your decision with regard to fertilizer quantity used on your farm?

- 1) The future price of crops you produce
- 2) The current price of Fertilizer
- 3) The price of improved seed
- 4) The last season price of crops you produce
- 5) Others _____

Barley	sorghum	Wheat	Ingido	Maize)	Teff	Others, Specify

PART III. Integration of fertilizer with other inputs

37. What is your average yield estimate per ha under?

- 1) local seeds with no fertilizer 1) Teff ____ qt 2) Wheat ____ qt 3) Maize ____ qt
- 2) local seeds with fertilizers 1) Teff ____ qt 2) wheat ____ qt 3) Maize ____ qt
- 3) improved seeds with no fertilizera) 1) Teff ____ qt 2) Wheat ____ qt 3) Maize ____ qt
- 4) improved seeds with fertilizer 1) Teff ____ qt 2) Wheat ____ qt 3) Maize ____ qt

38. Do you exercise crop rotation practices? 1) Yes 2) No

38.1 If yes, what is your major crop rotation sequence (mention crop sequences)?

38.2 If you use crop rotation, do you use fertilizers under the successive crop? (Two answers are possible)

1. Yes, use Same amount and type of fertilizers under the successive crop
2. Yes, use more urea under the successive crop
3. Yes, use less urea under the successive crop
4. Yes, use more DAP under the successive crop
5. Yes, use less DAP under the successive crop
6. No need of fertilizer use at all to apply under the successive crop

38.3 If the answer for question number 18.2 is no or less use of fertilizers, what are your justifications?

39. When do you use fertilizers **most** under the following crops?

- a) if the seed to be planted is newly introduced
- b) If the seed is local
- c) if the seed is recently adopted by surrounding farmers and still considered as improved seed
- d) If the farm plot is known to require fertilizer each year
- e) If there is adequate amount of moisture/ rain
- f) If the future price of the crop seem to be attractive
- g) If there is hybrid seed to be planted.

Barley	
Sorghum	
Wheat	
Ingido	
Maize)	
Teff	
Others, Specify	

40. Is there an alternative input to fertilizers around your farm so that you can cultivate your crops without fertilizer?

- a) Yes
- b) No

44.1 If the answer is Yes, list the alternatives in decreasing order (most important first)

1. _____, 2. _____, 3. _____ 4. _____

44.2 If you use manure, what is the amount you apply (kg/ha) for;

Barley	Sorghum	Wheat	Ingido	Maize)	Teff	Others, Specify

45. Do you plant improved varieties without fertilizer application? a) Yes b) No

45.1 If the answer is **Yes**, the **main reason** would be (multiple answers are possible)

- a) Because there is no difference in productivity
- b) Because I got the seeds but no fertilizers
- c) Whenever I plant on the fallow land I don't use fertilizers
- d) Whenever I plant the successive crop after crop rotation I don't need fertilizer
- e) I don't have money
- f) Fertilizers are not available

45.2 If the answer is **No**, the **main reason** would be (multiple answers are possible)

- a) Know the synergetic effect of fertilizers with improved seed.
- b) Know improved varieties are always demanding high fertility level
- c) I always harvest high yield when I combine the two
- d) it is how the extension agents told us to do

46 Do you get credit services for fertilizer purchase? a) Yes b) No

47 Do you get what you invest in fertilizers? a) Yes b) No

47.1 If the answer is Yes

a) it is **more than** I invested c) it is **less than** what I invested

b) it is **equal** to what I invested d) I don't know

48 Is soil and water conservation activity (such as terracing, etc) practiced on your farm plot?

a) yes b) no

48.1 If yes, what type of conservation measures? _____

48.2 If no why not? _____

PART IV. Extension Services

49. Do you know the amount of fertilizers that the extension agents advised you to apply under Teff, Wheat and maize? a) Yes b) No

49.1 If the answer is Yes, is it more or less than what you actually use under these crops? Please write more, less or the same in the respective box.

Barley	Sorghum	Wheat	Ingido	Maize)	Teff	Others, Specify

49.2 If you apply more fertilizers than the extension agent advices, what would be your justification?

- a) My experiences proved that it is better to apply more than what the extension agent advised me
- b) What they advised does not work for my farm plot, thus I apply more
- c) What they advised does not work for my crop type, thus I apply more

49.3 If you apply less fertilizer than the extension agent advices, what would be your justification?

- a) The extension agents always advises me to use more fertilizers, thus I use less
- b) I know my farm plots and the crop type that it require less than what they advised us to apply
- c) I know that they advised me to use the right amount but fertilizer prices are expensive

50. A total of how many quintals of fertilizers do you consume most of the cropping seasons.

- a) Less than 2 sacks/100 kg/ c) 3 sacks/150 kg/
- b) 2 sacks/100 kg/ d) 4 sacks /200 kg/ e) More than 4 sacks/200kg

PART V. Fertilizer Supply

55. Do you get improved seed whenever you need them? a) Yes b) No

56. Is the price of improved seed affordable?

a) Yes b) No

57. What was the price of a quintal of improved seed in the last three cropping seasons?

No	Crop	Price in Birr				
		1997	1998	1999	2000	2001
1	Teff					
2	Wheat					
3	Hybrid Maize					
4	OP Maize					
	Others					

58. From where do you buy improved seeds?

a) Cooperatives c) Private agro dealers
 b) Local seed growers d) Agriculture offices e) Others? _____

59. Is the quality of improved seed acceptable? a)Yes b)No

60. If the answer for question number 47 is No, what are the reasons?

b) Mixture c) Germination
 c) Uniformity d) Disease e) Others _____

61. What is the average yield for the three crops compared with the local varieties?

No	Crop	Yield Qt/ha	
		Local varieties	Improved varieties
1	Barly		
	Teff		
2	Wheat		
3	Hybrid Maize		
4	OP Maize		
	Others		

62. Is there a centre or project which produce improved seed in you locality? A. Yes B. No

63. If yes, have you ever take part to produce improved seed in your locality? A. Yes B. No

64. How do you see its effectiveness to distribute the seed to all local farmers?

A. Very good B. Good C. Nothing

65. How do you see the importance applying improved seed to increase crop production as compared to those past years in which you didn't use improved seed?

A. Very important B. important C. no change

66. What do you think are the major constraints to using improved seed for crop production?

67. Do you remember the time that you start to use agricultural technology to improve your crop production?

No.	Type of technology	Year
1	Fertilizer	
2	Improved seed	
3	Water conservation technology	
4	Irrigation technology	
5	Soil conservation technology	
6	Improved plowing material	

68. Why you started to use new agricultural technologies for your crop production? _____

69. How do you generally see the change in crop production after using them?

- A. Very good B. good C. not good D. no change

Change in the crop production calendar

70. Is there rainfall variability in the area? A. Yes B. NO

71. If your answer is yes, does it affect the schedule of planting food crops in the area and result in crop failure as well as reduce crop production in the area? A. Yes B. No

72. When did you start to change the crop planting calendar?

- A. 5 years ago B. 10 years ago C. 15 years ago D. before 15 years ago

73. How do you see the effectiveness of changing the crop planting calendar in relation to crop failure and production raise?

- A. Production increased
 B. Production decreased
 C. Production is constant or no change in production
 D. Decreased crop failure

Appendix 4

Part 1. Interview Guide

Overview of farmers' perception towards climate change

1. Is there an extreme weather (flood, erratic rainfall, and drought) in the area? 1. Yes 2. No
2. If your answer is yes how often it occurs in the area for the past 5 years?
3. What do you think is the reason?
4. What kinds of agricultural technology are used by the local farmers to enhance crop productivity?
5. Why you started to use improved agricultural technologies for crop production? When?

Fertilizer application

6. Do you use fertilizer for crop production? A. yes B. no
7. If your answer is yes, what type of fertilizers do you use?

8. If your answer is no, why?
9. Which type of fertilizer do you highly demand and which is less? Why?
10. How do you see the amount of fertilizer that you used for your crop production since you started to use it?
11. How do you see the availability and supply of fertilizer that you used for your crop production since you started to use it?
12. How do you see your demand over time?
13. How do you see the price of fertilizer that you used for your crop production since you started to use it?
14. Do you think that the price is affordable?
15. Is it in increasing or decreasing trend? what do you think is the reason?
16. What do you think is its importance to increase productivity of crops against the variable rainfall and drought in your area?
17. How do you see the gap between the demand and supply of fertilizer in the area?
18. If there is high gap what do you think is the reason?

Do the local agriculturalists help you for effective utilization of fertilizers?

19. If your answer is yes how?
20. What do you think are the major challenges in using/ applying fertilizers for effective crop production in the area?
21. What kind of measures did you take to solve them?
22. What do you recommend for the government/local administration for the effectiveness of fertilizer to enhance crop productivity/production?

Improved seed application

23. Do you use improved variety of seeds to enhance crop production? A. yes B. no
24. If your answer is yes for which crops that you produced and soil types do they apply it? Why for others?
25. If your answer is no, why?
26. How do you see your demand for improved crop varieties from the time since you started to use it? Is it increasing or decreasing? Why?
27. How many quintals/ qumta of improved varieties per crop have you used for the last 5 and 10 years?

Is it increasing or decreasing? What is the reason?

28. How do you see gap between the supply and demand of improved seed varieties per crop type in the area?
A. high demand but less supply B. demand and supply are equivalent C. high supply but less demand
29. For what kind of crops do you get more improved seed varieties in your area? Why for this?

And Why not for other crops cultivated in the area?

30. Is there any agricultural center (governmental, private...) which produces local improved varieties of seed in the area? A. yes B. no
31. If your answer is yes what do you think is its contribution for you to access improved seed varieties?

32. Which improved variety of seeds per crop type (brought by the woreda and which one is produced locally) which one is effective to increase the production of crop with high adaptation to the soil and climatic condition in the area?
33. What do you think are the challenges in the intervention, supply and demand, distribution, and application of improved seed varieties per crop type in the area?

Soil conservation and management techniques

34. Is there any critical problem in relation to soil fertility and erosion in the area? A. Yes B. No
35. If your answer is yes, what are they?
36. What kind of soil conservations do you practice in your area?
37. What kind of soil conservation and management technology/technique do most farmers use in the area? How do you see their effectiveness to conserve the soil?
38. Do you believe that you the conservation practice you are doing against flooding and erosion enhance your crop production?
39. What kind of crop do you usually produce per the type of soil per color?
40. What do you think are the major constraints to practice soil conservation and management practices you are making?
41. How do you see the contribution of the agricultural experts in solving soil infertility or degradation of soil in the area?
42. What do you think is the contribution of improved agricultural technologies that we mentioned above to reduce the impact of drought, flood, scarce and dynamic rainfall and enhancing your crop production?
43. What kind of changes do observe with regard to crop production due to the implementation of these technologies

Irrigation activities and technologies

44. Are there streams and rivers important for irrigation in your area? 1. yes 2. no
45. If your answer is yes, Is there any irrigation activity for crop production in the area? A. Yes B. No
46. If your answer is yes, what kind of irrigation activities do you and the local farmers use to cultivate crops?
1. Traditional or modern by using irrigation technologies like motor pump, washer pump geo membrane?
47. Which is commonly used by you and other farmers in your area?
48. What kind of crops do you and other farmers in your area produce by using irrigation?
49. How do you see the effective use of ground water, streams or rivers for irrigation activity in the area?
50. Do local agricultural experts in your area give technical and other support to make effective irrigation activity for enhanced crop production to cope the variable rainfall which is against crop production?
51. What kinds of support do the local or district agricultural experts providing for you and other farmers to make effective irrigation activities to enhance crop production in your area?
52. Do you have (do you know other farmers have) a plot of land that you used to produce crops nearby streams and rivers and is not yet been done for irrigation?

53. If your answer is yes what is your very reason (other farmers) behind it?
54. Have the local agricultural experts ever initiated you / other farmers to use it for irrigation?
55. How did you respond to them?
56. Is there any plan and implementation of irrigation scheme in the area by any governmental or nongovernmental organization? If yes what it is?
57. What do you think are the constraints for the intervention and application of irrigation technology in the area?

Part II. Issues for FDG

1. How do you see the trend of rainfall and temperature change and variability in the area for the last 20 and 30 years?
2. Have you ever encountered with extreme weather (erratic rainfall with snow, flood, and drought) in the area? What kind of measure do you start using to reduce its impact on your crop production? How the local agricultural experts helped you to respond for it?
3. Did you encountered with reduction of crop production or failure in the area? What do you think is the cause for it?
4. What kind of coping mechanisms did you use to reduce the risk of crop failure or reduction on your farmland?
5. Which mechanisms are better to enhance crop production and which do not?
6. How do you see the significance of the intervention of these new agricultural technologies in the area in enhancing crop productivity as compared to the traditional methods?
7. How do you see the trend of soil fertility of crop farmland in the area over time?
8. How do you see the contribution of different organizations/offices (either NGO, GO, CBO) to help the local farmers by increasing crop production for food security and poverty reduction vis-à-vis agricultural technologies?

Part III. Observation Checklist

1. Slope of the farmland used for crop cultivation
2. Erosion status of the farmland and soil conservation techniques used
3. Tree coverage around or in between the crop farmland
4. Any local improved crop seed production centers
5. Soil conservation practices
6. Irrigated farms

Declaration

I, the undersigned, declare that this thesis is my original and real work that has not been for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

Declared by

Candidate

Confirmed by

Advisor

