ECONOMIC IMPACTS OF CLIMATE CHANGE ON TEFF PRODUCTION IN LUME AND GIMBICHU DISTRICTS OF CENTRAL ETHIOPIA

DEGEFU KEBEDE BAYECHA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2013

ABSTRACT

This study was carried out with the main objective of analyzing the economic impacts of climate change on teff production in central Ethiopia. Specific objectives of the study were: i) To analyze the relationship of income from teff (*Eragrostis tef)* production with biophysical and socioeconomic variables, ii) To determine the marginal impact of temperature and rainfall on income from teff production, iii) To predict a range of potential future impacts on teff production under a mid-range emission scenario. The study used data collected from a randomly selected sample of 150 smallholder teff producers in Lume and Gimbichu districts from March 2013 to May 2013. The study assessed descriptively farmers' perceptions on climate change in terms of long-term change in climate variables including temperature and rainfall, and adaptations undertaken in teff production. The study used a cross sectional Ricardian approach to analyse the impact of climate change on net revenue from teff production. Net revenue per hectare per year for teff crop was regressed against climate predictor, biophysical and socioeconomic control variables. The results indicate that predictor variables had a significant influence on net farm returns from production. The marginal impact analysis revealed that temperature will have a significant ($p < 0.01$) negative impact on annual net revenue from teff. Rainfall will have a positive impact on net revenue from teff production. Based on a mid-range IPCC's emission A1B scenario for the country, the predicted future climate change will adversely impact on net revenue from teff for all time periods of near, mid and far century. Investment in research on teff improved technologies, and transfer of such adaptation technologies to teff smallholder farmers through improved extension services are recommended from this study as to increase farmers' adaptive capacity to reduce the impact of climate change on teff production.

DECLARATION

I, Degefu Kebede Bayecha, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within a period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

……………………………………   ………………………….

Degefu Kebede Bayecha   Date

(M.Sc. Candidate)

The above declaration is confirmed by:

……………………………………   ……………………………,

Dr. Khamaldin Mutabazi   Date

(Supervisor)

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ACKNOWLEDGEMENT

First and foremost, I would like to thank my God for allowing me to start and finish my study. My greatest thanks and appreciation goes to my supervisor Dr. Khamaldin Mutabazi for his professional support and due concerns from the designing of research proposal up to thesis write-up. It is my pleasure to thanks Dr. Damas Philip, Head of department of Agricultural Economics and Agribusiness, for his constructive professional comments on my research proposal and thesis, and Dr. Nhemachena Charles, University of Pretoria, South Africa for his valuable professional comments on my research proposal.

I also thank and heartfelt appreciation to African Economic Research Consortium (AERC) for the full scholarship grant, without which joining the M.Sc. program would not have been possible.

It is difficult to mention here all people who assisted me and contributions of organizations in various ways toward the successful completion of this research. In this regard, I would like to express my sincere appreciation to all of them, and to mention few; Dr Frew Mekbib, Fresenbet Zeleke, Habib Abu, Tolera Goshu, Abadi Teferi, Kedir Ahmed, Denu Lemma, Beatrice Daniel, Daniel Jaleta, Nano Alemu, Wondu Balcha, Sime

Biratu, Aster Leggese, Habtamu Admasu , staff members of both Lume and Gimbichu districts office of Agricultural and Rural Development, Ethiopian NMA for access and use of climate data and Debrezeit Agricultural Research center for access to teff research publications.

At last, but more importantly I would like to thank my family, for their unconditional support, valuable encouragement, inspiration and love.

DEDICATION

I dedicate this work to my beloved mother Zenebu Damesa for nursing me with affection and love, and for her dedicated partnership in both success of my life and career.

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LIST OF ABBREVIATIONS

AEZ	Agro-ecological Zone
CGE	Computable General Equilibrium
CGM2	Canadian Global Climate Model 2
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
ETB	Ethiopian Birr (Currency)(= 18.55US$)
FAO	Food and Agriculture Organization
GHG	Green House Gas
GPS	Global Positioning System
HadCM3	Hadley Centre Climate Model 3
IPCC	Intergovernmental Panel on Climate Change
LGP	Length of Growing Period
NAPA	National Adaptation Program of Action
NME	National Meteorological Agency
NR/ha	Net Revenue per hectare
MoFED	Ministry of Finance and Economic Development
PAs	Peasant Associations
PANE	Poverty Action Network of civil society organizations in Ethiopia
PCM	Parallel Climate Model
SPSS	Statistical Package for Social Sciences

SRES	Special Reports on Emission Scenarios
VIF	Variance Inflation Factors

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Agriculture sector is vulnerable to climate change. Climate change affects agriculture by altering yields and changing areas where crops can be grown. Increased variability in weather-related shocks and stresses, resulting from climate change, increases the risk of production failure for farmers particularly those engaged in rain-fed agriculture (IPCC, 2007). This is associated with the fact that agricultural production in developing countries is mostly based on rain-fed, whereas, in developed countries rain-fed agriculture is supplemented with irrigation facilities and other infrastructures. Increasing climate variability can put production at risk and is likely to further decrease farmer investment. Furthermore, risks in agriculture are associated with negative outcomes that arise from imperfectly predictable biological, climatic, and price variables. These variables include natural adversities such as, pests and diseases and, climatic factors which are not within the control of the farmers. Therefore, rainfall variability and other climatic risks account for a significant share of agricultural production risk (World Bank, 2001; FAO, 2008).

In Ethiopia, the average annual minimum temperature has increased by about 0.25^{o}C every ten years while the average annual maximum temperature has increased by about 0.1^{o}C. Moreover, the National Meteorological Services (NMA) further showed that there was a very high variability of rainfall over the past 50 years (NMA, 2007).

Africa's rain-fed agricultural production including production of cereals (such as teff in Ethiopian case) could be reduced by up to 50% due to climate change. This situation is worrisome for Africa, a region already having the highest proportion of people living in extreme poverty and the lowest level of agricultural productivity (Hellmuth *et al.*, 2007). The main environmental problems in Ethiopia include land degradation, soil erosion, and deforestation, loss of biodiversity, desertification, recurrent drought, flood and water and air pollution (NMA, 2007; MoFED, 2007). Furthermore, climate related hazards in the country include mainly drought, floods, heavy rains, strong winds, frost and heat waves (high temperatures).

Given the fact that the location of Ethiopia is in the Sahel Region, a region with erratic rainfall and unpredictable climate variability, the country has also suffered from extremes of climate, manifested in the form of frequent drought (1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, and 2002) along with recent flooding of 1997 and 2006 (Yesuf et al., 2008).

The main causes of most disasters are climate related for which deterioration of the natural environment due to unchecked human activities is the one and poverty has further exacerbated the situation. Moreover, according to NMA (2007) high dependence on rain fed agriculture which is very sensitive to climate variability and change, under-development of water resources; high population growth rate, weak institutions and lack of awareness are also among the other sources for vulnerability of Ethiopia to climate variability and change.

Teff (*Eragrostis tef*) is grown primarily as a cereal crop in Ethiopia and it has been cultivated for a long period of time in the country. Although traditionally grown in the highlands, teff can be grown under a wide variety of agro climatic conditions, including elevations from zero to 2800 meters above sea level (m.a.s.l), under a similarly wide variety of moisture, temperature, and soil conditions. Its optimal growing conditions coincide with its traditional production areas: 1800 - 2100 m.a.s.l, average annual rainfall of 750 - 850 millimeters (mm), and average annual temperature of 10 - 27^{0}C (Ketema, 1997).

The flour of teff grain is mainly used for making popular pancake-like local bread called *enjera* and sometimes for making porridge. The grain is also used to make local alcoholic drinks, called *tela* and ***katikala.*** Teff seed is gluten free. Further, the teff grain owing to its high mineral content has started to be used in mixtures with soybean, chickpea and other grains in the baby food industry (Ketema, 1997). Farmers highly value the straw of teff and it is stored and used as a very important source of animal feed, especially during the dry season. Moreover, teff straw, besides being the most appreciated feed for cattle, is also used to reinforce mud and plaster the walls of local grain storage facilities called *gotera* and walls of local houses by local communities.

The area under teff cultivation is large in the country as compared to other cereals. During the 2011/12 cropping season compared to three major cereals, teff occupied 23% of the cultivated land under cereals, while maize occupied 17%, sorghum 16% and wheat 12% (CSA, 2012). This shows an importance of teff in the country. By the year 2050, teff will expect to lose 24% of current suitable area due to climate change (Yumbiya *et al*., 2011).

This is mainly related to the fact that the temperature is expected to exceed teff species tolerance. The consequence of such loss will put at risk millions who depend on the crop for their livelihood unless different climate change adaptations are in place. Therefore, the need for assessing the economic impact of climate change on teff production would help to prepare for various climate change adaptations in teff production.

1.2 Problem Statement and Justification

Studies show that climate change affects agricultural production through shortening of maturity period and then decreasing crop yield (NMA, 2007; PANE, 2009). It was indicated that there will be expected future area loss in teff production in Ethiopia and the pattern of teff species will be restricted to higher altitude due to future changes in climate (Yumbya *et al.*, 2011). High water stress and increase in temperature which in turn reflects on low yield and crop failure are among the challenges associated with the impact of climate change on an important crop like teff.

Given the fact that farmers depend on the crop; they expect high and stable farm income from the crop to sustain their livelihoods. The income enables them to access goods and services that they are not producing by themselves. Therefore, the impact of climate change on teff production extends to a downturn in related farm income hence, undermining farmers' livelihoods.

There have been limited scientific evidences on impacts of climate change on teff production in Ethiopia. For instance those pertinent literatures addressed the economic impacts of climate change in the country were based on general agricultural crops produced by farmers (Deressa and Hassan, 2009; Molla, 2009; Belay, 2012). Hence,such studies considered the lump sum of agricultural crops in to one category while in reality; climate change affects different crops differently as long as different crops have different climate requirements. Therefore, under such findings it is difficult to disaggregate the impact on teff production, as long as the impact is not solely referred for teff production.

Moreover, Study by Yumbya *et al.* (2011) assessed impact of climate change on teff production for three teff potential districts of Ethiopia in terms of expected future loss in current suitable area for teff through future projections. However, the study was limited in in-depth analysis on the economic impacts of climate change on teff production. Therefore, assessments of an economic impacts of climate change on teff production with specifically focus on the role of socioeconomic aspects, the likely change in the magnitude of the impacts on the crop when the climate variables change marginally and projected climate change impact on net revenue per hectare of teff due to future changes in temperature and rainfall are among the gaps which the study intends to bridge. Nevertheless, an effort aimed at assessing the farm level economic impacts of climate change on teff is lacking, such assessment would have been enabled adoption of economically feasible adaptation actions to minimize the vulnerability of teff production and the people who directly depend on the crop.

1.3 The Objectives of the Study

1.3.1 The overall objective

The overall objective of this study is to assess the economic impacts of climate change on smallholder teff production in order to inform adaptation policies and actions.

1.3.2 Specific objectives

The specific objectives of the study are:

i To analyze the relationship of income from teff production with biophysical and socioeconomic variables;

ii To determine the marginal impact of temperature and rainfall on income from teff production; and

iii To predict a range of potential future impacts on teff production under a mid-range emission scenario.

1.4. Hypothesis

i Ho: There is no significant relationship between income from teff production and biophysical and socioeconomic variables;

ii Ho: The marginal impact of climate change on the net farm revenue from teff production will be significantly positive;

iii Ho: Teff production will be profitable under future mid-range emission scenario.

1.5 Significance of the Study

The study aimed on the analysis of economic impact of climate change on teff crop production. Identifying and quantify the economic impact of the climate change is among an important area of interest in climate change study, whereby, studies confirmed that climate change has already taking place. Hence, it is important to design study with respect to nature of the impact (economic impacts), perception of communities and adaptations mechanisms (with constraints associated) to the impact of climate change.

Therefore, this study was designed in line with these interests, to address the economic impacts of climate change with reference to teff production under two districts of central Ethiopia.

First, assessment of the perception status of the farming community, adaptation strategies undertaken by the farmers and limiting constraints with respect to teff production in the study districts highlights the introductions and existing situations in the study districts. Second, the relationship between net revenue from teff crop with climate variables, biophysical and socioeconomic variables shows how net revenue from the crop is dictated by climate variables and socioeconomic variables among others. Third, the marginal changes in the climate variables insight for the expected loss particularly with increases in temperature level on the net revenue from teff. Last, the result from the future projection provide an insight on what will likely happen under the future damage level under a mid-range emission scenarios that will demand urgent interventions.

In general, the finding is a useful insight for those who design various planning and policies that are addressing the ways to minimize the impact level through targeting adaptation options. In addition, the result from this study with other previous studies can be used as an input for future empirical studies which will target the areas of economic impacts of climate change on crop production and address various adaptation strategies in teff and other crops production.

1.6 Scope and Limitation of the Study

Given the fact that time and budget are among the limiting factors, the study targeted only two districts. Hence, it is important for further study to cover more teff potential districts of the country to investigate the national wise impact on teff production. With regards to adaptation strategies and constraints of adaptation to teff production, the study highlights them. However, it is recommended for further study to undertake the depth investigation on adaptation strategies and constraints of adaptations which are specific to teff production. Though the proportion of land size allocation among major crops grown for the season were captured, net revenue from other crops and livestock are not captured in the model for the study.

Other limitation of the study is that, the study focused on the aggregated long term temperature and rainfall data which are associated with length of growing period for teff production. Hence, the aggregated value of these climate variables which represented long term climate variables cannot enable to see the nature of the impact at each season. However, it has to be noticed that the findings for overall impacts (both marginal and future impacts) are not affected by such aggregation since the overall impact depends on the seasons aggregate. Moreover, the impact of the winter season was not captured under this study, as it has no direct association with the length of growing period of the crop. Hence, future study may look at the indirect impact of winter season on net revenue from teff crop production.

Finally, there is no idea considered for crop benefit from carbon dioxide fertilization, changes in price of both factor and product markets, and advancements in better technologies. Therefore, despite these and others limitations of the cross sectional Ricardian approach, the finding from this study shows an idea on relationship of climate variables and net revenue from teff crop in particular and economic impact of climate change on teff production in general for the study site included under this study.

1. 7 Organization of the Study

This study constitutes five chapters. After this chapter one which introduces and discusses the background, problem statement and justification of the study, objectives of the study, and hypotheses, chapter two elaborates and covers the relevant literature reviews concerning the empirical studies elsewhere and in the context of Ethiopia. The research methodology is covered under chapter three. Methodological aspects covered under he chapter include a description of the study districts, research design, sampling unit, sample size, sampling techniques, sources of data and collection methods, data analysis and specification of the empirical model. Both descriptive and econometric results are presented and discussed under chapter four. Finally, Chapter five summarizes the main findings of the study and highlighted interventions and policy implications.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definitions of Terms and Concepts

2.1.1 Climate variability and changes in crop production

Climate variability refers to natural climate fluctuations, including changes of mean state and varying occurrence of extremes. This denotes deviations of climate statistics over a given period of time, such as a specific month, season or year, from the long-term climate statistics relating to the corresponding calendar period. Hence, the climate is naturally in constant change. Climate change as compared to variability, on the other hand, can be detected if standard variations (patterns of climate variability and means) experiences significant measurable changes in the long-term (FAO, 2012).

2.1.2 Adaptation concepts

Adaptation is about reducing the risks posed by climate change to people's lives and livelihoods. It refers to responses by individuals, groups and governments to actual or expected changes in climatic conditions or their effects. Adaptation strategies in agriculture are based on a combination of specific actions (e.g. switching from one crop variety to another); and systemic changes; for example- diversifying livelihoods against risks or an institutional reform to create incentives for better resource management (FAO, 2008). Adaptation measures deal with the impacts of climate change and have the objective of reducing the vulnerability of human and natural systems in general.

Adaptation strategies include a broad set of activities ranging from activities that focus on reducing drivers of vulnerability to interventions aimed at confronting not yet experienced climate change impacts (FAO, 2008). There is a broad spectrum of activities with gradations of emphasis on the vulnerability and impacts that aim to build response capacity and better manage climate risks. These adaptation continuums are; addressing drivers of vulnerability, building response capacity, managing climate risk and confronting climate change (FAO, 2012).

Adaptation strategies include a broad set of activities ranging from activities that focus on reducing drivers of vulnerability to interventions aimed at confronting not yet experienced climate change impacts. The strategies can be autonomous adaptation where it is an adaptation that does not constitute a conscious response to climatic stimuli, but rather is triggered by ecological changes in natural systems and by the market or welfare changes in human systems and it is also known as spontaneous adaptation (IPCC, 2007).

The other form of adaptation is that which is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state (IPCC, 2007) which is known as planned adaptation. By undertaking adaptation strategies farmers can be able to increase their resilience to extremely low and high temperature. Therefore, adaptation increases the coping range.

2.2 Projected Climate over Ethiopia

All models predicting future climate change scenario in Ethiopia arrive at a similar conclusion in the sense that the temperature will increase over a period of time. However, they give conflicting results concerning the predicted level of precipitation/rainfall-constant, decreasing and increasing level of projected precipitation is generated using different models (Belayneh, 2011).

By using the software MAGICC/SCENGEN (Model for the Assessment of Greenhouse-gas Induced Climate Change) / (Regional and global Climate SCENario GENerator) coupled model (Version 4.1) for three periods centered around the years 2030, 2050 and

2080, NMA (2007) generated that the mean annual temperature will increase in the range of 0.9-1.1°C by 2030, in the range of 1.7-2.1°C by 2050 and in the range of 2.7-3.4°C by 2080 over Ethiopia for the IPCC mid-range emission scenario compared to the 1961-1990 normal. The report furthermore states that there will be expected for a small increase in precipitation in the country.

Deressa and Hassan (2009) applied the future projections value from three different SRES of IPCC projection models. The models are CGM2, HaDCM3 and PCM. All the models forecasted increasing temperature levels for the years 2050 and 2100 with respect to precipitation, while the CGM2 predicted decreased precipitation for both years, both HaDCM3 and PCM predicted increasing precipitation over these years. The magnitude of the projections for temperature and precipitation are higher as compared to the value projected by NMA (2007). In fact the difference is mainly due to the type of models used.

Strzepek and McCluskey (2007) using five climate prediction models; Coupled Global Climate Model (CGCM2), the Hadley Centre Coupled Model (HadCM3), ECHAM, CSIRO2 and the Parallel Climate Model (PCM); based on two scenarios (i.e., A2 and B23) from the IPCC Special Report on Emission Scenarios (SRES) showed that temperatures will increase in the coming decades in all of the models. However, precipitation might increase, decrease or become constant depending on the models used (Strzepek and McCluskey, 2007) cited by (Belayneh, 2011).

2.3 Policy Reviews of Climate change Impacts in Ethiopia

The government of Ethiopia has set various policies to address the impacts of climate change on community livelihood. Climate Resilient Green Economy (CRGE) is among such policy directions by which the Environmental Protection Authority (EPA) has been mandated to co-ordinate the national response to climate change. Moreover, through Ethiopia's Programme of Adaptation to Climate Change (EPACC) and emissions abatement initiatives including the Nationally Appropriate Mitigation Actions (NAMAs) the country has made a strong start. Every other sectorial agency, ministry and regional government has a role to be played in addressing a coherent response to climate change (CRGE, 2011).

Report by Wolde-Georgis, *et al*. (2000) highlighted the strengths and weaknesses of the Ethiopian government's response to El Niño-related climate impacts. The authors explained that the recurrence of drought in Ethiopia has led to the accumulation of experience in disaster response. The NMSA has developed an effective methodology of forecasting by analogy, which is being used up to now. The response side has also led to the creation of a strong institution such as the DPPC (Disaster Prevention and Preparedness Commission) with a department of early warning that works very closely with the Ministry of Agriculture and the NMA. The DPPC has accumulated experiences to provide early warning and effective response to disasters.

According to NMA (2007) there are already a number of existing national policy initiatives, sartorial policies, programmes and strategies that may directly or indirectly address climate change adaptation towards the impact of climate change. Hence, Plan for

Accelerated and Sustainable Development to end Poverty (PASDEP), Environmental policy of Ethiopia, Agriculture and rural development policy and strategy, Water resources management policy, Health sector development policy and program, National Policy on Disaster Prevention and Preparedness (NPDPP), National policy on biodiversity conservation and research, Science and technology policy, Population policy and National agricultural research policy and strategy are the most relevant policy and program documents which have relevance for climate change adaptation.

2.4 Emission Scenarios in Climate Change

According to IPCC (2007) the emission scenario for climate change is based on Special Report on Emission Scenarios (SRES). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socioeconomic, demographic and technological change serve as inputs to many recent climate change vulnerabilities and impact assessments.

A1 scenario is based on the storyline of a situation whereby, rapid and successful economic development in which regional average income per capita convergence- current distinctions between "poor" and "rich" countries which eventually dissolve. A2 scenario compared to the A1 storyline is characterized by lower trade flows, relatively slow capital stock turnover, and slower technological change. Accordingly to A2 scenario, economic growth is uneven and the income gap between now-industrialized and developing parts of the world does not narrow, unlike in the A1 and B1 scenario families (IPCC, 2007).

Explained by IPCC (2007), the central elements of the B1 future are a high level of environmental and social consciousness combined with a globally coherent approach to a more sustainable development. In the B1storyline; governments, businesses, the media, and the public pay increased attention to the environmental and social aspects of development. Technological change plays an important role although the storyline does not include any climate policies, to reflect the SRES terms of reference. The B2 world is also one of increased concern for environmental and social sustainability compared to the A2 storyline.

With respect to alternative energy supply technologies, the A1B scenario group assumes a "balanced" approach, in which none of the technologies mentioned under other scenario gain an overwhelming advantage. This scenario group includes the A1B marker scenario developed using the AIM model (Jiang *et al.,* 2000).

2.5 Approaches Used to Assess Impact of Climate Changes on Agriculture

There are different approaches used to assess the impacts of climate changes on agriculture. Generally speaking there are two major categories of these approaches- namely partial and general equilibrium approaches. The partial equilibrium approach is based on the assumption of absence of interactions among economic sectors in analyzing the portion of the overall economy whereas in general equilibrium approach, the scope is wide and aimed to capture all sectors in the economy.

There are three basic partial equilibrium approaches which have been developed to assess the impacts of climate change on agriculture. These are crop simulation models, Agro-ecological zone models, and Ricardian models (Mendelsohn and Dinar, 1999). Hence, as per the relevance to this study, the three types of the partial equilibrium approaches are discussed in the following sections.

2.5.1 Agro-Economic models (Crop simulation models)

The crop simulation approaches combines the result from detailed experiments of crops with the expected yields from the crop. In this model, the emphasis is on simulation of crop and farmer response through modeling to determine the response of specific crops and crop varieties to different climatic and other conditions. Among others, under this approach activities undertaken as farm managements can be included in the models, for example, modelling the impacts of changing timing of field operations, crop choices, adding irrigation (Adams, 1999; Adams *et al.,* 1998a; Schimmelpfenning *et al.*, 1996).

In this approach, the changes in yields are entered into economic models that predict aggregate crop outputs and prices. Accordingly, Computable General Equilibrium (CGE) models, other partial equilibrium models and basic linked system approach are among the models used along with agro-economic approach. For instance, economic impacts (e.g. changes in acreage, supply by crop and region, as well as resulting changes in prices) are then estimated by incorporating yield estimation results from crop simulation models. For example from GCM forecasts into economic models of the agricultural sector (Adams, 1999, Adams *et al*., 1998a), cited by Nhemachena (2010).

The following are among major strength of agro-economic models, such models allow for detailed understanding of the biophysical responses, as well as adjustments that farmers can make in response to changing climatic and other conditions (Adams, 1999; Adams *et al.,* 1998a; Schimmelpfenning *et al*., 1996). Economic models can estimate changes in clearing prices that can be translated into aggregate changes in well-being for consumers and producers (Adams, 1999; Adams *et al*., 1998a). As a result it is possible to identify the gainers and losers from changing climate conditions, and the distribution of the impacts. Such approach indicates the various technological and adaptation options that would offset the negative effects of climate change and positively increase yields. For more recent agronomic approaches make use of new global databases so that no need to rely on farm level experiments, and have no problem with using advanced technologies. When combined with agricultural sector models, these approaches can present some types of autonomous adaptation triggered by price changes (Nhmechena, 2010).

Among the limitations of agro economic models, adaptations included in agronomic models fail to account for economic considerations and limitations in human capital and other resources that affect actual farm-level decisions (Mendelsohn, 2000). Incase if the economist fails to correctly anticipate the potential farmer adjustments and adaptations, the estimates might be biased and as the result, there are chances for either overestimating the damages or underestimating the potential benefits of climate change (Adams, 1999). Furthermore, crop simulation models fail to account for the diversity of factors that affect production in the field (Adams *et al*., 1998a).

These models are usually associated with very high cost implications (for data collection) (Mendelsohn, 2000; Adams, 1999). As the result, it can make difficult to implement such models in context of poor and developing countries. The consequence for this eventually leads to the dependency of developing countries on experiments conducted in developed countries as the last and only option.

The agronomic models have historically ignored the adoption of new technologies and most of them impose climate change scenarios on current agricultural systems (Mendelsohn, 2000). As a result of this limitation, the impact of climate change does not materialize for decades and by the time the climate actually changes, the farming systems could have changed from their current form. For developing countries like Africa, modelling the adoption of new technologies and the transition from low input labour intensive agriculture to high input modern farming is particularly among essential aspects. The historical ignorance by these models leads to the lack of concerns on scope of assumptions to be made regarding baseline scenarios; for which these in turn leads to limit of scope on concerns regarding the speed of transition of climate change impacts (Nhemachena, 2010).

2.5.2 Agro-Ecological Zone Models

The Agro-Ecological Zone (AEZ) model uses detailed information about climate and soil conditions, crops and technologies to measure climate sensitivity of simulated crop yields. This model is also called crop suitability approach. This is due to the fact that the method used to assess the suitability of various lands and biophysical attributes for crop production. Under this approach, it further enables the identification and distribution of potential crop producing lands through the use of AEZ data on crop characteristics, existing technology, and soil and climate factors, as determinants of suitability for crop production (FAO, 1996). The model also includes climate as one determinant of agricultural land suitability for crop production so that it can be used to predict the impact of changing climate variables on potential agricultural outputs and cropping patterns.

Compared to the other models which are widely used, AEZ model has some of the strengths over them. One of an important strength of the AEZ model is that, the widespread applicability in developing countries, where little climate research has been done, and where data constraints may make the use of other methods difficult. The AEZ model can simulate the impacts of changing precipitation and cloud cover on potential crop production and to a lesser extent, the impacts of temperature changes. Another advantage of the AEZ model is that with full knowledge of the potential impacts of future technology and genetic strains on specific parameters, modelling of future climate sensitivities can be done based on detailed Eco physiological relationships (Mendelsohn, 2000).

Among main limitations of this method, it is not possible to predict the final outcomes without explicitly modeling all relevant components. It is also difficult to build a general model that will predict actual yields across locations, even with relatively simple agronomic systems. To address this problem the AEZ method compares simulated yields against reported yields and substitutes field data where there are major differences (Güther *et al.*, 2002; Mendelsohn, 2000), cited by Nhemachena (2010).

Although the AEZ model was not designed to perform economic analysis, economic variables may be linked into it through a linear optimization component. The inclusion of new technologies over time would have to be modeled and farmers' economic behavior would have to be integrated into the model. A serious new investment would be required for the AEZ model to be used as a predictive device in researching climate change (Molla, 2009).

2.5.2.1 Ricardian cross-sectional approach

The Ricardian model analyses a cross section of farms under different climatic conditions and examines the relationship between the value of land or net revenue and agro-climatic factors (Mendelsohn *et al*., 1994). The most important advantage of the Ricardian model is its ability to incorporate private adaptations. The farmers' response involves costs, causing economic damages that are reflected in net revenue. Thus, to fully account for the cost or benefit of adaptation, the relevant dependent variable should be net revenue or land value (capitalized net revenues), and not yield. Accordingly, the Ricardian approach takes adaptation into account by measuring economic damages as reductions in net revenue or land value induced by climatic factors. The Ricardian approach has been applied in the United States (Mendelsohn *et al*., 1994) and in some developing countries: South Africa (Gbetibiuo and Hassan, 2005; Deressa *et al.*, 2005; Benhin , 2006), Cameron (Molua and Lambi, 2007), Kenya (Kabubo-Mariara and Karanja, 2006), Zimbabwe (Mano and Nhemachena, 2007; Zivanomoyo and Mukarati, 2013), Nigeria (Fonta *et al*., 2011 and Ajetomobi *et al*., 2011) and Ethiopia (Deressa, 2007; Deressa, *et al.,* 2009; Deressa and Hassan, 2009; Molla, 2009 and Belay, 2012) to examine the economic impacts of climate change on agriculture.

The Ricardian approach regresses farmland values against climate, economic and other factors to estimate the economic impacts of climate change and other factors on farm performance (Mendelsohn and Dinar, 1999; Mendelsohn, 2000; Mendelsohn *et al.*, 1994, 1996; Adams *et al.*, 1998a). The assumption is that in a well-functioning market system, the value of a parcel of land should reflect its potential profitability. As the result it should be possible to estimate a meaningful climate-land value relationship by specifying a multivariate regression model whereby the estimated coefficients for the climate variables would reflect the economic value of climate in agriculture, holding other factors constant.

Among the areas of the strengths of the Ricardian cross sectional approach; the approach automatically incorporates farmer adaptation by including decision making changes that farmers would make to tailor their operations to a changing climate. For instance, an important example of farmer adaptation strategies is crop/crop variety choice where a particular crop will become the optimal choice depending on the effects of a warmer climate. Optimal crop switching is, therefore, an important component of measuring the agricultural impact of climate change (Mendelsohn *et al*., 1994, 1996; Mendelsohn and Dinar, 1999). Given the fact that this approach has the above strengths; it has also possessed some of the limitations which are detailed in the following paragraphs.

There is lack of the reliable data, particularly in developing countries (Mendelsohn and Dinar, 2005; Adams, 1999). It is also difficult to control for all variables that might affect the estimated relationship between climate and agricultural production using evidence from cross section data. For example, some variables might be included in the model but poorly measured, or might be excluded for lack of data (Reilly, 1999). Trying to control for spatial variations in other physical (e.g. variations in soils across landscape), economic (e.g. proximity to markets, labour and technology) and policy variables (e.g. trade restrictions, subsidies and taxes) (Mendelsohn and Dinar, 2005).

The fact that the model assumes constant prices is another drawback of the Ricardian approach (Cline, 1996). The inclusion of price effects into it is problematic. The Ricardian approach is weaker in this respect (Mendelsohn *et al*., 1994). Existing cross-sectional studies depend on a cross section within a country where there is little price variation across farms, with the result that the studies have not been able to estimate the effects of prices. The assumption of constant prices in Ricardian studies leads welfare calculations to be biased (Cline, 1996). The cross-sectional approach only measures the loss as producer surplus from climate changes. It takes no notice of price change that would occur if supply changed. As a result, it omits consumer surplus from the analysis. The result, according to Mendelsohn (2000), is that damages are underestimated (omit lost consumer surplus) and benefits are overestimated (overstate the value of increased supply). Although Ricardian approach does not address the problem of inclusion of price effects, Mendelsohn *et al.* (1994) contend that the bias is less than seven percent.

The arguments for the use of constant price are that, the difficulty to include price effects using any method (Mendelsohn and Tiwari, 2000). First, it is the global markets that determine the prices of most crops. Therefore, prediction of what would happen to each crop requires global crop models. It is difficult to predict what will happen to the global supply of any single crop in a new world climate since global crop models are poorly calibrated. Secondly, Reilly *et al*. (1994) pointed out that the range of warming expected in the next century has only a small effect on aggregate supply. This result is obtained from the few global analyses completed so far. Finally, if aggregate supply changes by only moderate amount, the bias from assuming constant prices is relatively small. Thus, Mendelsohn and Tiwari (2000) argue that keeping prices constant is justified because it does not pose a serious problem in using the model. Apart from the above mentioned limitations, the model does not take into account the fertilization effect of carbon dioxide concentrations is another weakness of the model (Cline, 1996; Mendelsohn and Tiwari, 2000).

However, provided that study which does control for relevant variables and other factors in the model for enabling improved accuracy of estimation results, it is possible to indicate way forwards and possible policy implications as indicated in those above mentioned literatures in context of both developed and developing countries. Therefore, despite the fact that the model has all these limitations, it is still the cross sectional tool to analysis the impact of climate change on agriculture in general and crop production in particular (Deressa, 2007; Deressa and Hassan, 2009).

2.6 Empirical Studies Assessing Impacts of Climate Change on Agriculture

2.6.1 Empirical studies on Climate Change Impacts else where

Study by Gbetibouo and Hassan (2005) employed a Ricardian model to measure the impact of climate change on South Africa’s field crops and analyzed potential future impacts of further changes in the climate. A regression of farm net revenue on climate, soil and other socioeconomic variables was conducted to capture farmer-adapted responses to climate variations. The analysis for their study was based on agricultural data for seven field crops (maize, wheat, sorghum, sugarcane, groundnut, sunflower and soybean), climate and soil data across 300 districts in South Africa. Most importantly the findings indicated as production of field crops was sensitive to marginal changes in temperature as compared to changes in precipitation. Temperature rise positively affects net revenue whereas the effect of reduction in rainfall is negative. The study also highlights the importance of season and location in dealing with climate change which has further connection with the need for agro ecology/location specific adaptation strategies. The results of the simulations of climate change scenarios indicated as many impacts that would induce (or require) very distinct shifts in farming practices and patterns in different regions where by an lead indicator the possibility of complete disappearance of some field crops from some region.

Deressa *et al*. (2005) analyzed the impact of climate change on South African Sugar cane production under irrigation and dry land conditions using a Ricardian Model. They used time series data of 21 years (1977 – 1998) pooled over 11 districts. The result from their analysis showed the nonlinear impact of climate change over net revenue per hectare of sugar cane in the country. The study further showed the more sensitivity of the net revenue from the crop per hectare to change in temperature as compared to precipitation. Finally the study confirmed that Irrigation did not proved to provide an effective option for mitigating climate change damages on sugarcane production in South Africa.

Kabubo-Mariara and Karanja (2006) measured the economic impact of climate on crops in Kenya by using Ricardian cross sectional approach. The result from estimated seasonal Ricardian showed that climate affects crop productivity, presence of a non-linear relationship between temperature and revenue on one hand and between precipitation and revenue on the other. Further, estimated marginal impacts suggested that global warming is harmful for crop productivity as indicated by the authors. Finally their result indicated as predictions from global circulation models confirmed global warming will have a substantial impact on net crop revenue in Kenya and the temperature component of global warming is much more important than precipitation.

Kurukulasuriya and Mendelsohn (2008) applied a Ricardian analysis of the impact of climate change on African cropland. The study examined the impact of climate change on cropland in Africa, using a Ricardian cross-sectional approach. Relying on farm data from an 11-country survey of over 9500 farmers, annual net revenue was regressed on climate and other variables. The study confirmed that current climate affects the net revenues of farms across Africa. Furthermore the result from the study showed that applying those results to possible future climates revealed that dry land farms are especially climate sensitive. They Authors indicated that even as early as 2020, change could have strong negative impacts on currently dry and hot locations. By 2100, dry land crop net revenues could rise by 51% if future warming is mild and wet but fall by 43% if future climates are hot and dry. The crop net revenues of currently irrigated farms are likely to be least affected.

Fonta *et al*. (2011) analyzed the impact of climate change on plantation agriculture in Nigeria using the Ricardian approach that captures farmer adaptations to varying environmental factors. The study used data collected from 280 farm households in seven different agro-ecological zones of Nigeria. The results from their study suggested that variables captured in the model have a significant impact on the net crop revenue per hectare of farmlands under Nigerian conditions. As indicated from their finding, ; seasonal marginal impact analysis indicates that increasing temperature during summer and winter would significantly reduce crop net revenue per hectare whereas marginally increasing precipitation during spring would significantly increase net crop revenue per hectare. Moreover from the predicted future condition, the net crop revenue impact of predicted climate scenarios from three models (CGM2, HaDCM3 and PCM) for the years 2020, 2060 and 2100 suggested drastic decline in future net revenue per hectare for plantation crops in the country. The authors finally noticed that those marginal impacts are not uniformly distributed across the different agro-ecological zones in Nigeria.

2.6.2 Empirical studies on Climate Change Impacts in Ethiopia

Deressa and Hassan (2009) analyzed the impact of climate change on crop farming in Ethiopia using the Ricardian approach that captures farmer adaptations to varying environmental factors. They collected data from farm households in different agro-ecological zones of the county; net crop revenue per hectare was regressed on climate, household and soil variables. Their results showed that these variables had a significant impact on the net crop revenue per hectare of farmers under Ethiopian conditions. Moreover their result revealed that the net crop revenue impact of predicted climate scenarios from three models (CGM2, HaDCM3 and PCM) for the years 2050 and 2100 indicated that there would be a reduction in crop net revenue per hectare by the years 2050 and 2100. Furthermore, the reduction in net revenue per hectare by the year 2100 would be more than the reduction by the year 2050 indicating the damage that climate change would pose increases with time unless the negative impact is abated through adaptation. Additionally, results indicated that the net revenue impact of climate change is not uniformly distributed across the different agro-ecological zones of Ethiopia.

Molla (2009) by using the Ricardian model assessed the economic impact of climate change on crop farming activities in Nile basin. The data used for the study was generated from 20 districts which included over 975 farmers. In his study, Annual crop net revenue was regressed on climate and other variables. The results from the analysis indicated as marginal increase in annual increase in temperature will have a positive impact on annual crop net revenues for irrigated farms, but a negative impact for dry land farms and farms that represent Nile basin of Ethiopia while in contrast, marginal impact of increasing precipitation will increase crop net revenue for both irrigated and dry land farms. The study further examined the impact of uniform climate scenarios on the crop net revenue per hectare of farmers. Accordingly, crop net revenues will fall for all farms under the four uniform climate scenarios (+2.5^{0}c, +5^{0}c, -7% and -14% temperature and precipitation levels) except irrigated ones for a 2.5^{0}C increase in temperature. Finally the study concluded as farmers in the study area were aware of climate change and adapting to the change in the study area.

Yumbya *et al*. (2011) assessed the effect of climate change on teff in Ethiopia as implications for food security in the country under the case studies from three districts representing different agro ecologies. The study aimed at assessing the likely effects of climate change on distribution and genetic diversity of teff in order to guide scientific, policy and farm level interventions as well as draw inferences and implications for food security. The methodology involved was the use of Global Positioning System (GIS), climate change modeling and socioeconomic processes to examine the spatial implications of climate change on the areas suitable for teff production with consequences of loss of genetic diversity and crop productivity. As the study showed there was a non-linear relationship between suitability indices, the output of spatial analysis and teff yield data collected from diverse ecological zones as the basis for countrywide crop yield analysis for both current and future climate scenarios. Results from their study of a socioeconomic and market survey to assess the economic implications of loss of teff productivity revealed that in the future (~2050); the teff production area will drop by 236,976.65 Km^2 which is about 24% of the climatically suitable area. Suitability index and the actual crop yield data showed a strong positive correlation of 74%. Moreover, the analysis revealed a severe predicted drop in teff yield of 0.46 tons/ha and above by the year (~2050) using projected future conditions. The expected loss of crop production at the national level is 1 190 784.12 tons.

Study by Belay (2012) analyzed observed climate variability, downscaled future projection (2046–2065 periods) with reference to base line data from years 1981-2009 by using Self-Organizing Map Downscaling (SOMD) technique and Ricardian approach in order to analysis climate variability and its economic impact on Agricultural crops in Arsi

Nagele district located in central rift valley of Ethiopia. Moreover, the study was extended to capture the corresponding adaptation strategies employed by farmers in response to climate variability in the study area. The result obtained from the study indicated that climate variability is expected to be observed both in Arsi Negle and Langano stations for the projection period from 2046 to 2065. The result from Ricardian model indicated that net revenue that considered climate, socio-economic and soil variables was found to have a significant impact on the farmers' net revenue per hectare. Furthermore, result from marginal analysis indicated that an increase in temperature during the main rainy and dry seasons marginally reduced the net revenue by 5179.65 and 704.19 Birr per hectare respectively. Whereas an increase in temperature marginally during the short rainy and autumn seasons was found to increase the net revenue per hectare by 1081.81 and 1542.65 Birr respectively, and an increasing precipitation marginally during the main rainy and dry seasons reduced the net revenue per hectare by 1184.00 and 328.90 Birr respectively. The study based on the data from sample district concluded as farmers in the study area are already aware of the occurrence of climate variability and changes, and hence, devised adaptation strategies in response to the change and variability in climate.

2.7 Empirical Studies Assessing Perceptions and Adaptations to Impacts of Climate Change on Agriculture

2.7.1 Empirical Studies on Perception and Adaptations to Climate Change Impacts else where

Lema and Majule (2009) carried study to understand local communities' perceptions on climate and variability issues and there by established its impacts and adaptation strategies within agricultural sector in two villages of Kamenyanga and Kintinku of Manyoni district, central Tanzania. They used using different Participatory Research Approaches including, focus group discussions and household questionnaires. Findings from their study showed that local people perceived changes in rainfall and temperature and the changes have affected crops and livestock in a number of ways resulting in reduced productivity. Furthermore, empirical analysis of rainfall suggested decreasing rainfall trend between 1922 and 2007 whereas mean maximum and minimum temperature increased by 1.9 and 0.2°C respectively. They also realized that the average annual temperature increase was 0.7°C between 1984 and 2004.

Mutekwa (2009) assessed climate change and weather issues of relevance to smallholder farmers’ activities, views and knowledge about climate change, its impacts and adaptation strategies in smallholder farmers in Zimbabwe. The study identified relevant adaptation strategies to the farming community which includes strengthening and improving indigenous land and water management practices, use of decision support tools, such as seasonal weather forecast data, growing drought resistant crops, improving indigenous animal breeds, and development of irrigation infrastructure. Finally the author indicated the following as the way forward; need to nonscientist farmers about climate change and design adaptation strategies that take into cognizance existing local level knowledge and practices on land and water management, the need to avail agricultural research results relevant to the small holder farmers and train them on how to use the results to make informed on-farm investment decisions.

Hassan and Nhemachena (2008) analyzed the determinants of farm-level climate adaptation measures in Africa using a multinomial choice model fitted to data from a cross-sectional survey of over 8000 farms from eleven African countries. The results of their study indicated that specialized crop cultivation (mono-cropping) is the agricultural practice most vulnerable to climate change in Africa. Warming, especially in summer, poses the highest risk. It encourages irrigation, multiple cropping and integration of livestock as indicated by the investigators. Moreover, increased precipitation reduces the probability of irrigation and will benefit most African farms, especially in drier areas. They also highlighted the importance of better access to markets, extension and credit services, technology and farm assets (labour, land and capital) as these are critical for helping African farmers adapt to climate change.

Moreover, the same authors: Hassan and Nhemachena (2008) examined farmers' adaptation strategies to climate change in Southern Africa based on a cross-section database of three countries (South Africa, Zambia and Zimbabwe). Their study describes farmer perceptions to changes in long-term temperature and precipitation as well as various farm-level adaptation measures and barriers to adaptation at the farm household level. They used a multivariate discrete choice model to identify the determinants of farm-level adaptation strategies and the result from the study confirmed as access to credit and extension, and awareness of climate change are some of the important determinants of farm-level adaptation.

Kurukulasuriya and Mendelsohn (2008) investigated crop switching as a strategy for adapting to climate change and examined the impact of climate change on primary crops grown in Africa. They used an innovative approach that bridges the gap between agro-economic and traditional Ricardian models which is a Structural Ricardian model. The model first captures the type of crop a farmer would select and then examines the conditional net revenue of that crop. They estimated the model using a sample of over 5000 farmers across 11 countries in Africa. The result of their analysis showed that farmers shifted the crops they plant to match the climate they face. Hence, according to the authors' studies that fail to account for crop switching will overestimate the damages from climate change and underestimate the benefits.

Gbetibouo *et al.* (2010) examined climate adaptation strategies of farmers in Limpopo Basin of South Africa by using a multinomial logit analysis. The descriptive analysis from their survey showed that, although many farmers noticed the long- term changes in temperature and precipitation, most could not take remedial action. Moreover, they found as access to water, credit, and extension services and off farm income and employment opportunities, tenure security, farmers' asset base and farming experience are key to enhance farmers' adaptive capacity in the study area.

2.7.2 Empirical Studies on Perception and Adaptations to Climate Change Impacts in Ethiopia

Drought impacts, drought risk management, and resulting drought resilience in Awash River Basin of Ethiopia was analyzed by Conrad *et al*. (2010) based on socioeconomic data collected from 43 randomly selected Peasant Associations (PAs). They found that severe drought periods have led to a significant depression of crop yields. Moreover in the study area it was indicated as Ex-ante adaptation strategies were widely practiced in the Awash River Basin and include the storage of crop residues as fodder for livestock, the rearing of drought tolerant livestock, mixed cropping, the use of short duration crop varieties, and the adoption of soil and water conservation practices. Ex-post coping strategies utilized to manage the consequences of drought in the study area include the sale of assets and the reliance on consumption loans and support offered by informal networks.

As far as production efficiency associated to change in climate is concerned the study by Alem *et al.* (2010) revealed that rainfall patterns affect fertilizer use decisions by farmers in Ethiopia. The same study by Alem *et al.* (2010) implies that climatic factors do affect the production efficiency as these factors influence the amounts of inputs used in production.

Using Tobit model and Cobb-Douglas production function, Tesso *et al.* (2012) analyzed the impact of adaptation to Climate Change on food production and provided an estimation of impact of climate change on the availability of food for households in North Shewa Zone of Ethiopia. The finding from their study showed that based on the time series analysis of climate variables, climate change has exhibited a serious impact on the food production level of farmers. They further found that climate change and adaptations to climate change have significant impact on farm productivity where as extension services, access to credit, indigenous early warning information, farm size, ownership of perennial crops, non-farm engagement, agro-ecological location and information on future climate changes affect adaptation positively and significant.

Deressa (2007) investigated on effects of climatic conditions and agro-ecological settings on the productive efficiencies of small-holder farmers in Ethiopia. The study argued that the adaptation measures farmers take to reduce the negative impacts of climate change do affect farmers' efficiency of production. He followed two steps to understand how climatic factors especially long term average seasonal rainfall and temperature; and agro-ecological settings affect production efficiency in Ethiopian agriculture. In the first step, he employed the stochastic frontier approach to analyze the farm level technical efficiency. In the second step, the tobit regression model was adopted to analyze how climatic and agro-ecological settings affect efficiency scores derived from the first step. Results from his study of the first step indicated that the surveyed farmers have an average technical efficiency of 0.50; with significant output elasticity of labour, draft power and tractor, whereas Results from the tobit regression model showed that soil types, run-off, seasonal climatic conditions and agro-ecological settings affect technical efficiency in Ethiopian agriculture.

Salvatore and Marcella (2011) investigated the impact of climate change adaptation on farm households' downside risk exposure (e.g., risk of crop failure) in the Nile Basin of Ethiopia. Their analysis relied on a moment based specification of the stochastic production function. They estimated a simultaneous equations model with endogenous switching to account for the heterogeneity in the decision to adapt or not, and for unobservable characteristics of farmers and their farm. The result from their study indicated as climate change adaptation reduces downside risk exposure, i.e., farm households that implemented climate change adaptation strategies get benefits in terms of a decrease in the risk of crop failure; farm households that did not adapt would benefit the most in terms of reduction in downside risk exposure from adaptation; and there were significant differences in downside risk exposure between farm households that did and those that did not adapt to climate change. The analysis also showed that the quasi-option value, that is the value of waiting to gather more information, plays a significant role in the farm household's decision to adapt to climate change. Farmers that are better informed may value less the option to wait to adapt, and so are more likely to adapt than other farmers.

Tazeze *et al.* (2012) identified the determinants of farmer's choice of adaptation strategies to climate change in the Babile district of Eastern Ethiopia. They used Multinomial logistic regression to analyze the factors influencing households' choice of adaptation strategies to climate change. The result from their analysis showed that sex of the household head, age of the household head and education of the household head, family size, livestock ownership, household farm income, non/off farm income, access to credit, distance to the market center, access to farmer-to-farmer extension, agro ecological zones, access to climate information, and extension contact have a significant impact on climate change adaptation strategies.

By using a multinomial logistic regression model, Tafesse *et al.* (2013) identified the factors affecting choice of adaptation strategies under changing climate represented from eastern Hararghe zone of Oromia Regional state and Dire Dawa administration, Ethiopia. The study included 330 household heads drawn randomly from the two different agro ecologies. Sex of household head, family size, Education status of household head, agro ecology, distance to market, cultivated land, credit access, decreasing precipitation and changes in temperature are among dictating factors in determining choice of adaptation strategies under climate change.

2.8 Conceptual Framework

Fig. 1 shows the interrelation ships that do exist between various factors that have assumed to influences climate change impacts in crop production with their directions of relationship. For instance, perception of farm households on climate change arises from multiple directions. This is because the household's socioeconomic factors can determine awareness level on climate change and on the other side; the severities of climate change by itself provide lessons for households to perceive the change. In similar way the nature of the direction of relationship applies for the case of adaptations.

Studies targeted the assessment of climate change impacts showed that climate component, biophysical and socioeconomic characteristics of households plays the important roles in addressing the levels of economic impacts on agriculture in general and on crop production in particular (Deressa and Hassan, 2009; Kurukulasuriya and Mendelsohn, 2008).

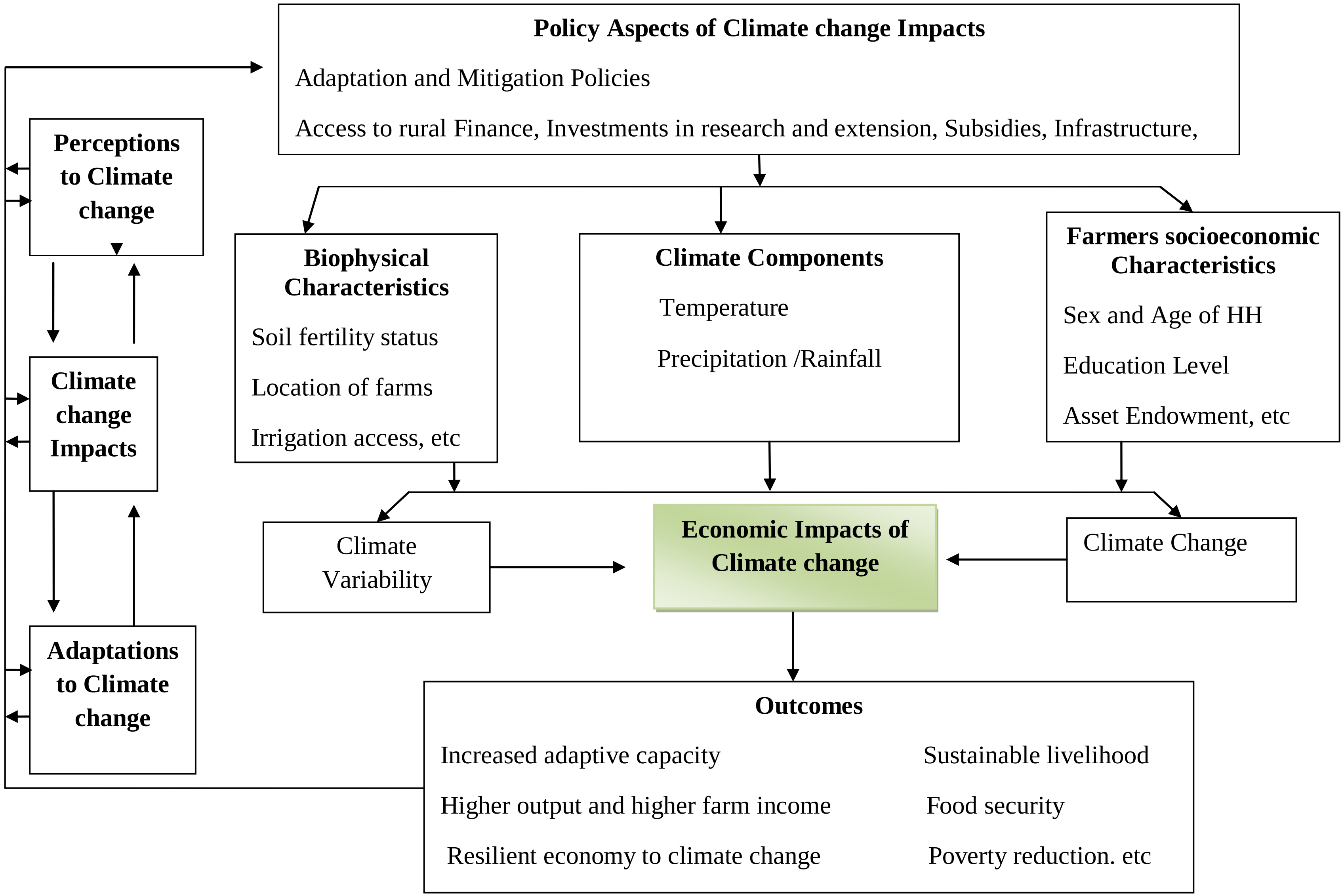
Policy Aspects of Climate change Impacts
Adaptation and Mitigation Policies
Access to rural Finance, Investments in research and extension, Subsidies, Infrastructure,
Perceptions to Climate change
Biophysical Characteristics
Soil fertility status
Location of farms
Irrigation access, etc
Climate Components
Temperature
Precipitation /Rainfall
Farmers socioeconomic Characteristics
Sex and Age of HH
Education Level
Asset Endowment, etc
Climate change Impacts
Climate Variability
Economic Impacts of Climate change
Climate Change
Adaptations to Climate change
Outcomes
Increased adaptive capacity
Sustainable livelihood
Higher output and higher farm income
Food security
Resilient economy to climate change
Poverty reduction. etc

Figure 1: Conceptual framework of Ecomoncs of Climate change Impacts in Crop production (Source: Modified from Carney (1998))

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Description of the Study Area

Lume and Gimbihu districts are known for teff production and their representation of different agro-ecology are among the reasons for selection of these districts for this study. Lume district is located at 70km from Addis Ababa in East Shewa zone in the Oromia Regional State. The district is situated between 8°12' to 8°5' N latitude and 39°01' to 39°17' E longitude. Lume district has an area of 730.03 km^2 and it is the second smallest district in East Shewa zone. The District altitude ranges from 1500 to 2300 Meters above Sea Level (m.a.s.l), except for a small portion in the northern part, which is over 2300 m.a.s.l in altitude. The major soil type of the district is Vertisols (Addis *et al*., 2001). Lume is bordered on the south by the Koka reservoir, on the west by Ada'a Chukala, on the northwest by Gimbichu, on the north by the Afar Region and on the east by Adama (Fig.2). Mojo is the capital of the district and there are other towns such as- Ejersa, Ejere and Koka.

The mean monthly temperature of the area ranges from 22^0C to 34 ^{0}C. A survey of the land in the district shows that 54.3% is arable or cultivable, 3% pasture, 2% forest, and the remaining 20% is considered degraded or otherwise unusable (CSA, 2005).

The major crops grown in Lume district includes; teff, wheat, barley, sorghum and maize from cereals whereas; lentils, horse beans, chick peas, field peas, vetch and haricot beans are among the pulses crops. Application of manure, crop rotation, fallowing, plant residue and chemical fertilizers are methods of maintaining soil fertility in the district. The average farm size in hectares and number of farm oxen per household were 3.75 and 2.12 respectively.

Gimbichu is also among one of the woredas/district in east shewa zone in Oromia Regional state of Ethiopia, Chefe Donsa is the administrative center located 35 km east of Debre Zeit, about 40 km northeast from Addis Ababa and its geographic location is at $08^0$57'15" North latitude and $39^0$06'04" East longitude. Gimbichu is bordered by North Shewa in the north and west, Amhara Regional State in the east and northeast, Ada'a Liben in the south, Akaki in the south west and Lume in the south east (Fig. 2). The district is with an area of 754.31 km^2 and it is the 3rd smallest district in East Shewa zone. The 2007 national census reported a total population for this woreda was 86 902, of whom 45 126 were men and 41 776 were women; 6 330 or 7.28% of its population were urban dwellers.

The altitude of the district is about 2450 m.a.s.l and most parts of the district are over 2300 m. Its textural class is Heavy Clay and Soil Types was Eutric Vertisol, Vertisols cover about 14.6% of the district. The district is with hot to warm sub-humid climate (NMA, 2007). The area is characterized by mean annual rainfall of 900 mm and temperature of 17 ^{0}c (Teklu *et al*., 2006).

In Gimbichu district, cereals constituted 74% of the cultivated land and 88.7% of the total production. Applications of plant residue and chemical fertilizers are methods employed to maintain soil fertility in the district. A survey of the land in Gimbichu shows that 37.6% is arable or cultivable, 14.2% pasture, 2.6% forest, and the remaining 45.6% is considered degraded or otherwise unusable. Lentils, chickpeas and fenugreek are important cash crops.

Table 1 shows the area cultivated, production and yields of major cereals cultivated in east Shewa Zone for *meher* production season of 2011/12, where the two districts are among the major contributors. *Meher* season is the summer season in the country with relatively heavy rain fall which includes June, July and August months. The table shows the highest area allocated and cultivated for teff crop as compared to other cereals in the zone for the production season. However, compared to the cereals below, except of Sorghum, the yield in quintal per hectare (qt/ha) for teff is relatively less than yield obtained from other cereals.

Table 1: Area, production and yield of cereal crops for private peasant holdings for meher season 2011/12 in East Shewa zone

Cereals	Number of holders	Area in hectare	Production in quintal	Yield (qt/ha)
Teff	197 091	183 272.6	2 573 358.3	14.0
Barley	59 194	10 958.5	209 282.1	19.1
Wheat	120 104	55 665.6	1 340 232.6	24.1
Maize	194 256	8 9730.7	3 089 003.6	34.4
Sorghum	27 752	6 356.5	76 478.5	12.0

***(*Source: CSA, 2012)**

Fig. 2 further shows the percentages of teff under share of cultivated area compared to other major cereals in east Shewa Zone for the *meher* production season of 2011/12**.**

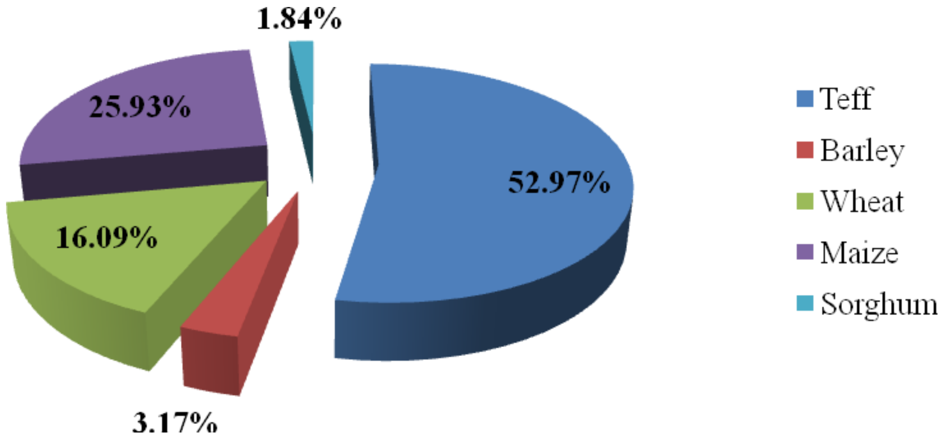

Figure 2: Area under major cereal crops in east Shewa zone for 2011/12 meher production season in percentage. (*Source:* Own computation from CSA, 2012)

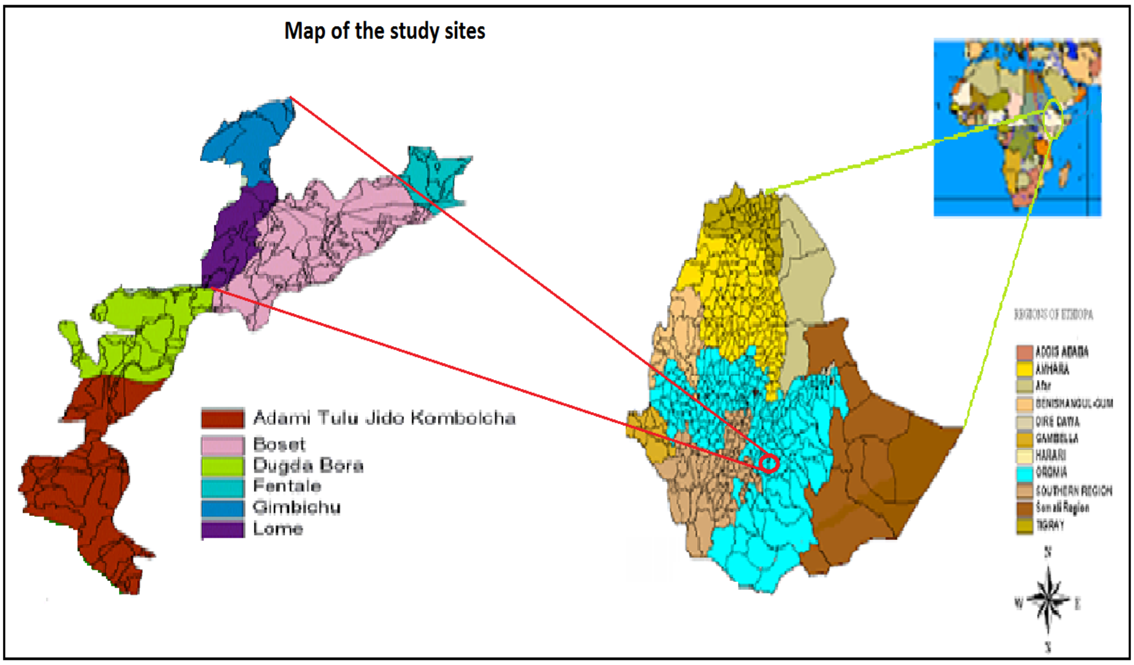

Figure 3: Map of the study sites (Lume and Gimbichu districts)

3.2 Research Design, Sampling Unit, Sample Size and Sampling Techniques

The research design for this study was a cross sectional study design. Multistage sampling technique was employed to address the objective of the research. The step involved the selection of the two districts purposely followed by the randomly selection of the representative PA's for each districts. At the next step, 150 respondents were randomly selected from the respective total number of households found in each Peasant Associations (PA's). However, with regards to appropriate sample size determination, initially, it was computed using the sample size determination formula, $\frac{Z\alpha_{/2}{}^{2} * P(1-P)}{e^2}$, where n= the total sample size, P= the proportion of the small holder farmers who grow teff for the season (in this case it is equal to 0.5 since among other factors that existed, the socioeconomic variations among the households don't known with exact value), e= the accepted level of error term. Hence, by applying this formula the total sample size was 382, however due to the fact that there were time and resource constraint; the study targeted 150 households who grow teff and which was drawn from the subset of 382 farmers through random sampling. It has to be noticed that the 150 sample respondents were within the 382 respondents and in which this in turn drawn from the total households found in the selected PAs

For the possible variations among sampled households in terms of agroecological locations, socioeconomic, demographic, soil and other sources of variations, stratification was considered. Hence, the importance of stratification was to capture the variability among the different agro ecological zones between the two districts and within each district. In the first stage, the woreda/district was classified as lowland (Kola), midland (woina-dega) and Highland (Dega). The two districts namely Lume and Gimbichu were selected and included in the study mainly due to the fact that the Ricardian model can be applied if there is a sufficient spatial variation in net revenue and climate variables across locations.

The agro-ecological zone currently used for agricultural planning and development in Ethiopia was developed by Hurni as part of the Soil Conservation Research Based on Project which was operational during 1987–1995 (Hurni, 1998). Based on this classification, the entire country falls into six major agro-ecological zones. These are *Bereha (* (desert), below 500 m.a.s.l.), *Kolla* (lowlands, 500–1 500 m.a.s.l.), *Weynadega* (midlands, 1 500 – 2 300 m a.s.l.) and *Dega* (highlands, 2 300 – 3 200 m.a.s.l.), *Highdega*

(3 200 – 3 700 m.a.s.l.) and *Wurch* (above 3 700 m.a.s.l.). Based on this classification of agro ecological zone of the country, the surveyed districts fall into two of these (*Dega and Weynadega*) so that the data could fit to the Ricardian model as variation in both net revenue and climate variables were expected.

At the first stage the two districts were selected. As further indicated in different literatures, the impact of climate change is likely higher in midland than highland, although teff crop varieties have wide range of adaptations. In order to capture this difference, 150 households were included in the study. Furthermore, these households were selected as the first criteria that they should be the one who grow teff for a long time in general and for the season 2012/13 in particular. Based on these selections with the proportion of 0.6 to 0.4, the two districts were allocated to the two different agro ecologies namely Lume district which represent midland altitude (60%) and Gimbichu district representing highland altitude (40%).

On the second stage, through acknowledgement of the variations in altitude within each districts', existing climate problem and variations, teff crop varieties grown and socioeconomic status the representative peasant associations within both districts were selected after discussion with both districts expert at office of Agriculture and rural development. Accordingly, from Lume district, out of the total 38 PAs', 9 PAs' were purposely selected. Similarly, 5 PAs' out of total 33 PAs' were selected from the Gimbichu woreda / district (see Table 2).

The farmers in each PA were then selected randomly from the list of household heads in each PAs'. Following the random sampling, however, a few farmers selected in the first place had no teff plot in the production year. As a result, there was an additional random selection made to replace the farmers who had no teff plot for the season 2012/13. In the random sampling process, both male and female household heads were included. Table 2 shows the allocation of the proportionate stratified sampling for the two study districts.

Table 2: List of PAs' in selected districts, population of households, sample size and number of enumerators involved in each PAs'.

Name of the District (*Woreda*)	Name of PAs'	Number of households	Sample size	Number of enumerators
Lume	Nannawa	467	9	1
	Kunche Dalota	285	6	
	Ejere Welkite	324	7	
	Dhaka Bora	754	15	1
	Sharra Dibandiba	600	12	
	Koka Negewo	309	6	2
	Ejersa Jero	1 774	35	
Gimbichu	Kersa Rega	962	16	2
	Lemlem Chefe	859	14	
	Menjikso Gora	480	8	
	Adadi Gole	627	11	1
	Haberu Seftu	673	11	
Total		**8 114**	**150**	**7**

3.3 Data Source and Data Collection Method

Data used for this research were obtained from both primary and secondary sources. Primary data were collected on the household socioeconomic and plot level soil types of the study districts whereas the climate data targeting the two districts were obtained from the National meteorological Agency (NME) head office and from Adama brunch as well. Hence, the study used plots level crops' net revenue and other variables for econometric estimation.

3.3.1 Climate data

Data on climate variables - temperature and rainfall used for each plot were obtained from the NMA. Both districts have their own meteorological stations. However, to increase the representativeness for the two districts, data from neighboring district station were used. Therefore, it is reasonable to use data from the nearest station to each plot to represent the long term mean of the climate variables. Accordingly for each surveyed PAs' in Lume the closest meteorological station data used were came from Mojo, Koka, Adami Tullu and Adama meteorological stations which covers an average of 37 and 25 years for temperature and rainfall respectively. The coverage of the data for Lume district ranges from 1964-2012 (temperature) and 1975 – 2012 (rainfall). Similarly for Gimbichu district, data from Chafe Donsa and Debrezeit metriological stations were used. On average 31 years temperature data and 42 years rainfall data were used for Gimbichu district as well. For all stations the data were collected and compiled from data obtained from Ethiopian NMA head office- Addis Ababa and Adama branch office. Despite the fact that there were limitations on stations reading of the data of climate variables for a few years, efforts were made to include long term climate variables data from each meteorological station to reflect the climate change rather than capturing the short term variability in the climate variables.

3.3.2 Socioeconomic data

The socioeconomic data were collected through a structured questionnaire survey. The survey covered a total of 150 households who have been growing teff for a long time and for the production season 2012/13 in particular. Hence, the questionnaire was targeted to households that have harvested teff crop and other major crops in 2012/2013 production season.

The pretest interview was conducted before the actual interviews, then the questionnaire was amended and data collectors/ enumerators who have better knowledge of the local tradition and language were trained before conducting the actual survey. Furthermore, research assistants, professionals and agricultural officers working in the study area were contacted for the detail understanding of the PAs' in each districts in terms of farm household aspects such as socioeconomic and topographical condition among others.

The questionnaire captured information on important variables required to calculate teff net revenues and to explain the variation in net revenues across the two study districts in the midland and highland agro-climatic zones. Other data on area planted, yields, input costs, output prices were collected to compute net revenue.

In general, the questionnaire had eight main parts. Part one focused on general information on household's characteristics- gender of household head, age of households, education, family size, and main activities of the household head. Moreover, farmers' access to credit and extension was also captured under this section. In part two, perception on climate change was highlighted. Though this part was not captured directly in specific objectives, the information was intentionally captured to observe the state of the perception by household due to the fact that for the household to deal with adaptation to climate change impact; perception is the starting point. Part three and four of the questionnaire focused on soil information, teff seed access, adaptation options farmers used and perceived hindrances to adaptations with specific to adaptations used for teff production. Part five and six of the questionnaire are about plot level information, farm and livestock assets owned by the respondent. These parts covered teff production (the yield and cost information) and other crops produced for the season under investigation.

The aim under these part of the questionnaire were to obtain detailed information at the plot level, on crop farming activities with respect to the type of crops grown in each plots' for the season, land tenure, GPS points for each plot to obtain plot based elevation and geographical coordinates namely altitude latitude and longitude, the area planted, the amount of teff harvested, sold, consumed and stored; and market price for each crop. In addition, related costs of seeds, fertilizer and pesticides, associated costs to band construction (if applicable for the plot), land renting, ploughing, planting, cultivation, weeding, harvesting, storage and transportation costs were collected. Finally, part seven and eight of the questionnaire were about off- farm income and asset based wealth of the household.

3.3.3 Soil data

Discussion was made with the soil and agronomic expert of each district on identification of the soil physical features in the PAs'. In addition, one soil labouratory assistant from Adama University, Assela campus was helped with the identification of the soil type. Then soil data regarding the physical aspect for each teff plot were obtained from the respondents and their response was compared with the observation undertaken on their plot. Hence, the soil data used for the study came from the survey as indicated under the third part of the questionnaire.

3.4 Data Analysis

3.4.1 The Ricardian approach: Theoretical background

The Ricardian model analyzes a cross section of farms under different climatic conditions to examine the relationship between the value of land or net revenue and the agro-climatic factors (Kurukulasuriya and Mendelsohn, 2008; Deressa *et al.*, 2005; Mendelsohn *et al.*, 1994; Nhemachena, 2009). The approach takes into account how variations in climate change affect net revenue or land value. By using net revenues and not individual crop yields, we allow farmers to adapt to climate change by choosing different crops, crop mixes, technologies and management practices under different climate conditions. Therefore, the Ricardian approach is an extensively used cross-sectional approach which is used to analyze the impact of climate change by incorporating adaptation. Moreover, the analysis of climate change impact on agriculture applying the Ricardian approach uses net farm revenue as a dependent variable, a more robust measure given concerns about equilibrium as it measures what the farmer currently receives without any concerns for future returns, discounting, capital or labour markets (World Bank, 2003). It has to be noticed that in the case of teff production, the crop is grown as mono crop which is associated with the nature of the plant growth and suitability in both agronomic and crop protection management practices.

3.4.2 Analysis of the relationships of income from teff production with biophysical and socioeconomic variables

Based on the work of Mendelsohn *et al*. (1994) by assuming the existence of a set of well-behaved production function, Ricardian approach involves specifying a net productivity function presented in Equation 1:

$$Q_i = Q_i(K_i, E) \quad , \quad i= 1, 2\ldots, n \ldots \tag{1}$$

Where Q_i is the quantity of the product of good i , $K_i = (K_{i1},\ldots, K_{ij}\ldots, K_{iJ})$ is a vector of all purchased inputs in the production of good i; K_{ij} is input *j* (1, 2..., *J)* used in the production of good *i,* and E = (E1, E2… E_m …, E_M) is a vector of site specific exogenous environmental factors such as temperature and precipitation/rainfall and soils which are common to a production site.

Given a set of factor prices w_j for K_j, *E* and *Q*, cost minimization provides the cost function presented in Equation 2:

$$C_i = C_i(Q_i, w, E) \ldots \tag{2}$$

Where: C_i is the cost function for the production of good *i* and *w* (w_1, w_2..., *wj*) is the vector of factor prices. Given market prices P_i for good i, producers' profit maximization on a given site can be specified in Equation 3:

[illegible] …………………………………………… (3)

Where: P_L is the annual cost or rent of land at that site, L_i is the land under the production of that crop.

Under perfect competition all profits in excess of normal returns to all factors (rents) are driven to zero i.e. it takes form of Equation 4:

$$P_i Q_i^*(X_i, E) - C_i^*(Q_i^*, W, E) - P_L L_i = 0$$ ………………………………………………..

(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 good i. Solving for P_L for the equation 4 gives land rent per hectare to be equal to net revenue per hectare presented in Equation 5:

$$P_L = \frac{\left(P_i Q_i^*(X_i, E) - C_i^*(Q_i^*, W, E)\right)}{L_i}$$ …..……………………………………………...

(5)

The cross sectional Ricardian method then assesses performance (Value V) of farms across landscapes capturing the impacts of variations in climate attributes and other factors (inputs, soils, prices etc.),Where V reflects the present value of future net farm revenue R (P_L). Hence, the present value of the stream of current and future revenues gives the land values, V_L*:* presented in Equation 6 and Equation 7:

$$V_i = \int_0^\infty R_t e^{-\phi t} dt$$ ……………………………………………………………………..

(6)

$$V_L = \int_0^\infty \left[P_i Q_i(X_i, F, Z, G) - \sum P_X X_i \right] e^{-\phi t} dt$$

…………………………………………….. (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 socioeconomic variables that affects farm value. Unlike other models, the Ricardian 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 and according to Ricardo, "Value of Land would reflect its net productivity", hence

[illegible] ……………….. (8)

[illegible] .... (9)

Where: F is a vector of climate variables (T for Temperature and P for Rainfall), Z= set of soil variables, G = set of socioeconomic variables and u is an error term.

F (T and P) and F^2 (T^2 and P^2) capture linear and quadratic terms for temperature and rainfall. The introduction of quadratic terms for temperature and rainfall reflects the non-linear shape of the response function between net revenue and climate. From past studies one expects that farm revenue will have a U-shaped or hill-shaped relationship with temperature. When the quadratic term is positive, the net revenue function is U-shaped, but when 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).

3.4.3 Analysis of marginal impacts of climate variables on teff income

Given the Equation 8, one can derive the marginal impact of climate variables (f_i) on crop revenue evaluated at the mean presented in Equation 10:

$$E\left[\frac{dV}{df_i}\right] = E\left[\beta_1 + 2\beta_2 f_i\right]$$

$$= \beta_1 + 2\beta_2 E(f_i) \quad \text{……... (10)}$$

From Equation 9, in order to analysis the marginal effect of each climate variables,

$$\frac{\partial Y}{\partial Temp} = Y(\beta_1 + 2\beta_2 Temp) \text{ and}$$

$$\frac{\partial Y}{\partial Prec} = Y(\beta_3 + 2\beta_4 Prec) \quad \text{……................................(11)}$$

Accordingly, the sign of the marginal effect depends solely on the term β1 + $2\beta_2 Temp$ and$\beta_3 + 2\beta_4 Prec$ which contain only the parameters of temperature it and none of those relating to other variables.

3.4.4 Prediction of potential future impacts on teff production under future climate change scenarios

As explained by the works of Kurukulasuriya and Mendelsohn (2008), one can analyze the impact of exogenous changes in environmental variables up on net economic welfare (ΔW). Hence, 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 of this environmental change is presented in Equations 12,13,14,15 and 16:

$$\Delta W = W(E_B - E_A) \qquad (12)$$

$$\Delta W = \int_0^{Q_B} \left[P(Q)\,dQ - \sum C_i(Q, R, E_B) \right] - \int_0^{Q_A} \left[P(Q)\,dQ - \sum C_i(Q, R, E_A) \right] \qquad (13)$$

If market prices do not change as a result of the change in *E,* then the above equation reduced to:

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

$$\Delta W = \left[P_Q Q_B - \sum_{i=1}^{n} C_i(Q_B, R, E_B) \right] - \left[P_Q Q_A - \sum_{i=1}^{n} C_i(Q_A, R, E_A) \right] \qquad (14)$$

By substituting for $P_L L_i = P_Q Q_i^* - C_i(Q_i^*, R, E)$ from Equation 5

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^{n} (P_{LB} L_B - P_{LA} L_A) \qquad (15)$$

Where P_{LA} & L_A are at E_A and P_{LB} & L_B are at E_{B}. Therefore, the present value of welfare change is,

$$\int_0^{\infty} \Delta W e^{-\phi t}\,dt = \sum_{i=1}^{\infty} (V_{LB_i} L_{B_i} - V_{LA} L_A) \qquad (16)$$

In line with Equation (12) to (16), by using the parameters of the fitted net revenue model, the impact of changing climate variables on the net revenue per hectare involves Equation 17:

$$\Delta NR = NR' - NR_c \text{ and } NR_a = \sum_{1}^{n} \frac{NR}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Where NR' is the predicted net revenue per hectare from the estimated net revenue model under the future climate scenario, NR is the predicted value of the net revenue per hectare from the estimation model under the current climate scenario, ΔNR is the difference between the predicted value of the net revenue per hectare under the future climate scenarios and the current climate scenario, the NRA is the average of the change in the net revenue per hectare and n is the number of observations.

Equation 17 can be further disaggregated to Equation 18:

$$\Delta NR_i = NR_{i,f}(T_f, P_f) - NR_{i,c}(T_c, P_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

Where $T_f = T_c + \Delta T$, $P_f = P_c + \Delta P$,

$NR_{i,f}(T_f, P_f)$ is the predicted net revenue per hectare of teff crop from the estimated net revenue model under the future climate scenario expressed as the function of temperature and rainfall for the study site under the new climate scenarios whereas, $NR_{i,c}(T_c, P_c)$ is the predicted value of the net revenue per hectare from the estimation model under the current or base line climate scenario derived from climate variables- temperature and rainfal. Finally the average of ΔNR_i per hectare and evaluated at the number of observations, gives the impact of a given climate change scenarios (Gbetibouo and

Hassan, 2005; Deressa, 2007; Deresssa and Hassan, 2009; Molla, 2009; Fonta *et al*., 2011).

The Ricardian model takes either Equation 7 or 8, depending on whether data are available on annual net revenues or capitalized net revenues (land values, $V_{L)}$. The model in Equation (7) was employed in this study to measure the impact of climate change on teff crop production in central Ethiopia. This is because of the fact that, data on land prices for the selected samples were not available in general as per the current land policy of the country. Farmers have full ownership on the use of their land but, neither selling nor buying of the land is allowed. Therefore, there is no direct market price which reflects the land value. Therefore, as per other studies, the value of the land is reflected by the net revenue obtained from the farm evaluated per hectare basis.

This approach has been applied the following authors- South Africa (Gbetibiuo and Hassan, 2005; and Benhin , 2006), Cameron (Molua and Lambi, 2007), Kenya(Kabubo-Mariara and Karanja, 2006), Zimbabwe(Mano and Nhemachena, 2007; Zivanomoyo and Mukarati, 2013), Nigeria (Fonta *et al*., 2011 and Ajetomobi *et al*., 2011) and Ethiopia (Deressa, 2007; Deressa, *et al.*, 2009; Deressa and Hassan, 2009; Molla, 2009 and Belay, 2012).

3.4.5 Econometric model specification

The model specified in this study relates annual net revenue from teff production as the dependent variable. It is known that the standard Ricardian model relies in an implicit form of land value as a function of climate variables set of soil variables and vector of socioeconomic variables (Mendelson *et al*., 1994). Following the approaches used by different authors mentioned in above section, net revenue per hectare was used as the response variable in this study.

Net revenue per hectare was regressed on the set of climate variables: temperature and rainfall; soil types, and socioeconomic variables (e.g. education level of household head, family size, and distance from markets, access to credit and extension services, proportional farm size allocation to teff crop under the study) and geographical coordinates. Therefore, the modified model of Ricardian adopted for this study depends upon the model with a set of both climate and other non climate variables considered as drivers of adaptations.

In previous studies, however, the model with and without adaptations were specified and the estimates from both models are compared. In dealing with the impact of climate change on specific crop yield and translated impact on net revenues from the crop, comparison of models with and without adaptation seems unrealistic. For instance for model without adaptations, the result from regressing net revenue from teff over all variables except set of socioeconomic variables are compared with the estimates from alternative specification with the inclusion of a set of socioeconomic variables; as the result the role of adaptation is knowledgeable provided that the negative impact is minimized in the inclusion of socioeconomic variables.

The comparison of both models is important especially in the case where the impact assessment estimates are wider in scope rather than targeting specific crop like teff in this study and moreover, key adaptation variable like irrigation are not considered for this study. Irrigation is among important adaptation variable that reduce the negative impact of climate change. However, in teff production the crop is small cereal, and so far production of the crop is rain fed and farmers totally depend on rainfall received annually. Therefore, in the absence of such influential adaptation variables- irrigation, it is difficult to assume the model without adaptation. Hence, the Ricardian model specified with both climate and non climate variables presented in Equation 19:

[illegible] ……... (19)

Where: LGP*temp* and LGP *temp*^{2} are the linear and square mean long-term weather temperature for the length of growing period of the crop. LGP*precip* and LGP*precip*^{2} is the mean long-term weather linear and square rainfall for the length of growing period. The variables X_j is set of socioeconomic variables and geographical coordinates and the β_1 , β_2, β_3 , β_4 , γ, and ω are coefficients for the linear and squared temperature and rainfall of growing period, soils and socio-economic variables respectively where as ε_k is the random disturbance term of the model.

There problems of multicolliniarity can be expected due to inclusion of linear and squared terms for climate variables specified in the model. Hence, one of the possible ways to reduce the problem is to center the original variable before computing the squared term. Accordingly, the original climate variables were centred to compute the squared variable by subtracting the mean from every case. By doing so, the mean of the centred variable was then zero for which in fact the standard deviation remain the same.

3.4.6 Econometric estimation of parameters' of empirical model

Using the Ricardian approach, the study estimated the contribution of climate variables– temperature and rainfall in relation to teff crop production in two sample districts of the east Shewa zone, central Ethiopia. In line with the existing body of literatures, a quadratic relationship between net revenue per hectare from teff crop production and climate variables, but a linear relationship with other socioeconomic variables was assumed. The interest of inclusion of the quadratic term in Ricardian studies was to capture the non linearity between crop output and climate variables after optimal points (Mendelssohn *et al*., 1994; Dinar *et al*., 1998; Mendelshon and Dinar, 2003; Deressa, 2007; Deressa and Hassan, 2009; Molla, 2009; Belay, 2012).

The model employed in this study is the multiple regression models with functional form of a nonlinear (quadratic) model. It was chosen as it is easy to interpret (Mendelsohn *et al.,* 1994). Ordinary Least Square (OLS) technique was used as the econometric (statistical) techniques of obtaining estimates of the regression coefficients. In OLS technique, the parameter estimator needs to have the desirable statistical properties. However, the optimality of the OLS estimator (best linear unbiased estimators - BLUE) is highly dependent on the underlying OLS assumptions.

In an econometric analysis of cross sectional data, presence of outliers in the data set, the problem of heteroscedasticity, multicollinerity and endogeneity of explanatory variables are major problems and hence need to be addressed before analysis.

The existence of heteroscedasticity in the error terms does not pose a serious problem in terms of obtaining consistent estimates as it only causes a bias in the estimates of standard errors. However, as Glejser test indicates it was not a serious problem under this analysis. However more serious problems are posed by multicollinearity and the influence of outliers.

In the case of outliers, attempts were made to identify for both univariate and multivariate outliers in the data used for this analysis. Hence, the analyses addressed concerns with outliers for the dependent variable- net revenue per hectare from teff and with the group of explanatory variables for multivariate outliers in the data. The totals of three households were considered as outliers for various reasons. These were omitted from the analysis by substituting with the extra sample data after rechecked for outliers with the interest of keeping the sample size. Hence, on the second step of the detection for substituted sample for removing outliers, it indicated as the outliers were not the case.

With regards to multicollinerity, several attempts were made in the initial stage of the analysis especially in handling the squared terms of climate variables in the model since the independent variables include both the linear and quadratic temperature and rainfall term. As per various literatures, three definitions of the climate variables were tried. First, using the four seasons (winter- average for December, January and February; Spring- the average for March, April and May; Summer- the average for June, July and August and Fall for September, October and November) climate data to represent the annual impact. Second, defining only for summer and Fall seasons where the crop stay on field and third, inclusion of Spring season data to the second definition because of its relevance with preliminary farm activities before the crop sown in summer season. Among the above run, the third definition had better statistical quality as compared to the first two definitions and so that implemented for this study.

In order to avoid the linear relationship between the climate variables, the average for the three seasons-spring, summer and fall average were computed and considered at length of growing season climate variables. Regarding the problem related to inclusion of squared and interaction term, the interaction term was not considered in the model because of reason discussed under model specification section of this paper whereas, for squared variables, it is sometimes suggested that, the original independent variables should be centered before computing the other variable(s) from it. Accordingly, the original climate variables were centered to compute the other squared variable. The overall variance inflation factors (VIF) of all independent variables in the Ricardian model for this study were less than 10 (see Appendix 2) that shows as multicolliniarity was not a problem with the finally implemented model.

The nonlinear (quadratic) functional form of the model was used in which the net revenue per hectare obtained from teff production taken as the dependent variable. The soil characteristics, socioeconomic variables and geographical coordinates are the regressors of the model as indicated and consistent with functional form specified under model specification section. It was estimated using the absolute values of variables to produce residuals of the estimated linear equation. As the result, the residuals were almost normally and the empirical model was well behaved. However, the alternative log linear specification of net revenue as dependent variable, over linear climate, socioeconomic variables and geographical coordinates didn’t fit to data for this study. Hence, a linear functional form of net revenue was used which was consistent with functional form specified under model specification section.

3.4.7 Description of dependent and independent variables

3.4.7.1 Teff crop net revenue per hectare

As mentioned in section 3.4.2, net revenue per hectare from teff crop was the dependent variable in the model specified. The gross revenue for each household for the season teff harvest was computed; which is the product of the season harvest of teff with the average market price. Attempts were made to include all quantities of teff produced during the season which include amount stored, the amount sold, and amount consumed which is basically the value of teff produced during the season.

The associated production costs were computed and deducted from the gross revenue to come up with the net revenue during the 2012/13 production season. The variable costs covered expenditures for purchase of teff seeds (equivalently valued for those who used own seed), fertilizer costs, pesticide costs, labour and other associated costs related to ploughing, sowing, weeding, harvesting, storage and transportation.

The fixed costs were insignificant in smallholder teff so it was omitted from the computation. The other cost included was the land rent which is the proportion of costs paid per year by household to government for the whole land they own. It was computed from teff farm size cultivated for the season for households who used their own plot whereas total costs of rent was captured for those households who rented farms.

As far as family labour is concerned, most of the previous studies excluded the costs of family labour due to associated fears of over-estimation of the family labour costs so that the resulting net revenue to be negative. Some of the Ricardian studies used household size as proxy for the impact of family labour on net revenue per hectare, the dependent variable. However, some of the households hired the labour on farm operations especially on critical time like weeding and harvesting season. Therefore, excluding the cost of hired and family labour in the estimation of costs make the computation for net revenue unrealistic.

Therefore, in this study apart from costs for the hired labour, teff net revenue per hectare was explained by the inclusion of family labour especially during critical teff farm operation like ploughing, planting, weeding and harvesting by using the average estimated wage rate in the study districts. Moreover, the estimated daily prevailing wage rate was cross checked with the price paid by those households who employed the labour per each teff farm activity.

Eventually, after the sum of computed costs was deducted from gross revenue for each household, the respective teff net revenues were expressed in per hectare further comparisons and analysis. This was the net revenue per hectare which further regressed on a set of regressors which includes Climate variables: temperature and rainfall, soil types and different socioeconomic variables.

3.4.7.2 Climate variables: temperature and rainfall

The data for climate variables namely temperature and rainfall were obtained from nearby weather stations to each plot/districts. The long-term computed mean values were used to represent the climate variables to explain the long term plot level climate information. The use of data from meteorological station is crucial due to the fact that data from weather station are accurate measures of ground conditions (Mendelsohn et al., 2004). The months normally teff crop stays on field from sowing to harvesting is July to November (Ketema, 1997); However, due to the fact that the farmers start to prepare the land based on the offset of the short rain season, *belg* season which include from March to May, it is reasonable to include the long term mean of climate variables for these three months to the length of the growing period months'. *Belg* is the Short and moderate rains from February/March to May are known by the little rains or *belg*, and correspond to the Ethiopia's secondary harvest season for the northern highland areas. These rains are very important to: plant short-cycle crops such as wheat, barley, teff, and pulses which are harvested in June or July.

Hence, the long term average for temperature and rainfall for this study defined in terms of the three seasons namely; spring season (March to May)- *belg*, summer season (June to August)- *meher* and the fall season-(September to November). Hence, the representative value of the teff length of growing period climate variables for the months of the seasons were estimated from long term metrological stations records. Finally, the computed long-term average value was represented for each metrological station nearby to the plot.

Accordingly the computed linear and quadratic terms of temperature and rainfall were included in the model. Furthermore, attempts were made to include the interaction term between linear climate variables as agronomic literatures suggest, however they are not statistically significant to shown any importance in the model.

The partial analyses of temperature and rainfall impacts make computations and interpretation of marginal impacts somehow easier. However, in Ricardian model, the net change in both climate variables eventually explained by the net gain or loss from the variables on net revenue. Therefore, considering the clearly unknown reason for which interaction term was not captured in majority of previous Ricardian studies and in specification of Ricardian model; the interaction term was dropped from this analysis.

3.4.7.3 Soil variables

Soil was included in the model with reference to soil physical characteristics. The texture of the soil was considered as a classification of the soil type for each plot the farmers were asked for their plots' soil type accordingly. Furthermore the features of each soil textural class was explained to the respondent and the household identified their own plot to which soil type it belonged. Their responses were compared with the observation undertaken on their plot by the time more plot information like altitude, latitude and longitude was taken at each plot level using Global Positioning System (GPS). Accordingly, the types of soil of the plots included are sandy soil, sandy clay, loam, clay and clay loam.

3.4.7.4 Socioeconomic variables

The socioeconomic parts of independent variables include the linear terms of farm characteristics (Table 3). Variables like sex, age of household head, and education level of household head, off farm income, value of livestock owned by households and value of other crops were initially fitted in the model. However, they were not statistically significant and had no impact on the overall model (F statistic), hence were excluded.

Therefore, the Ricardian model was re-specified for the important socioeconomic variables captured. These variables were; proportion of farm size allocated for teff since it was hypothesised to capture the opportunity cost of farmers' decision to allocate their scarce resource- land among crops grown for the season. Initially, farm size for teff was captured but it was not shown improvement on the model, rather the latter option showed better improvement in the model hence, introduced in the model by replacing with the farm size variable.

Other important variable were distance from input and output market which are indicators for the role of socioeconomic variables to adaptations, access to formal credit and extension services. Family size as a proxy for labour, household head education obtained from years spent in schooling which serve as a proxy for accessibility to adaptation strategies were also fitted in the model. A further attempt was made to extend the Ricardian model to capture the role of geographical coordinates on the teff farm net revenue. These inclusions of geographic coordinates were based on previous similar studies on specifications made on the Ricardian model to analyze the impact of climate change on field crops (Gbetibouo and Hassan, 2005; Deressa *et al.*, 2005). In such literatures, however, the altitude was considered as a proxy for day length whereby, the difference in length of the day matter the amount of light received by plants to undertake photosynthesis. Although there is no such differences in the length of the day since the districts are close to each other, it was expected that the amount of light received by the plant, however, differs as long as there is differences in altitude of the plots. However, with regards to altitude, literatures also expect the opposite direction of relationship with net revenue (Gbetibouo and Hassan, 2005).

Spatial variations caused by altitude create rainfall variations in Ethiopia leading to the existence of various microclimates. Altitude is an important factor in creating various climatic zones in Ethiopia. The four types of climate zones in Ethiopia are the '*dega',* *'weina-dega', 'kola'* and '*bereha'*. The '*dega'* is cool and usually receives adequate rainfall. The '*weina dega'* is temperate and supports most Ethiopian crops. The '*kola'* is hot and includes the lowland areas. The '*bereha'* is the desert type area in the peripheral parts of the country in which nomadism is the main economic activity (Wolde-Georgis, 2010).

Therefore, in line with such literatures, it was further hypothesised for the positive relationship between altitude and net revenue from the crop. Therefore, altitude is hypothesised from two points of view which contradict each other in explaining direction of relationship with net revenue. Therefore, with these interests each plot altitude and latitude was included in the model as proxies for day length for the agro ecological differences and solar radiation respectively. Table 3 shows the variables included in the empirical model for teff crop production of the study site.

Table 3: Description of the variables included in the Empirical model

VARIABLES	TYPES OF VARIABLE	DESCRIPTION OF VARIABLE	EXPECTED SIGN
DEPENDENT VARIABLE			
NRperha	Continuous	Net revenue from teff crop production measured in Ethiopian Birr per hectare(eventually converted to equivalent USD/ha for convenience and analysis)	None
INDEPENDENT VARIABLES			
LGPTEMP	Continuous	Average temperature of Length of growing period (March – November), measured in ^{0}c over 30 years.	-/+
LGPTEMPsq	Continuous	Square of LGPTEMP	-/+
LGPPrecptn	Continuous	Average rainfall of growing period (March–November), measured in millimeters over 30 years.	-/+
LGPPRECIPsq	Continuous	Square of LGPPrecptn	-/+
Altitude	Continuous	Altitude above sea level (in maters) taken at the farm plot of every household using GPS	-/+
Latitude	Continuous	Plot latitude , taken using GPS reading (in degrees)	-
DSANDY	Dummy	Sandy soil type, takes the value 1 if the soil is sandy type in texture, and 0 otherwise.	-
DSANDYCLAY	Dummy	Sandy clay soil type, takes the value 1 if the soil is sandy clay type in texture, and 0 otherwise.	-
DLOAM	Dummy	Loam soil type, takes the value 1 if the soil is loam type in texture, and 0 otherwise.	+
DCLAY	Dummy	Clay soil type, takes the value 1 if the soil is clay type in texture, and 0 otherwise.	-
FARMSIZEteff	Continuous	Proportion of area of cultivated farm/land size for teff for the season 2012/13 to allocated land size for other crop for same season, originally measured in ha.	-
DistanceINPUTmrkt	Continuous	The distance of household homestead from output market, measured in Kilometers.	+
DistanceOUTPUTmrkt	Continuous	The distance of household homestead from input market, measured in Kilometers.	+
Access to extension	Dummy	1= if the household had any service of extension, 0= otherwise	+
Access to formal credit	Dummy	1= if the household had any access to credit , 0= otherwise	+
Family Size	Continuous	Number of individuals in a household	+/-
Education	Continuous	The educational level of the head of household represented by years of schooling	+

Exchange rate (US$1= Ethiopian Birr (ETB) 18.55)

CHAPTER FOUR

4.0 RESULTS AND DISCUSIONS

4.1 Descriptive Statistics

The descriptive statistics presented under this section includes the socioeconomic and demographic characteristics, perceptions of farmers' to climate change, adaptations to climate change in teff production and constraints of adaptations.

4.1.1 Socio economic and demographic characteristics

The sampled household varies in terms of socioeconomic and demographic characteristics among the two districts. Table 4 presents the selected socioeconomic and demographic characteristics of sample households. Moreover, Table 5 and Table 6 presents selected socioeconomic and demographic characteristics for each districts separately.

Table 4: Summary of demographic and socioeconomic characteristics- combined districts (n=150)

Characteristic	Unit	Mean	Standard Deviation
Age of household Head	Years	47.07	10.69
Education of Household head	Years	3.19	2.88
Family Size	Number of Persons	6.49	2.50
Total Land Holding (under cultivation)	Hectares	2.42	1.35

Dummy Variable	Response	Frequency	Percentage
Sex of Household head	Male	136	90.7
	Female	14	9.3

Source: Own Survey data, 2013

The average age of sample household heads was 47.07 with a standard deviation of 10.67. The average value for Lume and Gimbichu district were 48.17 and 45.43 with the standard deviations of 10.76 and 10.47 respectively. With regards to level of education on average, household heads have 3.19 years of education which was evaluated using the number of years they spent at schooling. District wise, an average household head have 3.96 years for Lume and 2.05 years for Gimbichu district.

Table 5: Summary of demographic and socioeconomic characteristics- Lume district (n=90)

Characteristic	Unit	Mean	Standard Deviation
Age of household Head	Years	48.17	10.76
Education of Household head	Years	3.96	2.86
Family Size	Number of Persons	6.78	2.67
Land Holding (under cultivation)	Hectares	2.61	1.45
Dummy Variable	Response	Frequency	Percentage
Sex of Household head	Male	84	93.3
	Female	6	6.7

Source: Own Survey data, 2013

In Table 4, Table 5and Table 6 it was indicated that in the study area the average family size is 6.49 persons per household for combined districts whereas, 6.78 persons per household and 6.07 persons per household for Lume and Gimbichu districts respectively. In all cases the implication of the results are that the mean family size in the study districts are relatively higher as compared to the national average agricultural household family size holding which is approximated to 5.2 persons per households.

Table 6: Summary of demographic and socioeconomic characteristics- Gimbichu districts (n=60)

Characteristic	Unit	Mean	Standard Deviation
Age of household Head	Years	45.43	10.47
Education of Household head	Years	2.05	2.55
Family Size	Number of Persons	6.07	2.18
Land Holding (under cultivation)	Hectares	2.14	1.14
Dummy Variable	Response	Frequency	Percentage
Sex of Household head	Male	52	86.7
	Female	8	13.3

Source: Own Survey data, 2013

The result further shows that compared to male headed household head, 9.3% of the households are female headed for combined districts whereas, 6.7% and 13.3% for Lume and Gimbichu districts respectively. In the context of Ethiopia, the ratio of national average female-headed agricultural households is about 17.6% (cited by Chanie, 2011). Hence, this shows that in the study districts, relatively lower proportion of female household headed have engaged in agricultural activities including teff production compared to the national average. The implication behind this can be female as compared to male in rural areas, involved in more of their time on family home based activities and obligations such as food preparation, collecting firewood, fetching water from distances, attending local social affairs, assisting the family at farm routines.

4.1.2 Perceptions of farmers' to climate change

Majority of respondents in Lume and Gimbichu districts (92.5% and 94.7% respectively) confirmed that they are already aware of long-term changes in climate variables entailing temperature and rainfall. In Lume district, concerning the direction of the changes in climate variables over the past twenty years, 91.1% of the sample households perceived an increase in the long-term mean temperature whereas, 6.7% reported the decrease in the temperature. Furthermore, 2.2% of the sample respondents reported that no changes observed in the temperature over time. In the same district, regarding the direction of changes in the mean state of rainfall, about 10% of sample respondents confirmed increasing rainfall whereas, about 83.3% and 6.7% of them reported that they observed decreasing rainfall and no changes in the long-term mean state of rainfall over the past two decades, respectively (Fig. 4).

In Gimbichu district, about 90% of the sample household perceived an increase in the long-term mean temperature whereas about 8.3% and 1.7% of the sample households perceived decrease and no change in mean temperature over the past twenty years, respectively. With regards to the direction of the long term change in rainfall; 11.7%, 83.3% and 5% of the sampled household in this study district perceived increase, decrease and no change in rainfall over the past two decades, respectively (Fig. 4).

In general, an increase in temperature and a decrease in rainfall are the common perceptions observed among the sample households in both districts which were exactly matched with the metrological data. These perceptions can be associated with the changes they observed in relation to the interferences of the climate variables with farm operations such as delay in farm operation in waiting for rainfall and prevalence of high temperature in the area where these communities normally live. However, it has to be noticed that the report by farmers were more of reflection of the variability of climate and further limited by several factors among which educational background of the farmers is one. Hence, acknowledging the local communities perception on climate change, however, for the analysis of the climate change impacts, the metrological data reflects about the long-term state of climate variables as compared to farmers view.

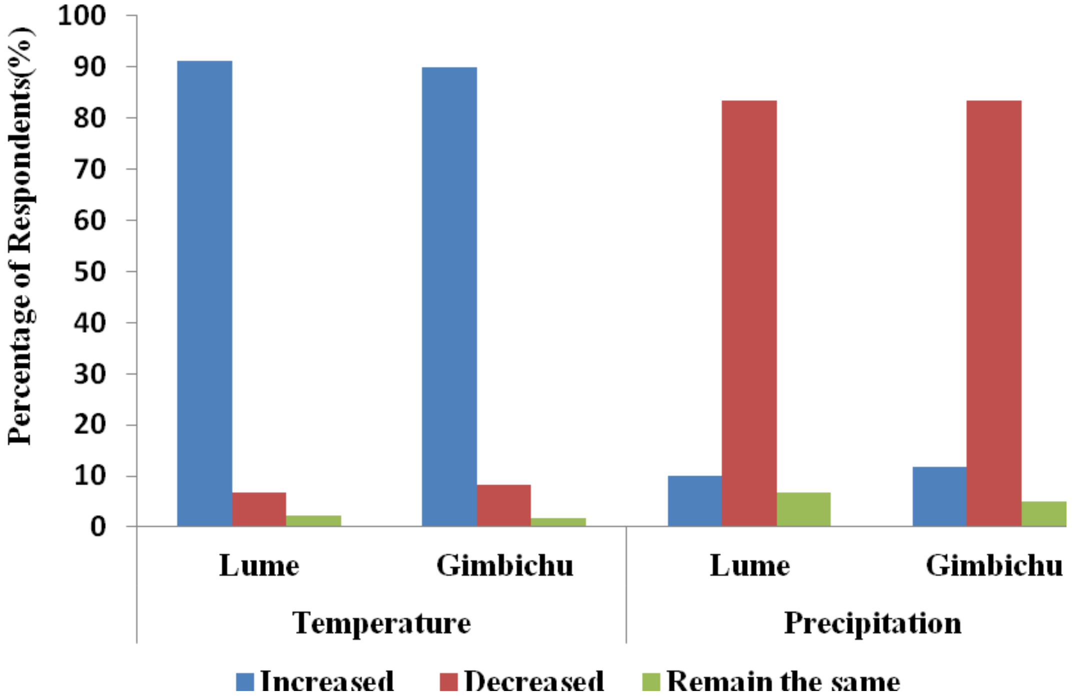

Figure 4: States of climate variables in Lume and Gimbichu districts

4.1.3 Adaptations to climate change in teff production

Adaptation to climate change with reference to crop production varies in the study sites from household to household. Some of the households did not use any adaptation. According to various literatures, farm level adaptation depends on: technology (e.g. the availability of different varieties of crops and irrigation), soil types, and the capacity of farmers to detect climate change and undertake necessary actions (Maddison, 2006; Kurukulasuriya and Mendelsohn, 2008; Hassan and Nhemachena, 2008). In Ethiopia as well, there are traditional and contemporary coping mechanisms to climate variability and extremes in the country which include changes in cropping and planting practices (NMA, 2007). Hence, this also applies further for climate change aspects as long as coping strategies against climate variability may help or develop in case of climate change in terms of improving climate resilience.

In this study, sampled household heads were asked to identify the specific adaptation measures they practiced is teff crop production. Accordingly, the use of different teff crop varieties, crop diversification, changing planting date and use of compost are among the common adaptation strategies undertaken by farmers at sampled districts.

In Lume district, 74.4% and 58.9% of the households reported that they used drought tolerant and early maturing teff varieties, respectively. In Gimbichu, those who used drought tolerant and early maturing teff varieties accounted for 58% and 60% of sample households, respectively. Some farmers acknowledged the role of some local varieties of teff as an adaptation measure to the changing climate. Some of the traditional crops are very useful because they either tolerate dry conditions or are fast growing. Teff, red teff, barley, corn, and potatoes are some of those crops. For instance teff is adapted to a wide range of environmental conditions and can be grown at altitudes from 1000 to 3000 meters above sea level (Teffera *et al*., 2000).

Adjusting the time of planting was among important strategies practiced in the study area. The choices of adaptation strategies to climate change impacts involve mainly strategies which are autonomous and in line with farmers' resource base. About 77.8% and 81.7% of respondents in Lume and Gimbichu districts confirmed that they adjusted the planting date for teff with change in the onset and end of rainfall (Fig. 5).

Moreover, crop diversification was also among adaptation options explained by the sample respondents. About 85.6% and 55% of the sample households in Lume and Gimbichu respectively, reported that they practiced crop diversification. Crop diversification is a widespread climate change adaptation strategy in Ethiopia (Deressa *et al*., 2009; Mesfin *et al.*, 2012). Similarly, sampled farmers also confirmed that they used compost which accounted for about 47.8% and 28.3% in Lume and Gimbichu districts respectively.

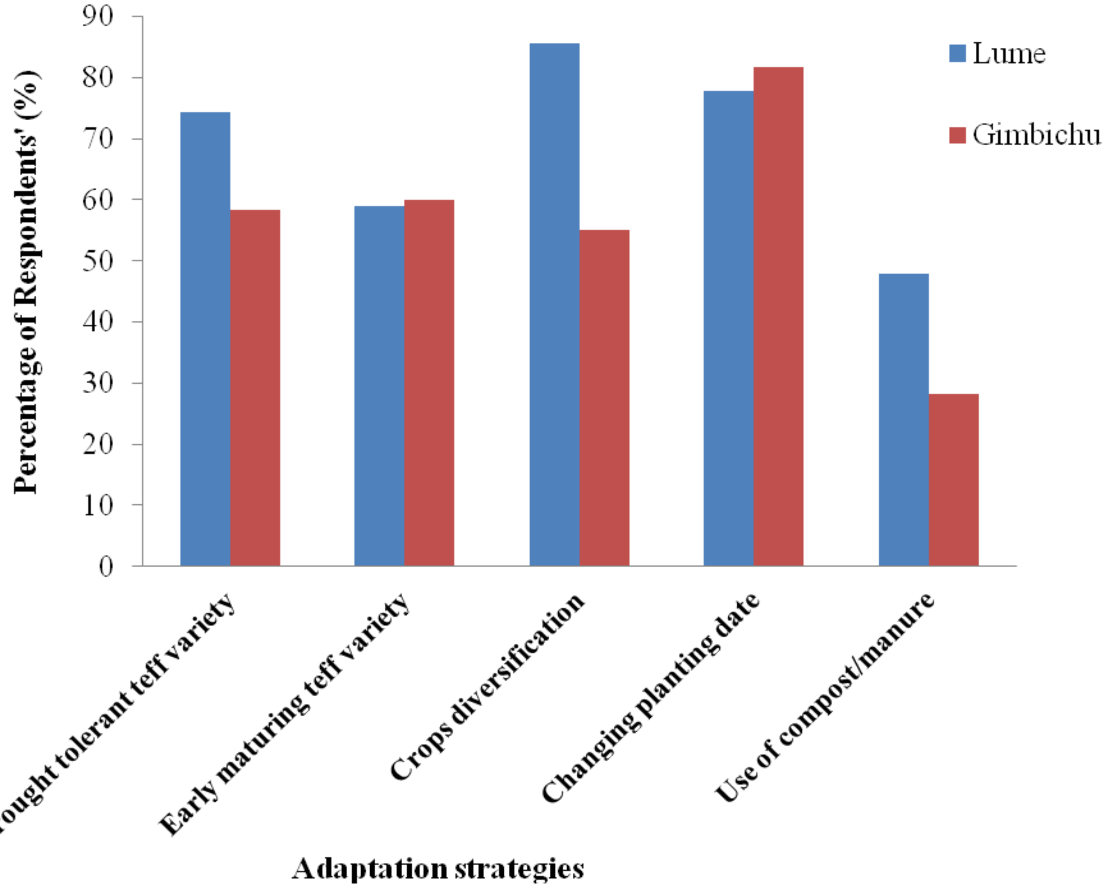

Figure 5: Adaptation strategies undertaken by the sample households

4.1.4 Constraints of adaptations

There are constraints that limit the adaptive capacities of farmers. Capital among other things limits the farmers' capacity to purchase fertilizers and improved seeds. Sampled households reported some challenges that limit them in teff production. Lack of improved seed of teff varieties, lack of information and lack of capital to purchase seeds, fertilizers and other inputs were among the major constraints reported by the farmers (Fig. 6). The constraint to adaptation, however, shows differences among the two districts. For instances, at Lume almost all constraints were higher compared to Gimbichu district. Although there is no clear justification for that, resource ownership, availability effective institutions and higher expected climate change impact at higher altitude as compared to lower altitude could be among the possible sources of the observed differences.

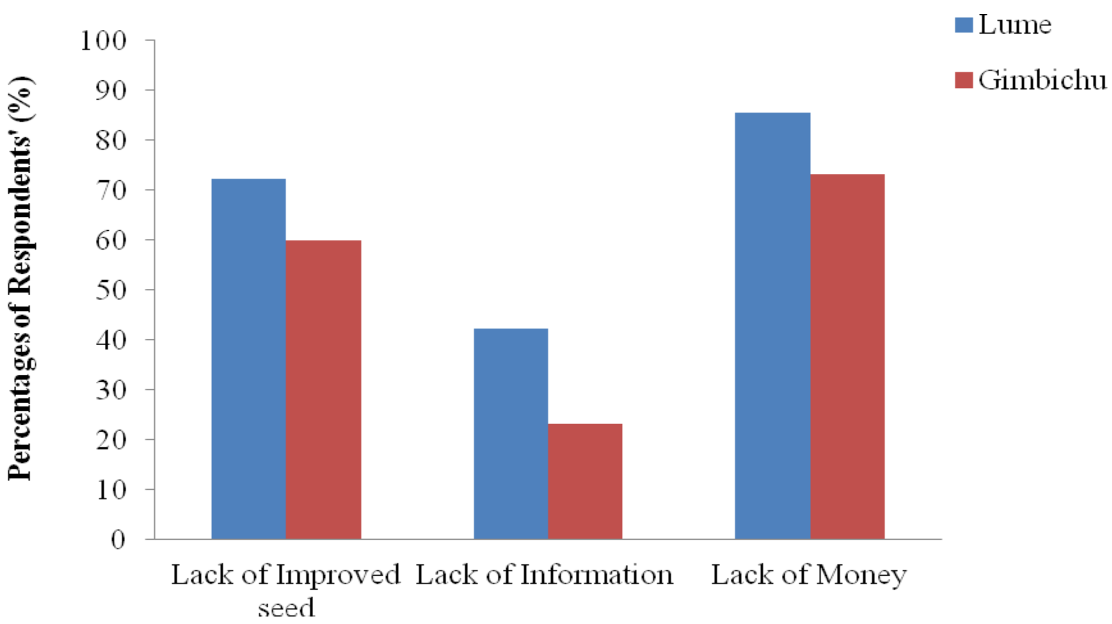

Figure 6: Constraints to adaptation in relation to teff crop production

4.2. Results of the Regression Analysis

The relationship between net revenue per hectare from teff production with climate variables and control for biophysical and socioeconomic variables in the Ricardian model yielded the expected results. The model demonstrated a good fit at 1% level of significance that observed from F statistic. Furthermore, the coefficient of determination (R^2) showed that the model explained 39% of variation in net revenues from teff production (Table 4).

The value of the coefficient of determination is 39% and this value along with the adjusted coefficient of determination are in fact seems lower. However, these results are within the ranges of other climate change impact studies which employed the same approach - Ricardian model with almost similar model specifications and functional forms (Deressa, 2007, Deressa and Hassan, 2009; Molla, 2009; Belay, 2012, Kabubo-Mariara and Karanja, 2006, Molua and Lambi, 2007). Among the likely implications, provided that for farms that vary from small scale to large commercial operations it can be true that large part of the variation in the agricultural income remains unexplained by the variables taken into account (Kurukulasuriya & Mendelsohn, 2006). However, under this study which targeted teff, although the study targeted small holders, there were variations on scale of operation among teff smallholders. This was because some of the sampled farmers rented more land and cultivated.

Another general likely reason for less in the value of coefficient of determination was that the nature of complexities to capture other several important biophysical and other climate variables that explain net farm revenue with their complex interactions.

In line with the above arguments, it is known that as sample size increases, the differences between the R squared (R^2) and adjusted R squared (adj R^2) become less. The differences between the values for R squared and adjusted R squared for the model is 7 % which shows the relative adequacy of the sample size used for this study.

4.2.1 Relationship of biophysical and socioeconomic variables with net farm returns from teff Production

The results from the regression showed that the climate variables including length of growing season, temperature and rainfall, soil types, geographical variable (altitude and latitude), allocated proportion of the land for teff crop, distance from input market, access to extension services, access to formal credit, and household heads' education levels had significant statistical influences on the net revenue per hectare obtained from teff.

4.2.1.1 Relationship of climate variables with net farm returns

The effect of quadratic seasonal climate variables on teff net revenue is not simply determined by looking at the coefficients, since both the linear and the squared terms play a role (Kurukulasuriy and Mendelsohn, 2008). Moreover, it was the aggregate mean for the three seasons which represented the long-term mean temperature and rainfall under this study. Hence, the signs of both linear and quadratic climate coefficients are difficult to interpret without considering the marginal effects. Indeed, looking at the significance of the squared term of rainfall holds little message concerning the relationship between net revenue from teff and rainfall. Accordingly, the quadratic term of rainfall was significant at 10% level of significance indicating for existence of a nonlinear relationship between the rainfall and net revenues from teff whereas, the quadratic term for temperature was not statistically significant.

Table 7 shows the parameter estimates of the Ricardian model.

Table 7: Parameter estimates of the Ricardian teff model

Independent variables	Coefficient	Independent variables	Coefficient
LGP temperature	44.59***** (1.78)	Loam (Black) soil	7.97 (0.11)
LGP temperature sq	-16.25 (-1.12)	Farm size (Teff: other crops)	-37.69****** (-2.24)
LGP rainfall	-0.54***** (-1.73)	Distance of input market	-90.48****** (-2.44)
LGP rainfall sq	0.03****** (2.41)	Distance of output market	48.66 (1.56)
Altitude	0.39******* (2.79)	Access to extension	199.39******* (3.55)
Latitude	-83.67 (-0.54)	Access to formal credit	-107.50****** (-2.21)
Cay Loam *(Reference group)*		Family size	7.12 (0.75)
Sandy soil	-317.49****** (-2.56)	Education of household head (Years at schooling)	16.25***** (1.96)

Sandy clay	-144.82* (-1.94)	Constant	37.10 (0.03)
Clay (Red) soil	-47.19 (-0.57)		
R squared	0.39	Adjusted R squared	0.32
F- Statistic	5.09***		

Note: * Significant at 10% level ** Significant at 5% level *** Significant at 1% level

4.2.1.2 Relationship of soil and geographical location with net farm returns from teff production

The relationship between most of the soil indicators and net revenues from teff were negative. However, a positive relationship with black soil (loam soil) was found. Hence, the significance of control for soil variables showed the existence and importance of these variables in explaining net revenue from teff production.

Among others, wide range of adaptive capacity of the teff crops for different soil types and the fact that the fertility status of the soil is the function of geographical location, the soil fertility management provided by farmers such as the use of compost and inorganic fertilizers are the possible factors behind the differences in the direction of the relationship existed between net revenue from teff and soil quality indicators. Moreover, the soil indicators are related to the physical property of the soil since the texture of soil was used as proxy in this study. Further, soil texture is the single most important physical property of the soil. However, knowing the soil texture can provide information about water flow potential, water holding capacity and fertility potential of the soil among others.

With regards to sandy soil (significant at 5%) textural proximity under this study; it is associated with less availability of nutrients for plants as compared to other soil textural groups. This is because voids between sand particles promote free drainage and entry of air, holds little water. Therefore, coupled with high temperature it is prone to drought as far as less soil moisture leads to poor crop growth, thereby increasing the crops' susceptibility to further temperature stress undermine crop productivity. The concern with the sandy clay (significant at 10%) was also somehow similar with sandy soil since in category of sandy clay, the proportion of sand is reduced since silt and /or clay soil particles are present in the textural combinations. Hence, the improvement in water holding capacity and nutrients are expected to be improved unlike for the case of pure sandy soil. In general, the direction of the relationship between net revenue and sandy clay soil showed the negative relationship as expected.

The altitude of the plot was significantly explained the net revenue obtained from teff at significance level of 1%. The direction of the relationship was in line with the expectation of altitude to explain that the location of the farm plot matter for which the impact of the climate change is relatively higher at lower altitude as compared to the locations found at higher altitude. On the other side of agronomic hypothesis, however, the direction of relationship between net revenue from teff and altitude was not expected. From agronomic perspective, the agronomic requirement of day length which states that relatively districts at higher altitude are related to lower day length so that the light captured during such days matter for the crop physiological activities like photosynthesis, so that this impact in turn lead to lower yields and less net revenue obtained from the crop assuming other factors constant.

Acknowledging the differences in day length in countries like South Africa where by the day length differ on hours bases as compared to Ethiopia where there is no such differences in hours per day, the finding from this study is against findings of Gbetibouo and Hassan (2005) who hypothesized altitude from the agronomic prospective. The basic intention for maintaining this hypothesis was that, although there are no such differences in the length of the day since the study districts are close to each other in this finding case, it was expected that the amount of light received by the plant, however, differs as long as there is differences in altitude of the plots. Therefore, the positive relationship existed between net revenue from teff showed the impact of altitude in determining the income from teff.

4.2.1.3 Relationship of socioeconomic variables with net farm returns from teff production

With regards to control variables for socioeconomic variables in the Ricardian model; proportion of farm size allocated for teff (significant at 5% level), distance from input market (significant at 5% level), access to extension (significant at 1% level), access to formal credit (significant at 5% level), and education of household head (significant at 10% level) were statistically significant in explaining net revenue from teff production.

Teff farm size was considered as the share of farm plot allotted to teff in comparison with plot allocated to the other crops for the productions' season. The result for the direction of relationship was as hypothesised earlier. This is due to the reason that land is scarce resource and the allocation of such scarce resources among competitive ends requires a wise decision. Hence, keeping other factors constant, as more land size are allocated to another crop, less plot remains for teff which in turn associated with reduction in net revenue obtained from teff production.

Farm size in relation to adaptation to climate change is associated with greater wealth, so it is hypothesized to increase adaptation to climate change. In body of literatures however, the effect of farm size on adoption of agricultural technologies is inconclusive since farm size has both negative and positive effects on the adoption of agricultural technologies (Bradshaw *et al*., 2004). Arguments of other findings regarding farm size in crop production expected inefficiencies related to large farm size associated with the capacity of farmers in order to manage large farm size (Ouedraogo *et al*., 2006). Moreover, there are associated possibilities for those farmers to leave their land fallow. Given the constrained farm size owned by household under the context of countries like Ethiopia where the current population is high and will grow at a high rate, farm size can be hypothesized in line with such constraint. Among supportive evidences, there was demand for more plot size and such gap filled through renting in plots for teff production which was reported by farmers. Hence, this in general supports the presence of limited farm size and requirement for capital to use various technologies on the fixed cropping land size. Therefore, this further support the regularly hypothesis made as the implementation of new agricultural technologies requires sufficient financial wellbeing (Knowler and Bradshaw, 2007).

Therefore, the result from this study showed that net revenue from teff increased with increasing in land size dedicated to teff production under the context of the study districts. The result is in line with findings of Deressa (2007) that showed possibilities of the household allocation of owning farm size among the crop type they grow.

Regarding the households' distance from the input markets; the closer the distance to input markets, the more adaptation to climate change was hypothesised. The proximity to such market is an important factor for adaptation since among others it is the better social capital and the place where farmers can exchange information with other farmers (Maddison, 2006). However, the finding from this study showed that the distance to input market place was with an unexpected sign which was negative but significant. Though the coefficient for distance from output market was not statistically significant the direction of relationship holds true with earlier expectation.

In general, according to result from this study with regards to distance from input market, it seems to be no clear relationship between distance to the market and net revenue from the crop. However, it was not surprising that the probable reason might be that farmers incur more cost in terms of money and time as the marketplace becomes far away from their farm plots and the tendency of farmers to shift to other alternative input markets in the neighbouring districts. This was in line with the findings of Molla (2009) who found the negative relationship between net revenue from crop production and distance from input market.

Similar to other control variables included in the Ricardian model, access to extension services and formal credit source were statistically significant at 1% and 5% level of significance. The finding for extension access is in line with various studies conducted in developing countries including Ethiopia. The presence of a strong positive relationship between access to information through extension services delivery increases the farmers likelihood of adapting to climate changes (Maddison , 2006; Yirga, 2007; Nhemachena and Hassan, 2007; Deressa *et al*., 2009).

However, the direction for access to formal credit was not expected. The fact related to the availability of credit eases the cash constraints and allows farmers to buy inputs such as fertilizer and improved crop varieties. However, as observed from this finding, the reversed direction of relationship with net revenue from teff and access to formal credit from what hypothesized was in fact not surprising since it was probably because of the miss use of the loans or allocation of the loan obtained through credit to other crops while it was basically meant for teff production.

Moreover, education of the household head measured in terms of number of years spent at schooling explained net revenue from teff significantly as expected. This is because in line with previous findings such as Norris and Batie (1987) which explained as a higher level of education is believed to be associated with access to information on improved technologies and higher productivity. Similarly our finding is in line with works by

Maddison (2006), and Deressa *et al*. (2009) which confirmed as farmers with higher levels of education are more likely to adapt better to climate changes.

Furthermore, there is an existence of a positive relationship between education of the farmers and the number of adaptation strategies household head implemented for teff crop production, and hence, those households who spent more years at school are most likely to adopt more numbers of adaptation strategies as compared to those who attend school for only few years as observed from cross tabulation results. Therefore, farmers with higher levels of education are more likely to better adapt to climate change.

4.2.2 Marginal impact analyses

The marginal impact analysis was undertaken to observe the effect of small changes in temperature and rainfall on farm net revenues from teff. As observed from the result presented in Table 8 (based on the coefficients for temperatures and rain falls from table 7), increasing temperature during the overall length of growing period for aggregated seasons captured significantly decreases the net revenue per hectare for teff. However, it has to be noted that this result was based on seasons aggregate long term temperature, hence, some of the seasonal marginal benefits' was expected whereas in some of the seasons' marginal loss was expected due to the prevailing temperature benefits and adverse conditions in portions of the seasons with regards to crop temperature requirement per each growing season.

In general, the length of the growing period temperature reduced the net revenue per hectare.The marginal impact of temperature on net revenue from teff is ETB 602.96, meaning that within the study area, one degree centigrade increase in temperature for the length of growing period decreases the net revenue per hectare per annum by ETB 602.96 or US$32.51 and the change is statistically significant. However, with regards to rainfall, unlike negative marginal impact of temperature, increase in rainfall during the length of growing period has a very small positive marginal impact on net revenue of teff per hectare on per year basis. Accordingly, one percent increase in rainfall, increase the net revenue of teff production by ETB 10.20 or US$0.55 for which the effect is not statistically significant.

Though the interaction term between the two climates variables were not captured in this study, the small positive marginal change in rainfall seems related to the offsetting interaction nature with high temperature. The combined marginal impact of temperature and rainfall on net revenue from teff plot is approximately ETB 592.76 or US$31.96 decrease per hectare per year. In interpreting the marginal impact of these climate variables, it has to be noticed that particularly the increase in temperature by one degree centigrade is relatively time taking. The estimated marginal impact of temperature and rainfall on teff crop net revenue is presented in Table 8:

Table 8: Marginal effects of climate variables on teff crop net revenue based on coefficients in Table 4.

	Temperature	Rainfall

Length of growing period (March to November)	-32.51 ***	0.55

Note: *** Significant at 1% level.

4.2.3 The Impact of forecasted climate scenarios

It is possible to analyze the impact of climate change on net revenue based on the baseline and future scenarios on the basis of the future climate change projection models (Deressa, 2007; Deressa and Hassan, 2009; Fonta *et al*., 2011). In line with these literatures, this study analyzed the impact of climate change in net revenue from teff per hectare. The predicted values of temperature and rainfall for these studies for the year 2050 and 2100 was based on three climate change prediction models (CGM2, HaDCM3 and PCM) to understand the likely impact of climate change on crop production.

In this study however, the magnitude of future level of changes in climate variables (change in temperature and change in rainfall) were based on Ethiopia NAPA projections (NMA, 2007). Accordingly, their projections were for a mid-range emission scenario which was based on A1B-AIM (no policy scenario) and B2-MES (a policy scenario); and the temperature and rainfall change scenarios generated were composites (averages) of nineteen GCMs that supplied the SCENGEN data .The result from their projection shows increase in mean annual temperature by the year 2030, 2050 and 2080 and expected small increase in precipitation over Ethiopia for the IPCC mid-range emission scenario compared to the 1961- 1990 normal (NMA, 2007). The main reason for selecting this mid-range emission scenario for this study is due to the fact that it involves the policy directions targeted in Ethiopia to address future climate change impacts.

Based on the coefficients in Table 7 and a mid-range emission scenario of climate changes from NMA (2007), Table 9 shows the predicted values of temperature and rainfall for the years 2030, 2050 and 2080. Under this scenario, the models forecasted increasing temperature levels for these years (2030, 2050 and 2080) and increasing rainfall over these years was predicted.

As observed from the table 10, all the predicted values used from the bench mark of mid-range emission scenario (IPCC mid-range (A1B) emission scenario) shows the reduction of the net revenue from teff production by the years 2030, 2050 and 2080. The magnitude of the reduction in net revenue from teff per hectare is US$31 (5.84%) for the year 2030, US$58.90 (11.10%) for the year 2050 and US$94.50 (17.80%) by the year 2080.

Table 9: Climate predictions of mid-range emission scenario for 2030, 2050 and 2080

Year	Temperature	Rainfall
Current (Baseline)	19.38	916.54
2030	20.38	941.75
2050	21.28	964.20
2080	22.43	993.99

Source: Own computation based on prediction by NMA (2007) under IPCC mid- range (A1B) emission scenario for future by the year 2030, 2050 and 2080 under Ethiopian context.

The magnitude of projection for change in temperature and change in rainfall were therefore taken from NMA, (2007) which were applied to future level of changes of these climate variables for a mid-range emission scenario under Ethiopian context. The results of the predicted impacts on net revenue from teff production are presented in Table 10 and the magnitude of the impact associated to the computation of the modeled forecast can be seen from Appendix 3.

Table 10: Forecasted Average Net Revenue per Hectare Impacts based on mid-range Scenario (US$) for Temperature, Rainfall and Net impact:

Impacts	Under mid-range (A1B) emission scenario /years of projections		
	2030	2050	2080
Change in NR/ha (US$) due to change in Temperature	-32.51	-61.76	-99.14
Change in NR/ha (US$) due to change in Temperature	1.51	2.86	4.64
Change in net Revenue per hectare(US$) due to change in Rainfall			
Net changes in net Revenue per hectare (US$)	-31.00 (5.84%)	-58.90 (11.10%)	-94.50 (17.80%)

Source*:* Own computation from the modelling based on values of climate variables in Table 9 and modelled values in Appendix 3.

The result presented on Table 10 shows that though the reduction in net revenue from teff is common for all the years, the increasing impacts on the net revenue will be expected as time goes from 2030 to 2080. Hence, this indicates that the climate change damage continues to increase in the future. It further indicates the need for adaptation to overcome such negative climate change impact for which otherwise, the impact will be worse in future time. This result is also in line with literatures that indicated as the future climate change is damaging to African agriculture in general and Ethiopia in particular (Hassan and Nhemachena, 2008; Kurukulasuriya and Mendelsohn, 2008; Gbetibouo and Hassan, 2005; Fonta *et al.,* 2011; Deressa and Hassa, 2009 ; Molla, 2009; Belay, 2012).

The projected impacts associated with teff production due to changes in temperature and rainfall shows the damage level imposed on the income expected from the crop. According to CSA (2012) report, national wise about 2.7 million hectares of land was under teff production for 2011/12 *meher* season. The contribution from east Shewa Zone to national teff area coverage in hectares for the same year accounts for 183 272 hectares.

Based on the projected value of the net revenue impacts due to temperature and rainfall for instance, under the future scenarios of a mid-range emission scenario for the year (Table 7); by the mid-century assuming other factors constant, an estimated economic loss of US$10 794 754 to farmers for east Shewa Zone and national economic loss of US$160 862 477 under *meher* season will be the expected based on market price.

In general, such magnitude of estimated future losses in net revenue from teff production indicates the need for necessary interventions on time to reduce the future impact of climate change on the crop.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study analyzed the impact of climate change on teff revenue using modified Ricardian approach. The study was based on 150 teff producing households from Lume and Gimbichu districts of east Shewa Zone, central Ethiopia. In the first part of the work, perceptions of climate change and relevant adaptation strategies as farming practices for teff crop production were descriptively assessed to have views of the smallholder farmers on climate change in the study districts. The major focus of the study was on analyzing the impact of climate change on teff production in the same study area.

The majority of the farmers in the study districts' are aware of changes in climate variables- temperatures and rainfall over the past two decades. With regard to farming practice as adaptation strategies specific to teff crop production; drought tolerant teff varieties, early maturing teff varieties, crop diversification, changing/adjusting planting time and use of compost/manure are among commonly used adaptation strategies by the farmers. Lack of improved seed, lack of information and lack of money are among the main constraints hindering farmers not to undertake these adaptation strategies.

Under the subsequent and the main section of this study; net revenue from teff crop was regressed on climate variables- long term mean temperature and rainfall, and control for biophysical and socioeconomic variables to investigate the relationship between these regressors and net revenues from the crop. The result of regression shows there is a significant relationship between net revenue from teff production with biophysical and socioeconomic variables.

Accordingly, long-term mean temperature (linear), long-term rainfall (linear and squared term) were significantly explained the net revenue from teff production per hectare. Similarly, the soil variables also found significantly explained the net revenue from the crop. Moreover, proportion of farm size allocated for teff, distance from input market, and access to extension, access to formal credit and the education level of household head were among control socioeconomic variables that significantly explained net revenue from teff production. Therefore, the presence of significant relationship of net revenue from teff production with the climate variables, biophysical and socioeconomic variables shows the importance of these variables in explaining income from the crop. Moreover, the significance relationship of the climate variables further shows their importance in determining the impact on income from teff production.

The marginal increase in temperature significantly results in a net loss of US$32.51 NR/ha of teff per year in the study area. About 2.7 million hectares of farmland were allocated for teff production in Ethiopia (CSA, 2012). Hence the projection of the marginal impact due to temperature at the east Shewa Zone and national scales shows huge losses in net revenue from teff production. Thus, in order to minimize the loss, teff production adaptation strategies suited to higher temperature should be in place.

The study further predicted the impacts of climate change in net revenue from teff production under a mid-range emission scenario. Hence the benchmark for future levels of above quarter (2030), mid-century (2050) and far century (2080) for climate variables were taken from projections by NMA (2007) under NAPA of Ethiopia. The result of the projections indicates that there will be reduction in net revenue from teff for both years under the scenario. The result further shows as the magnitude of the loss is high by the year 2080 as compared to the year 2030 and 2050.

Hence, climate change projections for above quarter, mid and far century indicated that teff will not continue to be a profitable enterprise. The prediction shows the increase in the impact associated with changes in long term climate variables (temperature and rainfall) will have a considerable impact on net revenue from teff production as time goes forward. Therefore, it is important to give due attention to reduce the projected impact on time through increasing the smallholder farmers' adaptive capacity.

5.2 Recommendations and Policy Implications

The following are recommendations drawn from this study to reduce the projected impacts of climate change on teff production for the study area.

i. In order to reduce the impacts of increase in temperature on net revenue from teff production; innovating, spreading and transferring adaptation technologies such as improved varieties of teff which are adaptive under different agro-ecologies, for example high temperature stress tolerant teff varieties along with soil and water conservation measures should be promoted at both the study areas and other similar agro-ecologies.

ii. Climate change projections for near quarterly, mid and far century indicated that teff will not continue to be a profitable enterprise. Hence, solutions to constraints of alternative adaptation strategies including improved extension services, credit access and education for the sustainable teff production are recommended.

iii. Along with other stakeholders (e.g. research centers, cooperatives, farmers' group, seed multiplication units, NGOs, etc.), The government has to do better in supporting teff producing smallholder farmers to increase their adaptive capacity

iv. The existence of significant relationship of net revenue from teff production with climate variables shows the need for the importance of considering these variables in determining the economic impacts of climate change on teff production. Therefore, considering such importance, in particular to climate variables, the NMA should work on expanding the numbers of meteorological stations in the country in order to record and observe the future changes of these variables at local and national level.

v. Policy makers should consider investment in research on teff improvement technologies to reduce the projected adverse impacts of climate change on teff production.

vi. This study recommends two major further researches. These are national-wise study on impact of climate change on teff production and in-depth investigation on adaptation strategies and determinants of adaptations which are specific to teff production.

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APPENDICES

Appendix 1: Descriptive value for the variables used in the empirical model

Variables	Mean	Standard Deviation
Net Revenue per hectare ($)	543.30	316.01
LGP temperature (^{0}c)	19.38	1.99
LGP rainfall (mm)	916.55	174.43
Altitude (m.a.s.l)	2096.75	312.80
Latitude (^{0})	8.49	0.25
Sandy soil (1/0)	0.07	0.25
Sandy clay soil (1/0)	0.16	0.37
Clay soil (1/0)	0.23	0.42
Loam soil (1/0)	0.24	0.43
Farm size- teff: other crops (hectare	0.86	1.42
Distance from Input market (km)	3.99	1.31
Distance from Output market (km)	3.41	1.53
Access to Extension (1/0)	0.81	0.39
Access to formal credit (1/0)	0.34	0.48
Family size	6.49	2.50
Education (years in schooling)	3.19	2.89

Appendix 2: Variance Inflation Factor for Multicollinearity test among variables included in the Ricardian model.

Variables	VIF
LGP temperature	5.41
LGP temperature sq	5.05
LGP rainfall	6.41
LGP rainfall sq	6.35
Altitude (m.a.s.l)	4.35
Latitude (^{0})	3.14
Sandy soil (1/0)	2.11
Sandy clay soil (1/0)	1.66
Clay (Red) soil (1/0)	2.69
Loam (Black) soil (1/0)	1.97
Farm size- (Teff: other crops) (hectare)	1.26
Distance from Input market (km)	5.19
Distance from Output market (km)	4.95
Access to Extension (1/0)	1.09
Access to formal credit (1/0)	1.17
Family size	1.23
Education of household head (years in schooling)	1.25
Mean VIF	**3.25**

Appendix 3: Modeled Forecast for NR/ha Impacts based on mid-range Scenario (US$) for Temperature and Rainfall:

Climate Variable	Year	Magnitude of the Change	NR/ha Level
Temperature (^{0}C)			
	Baseline(2012/13)	-	-585.30
	2030	1	-617.81
	2050	1.9	-647.06
	2080	3.05	-684.44
Rainfall (%)			
	Baseline(2012/13)	-	54.46
	2030	2.75	55.97
	2050	5.20	57.32
	2080	8.45	59.10

Appendix 4: Survey Questionnaire

Part 1: General information

1. I) Questionnaire Number ________ II) District/*Wereda* ________________

   III). PA ________________ IV) Residence locality (*Gote*) __________

2. Please indicate/encircle location of the farm;

   1= Highland/*'Beda'*

   2= Midland /'Bade dare'
   3= Low land /'*Gamojjii'*

3. Fill the following household roster/information's

SN	Name of the hh head	Current residence	Sex	Age of the hh in years	Education level	Years in school	Working on the farm	Main activities of the household
		1.Always at home 2.Temporarily away	1=male 2=Female		1.Illiterate 2.Primary 3.Secondary 4.Beyond secondary 5.other(specify)		1=Doesn't participate in the farming 2=Rarely participate 3=Always participate	1=crop production 2=livestock production 3=both crop and livestock production 4=fishing 5=casual labour 6=salaried job 7=Artisan 8=own business 9= student 10=others (mention)

4. Size of your household, i,e the number of people , including yourself , who live in your house ______ persons.

5. Were you born in this village (encircle)? 1= Yes 2=No

6. In case you were not born in this village ,fill in the following table

Migrated from(1=Neighbouring rural area, 2=district 3=Regional/city)	Year of migration	Reason for migration*

* Reasons for migration:
1=marriage 2=accompanied parents
3=farming in rain fed served areas 4=farming in irrigated served areas
5=farming in rainwater served areas 6=employment transfer
7=searching for wage work 8=other specify

7. Do you have access to extension services on teff production?
1 = Yes 2 = No

8. Do you have access to formal credit to run your teff farming activities?
1 = Yes 2 = No

9. If 'YES' for the access of formal credit, where is the source of the credit (Name the source)

Part 2: Farmers perception on climate change impact

1. Are you aware that climate change is taking place? 1= Yes 2=No

2. What do you feel about the state of climate variables over the past ten / twenty years? /encircle the choice/

Temperature	1. Increases	2. Decreases	3. No changes(Remained the same)
Precipitation /Rainfall	1. Increases	2. Decreases	3. No changes

3. The threat of climate change is more on /encircle(s) the choice/

1. Health
2. Agriculture production
3. Both health and agriculture production
4. Fuel wood availability
5. Biodiversity

KINDLY USE THE OPTION BELOW TO ANSWER THE FOLLOWING QUESTIONS ACCORDING TO YOUR LEVEL OF AGREEMENT OR DISAGREEMENT (Write the choice in front of each of the questions)

STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONG DIS AGREES
5	4	3	2	1

	Questions	Level of Agreement or Disagreement
•	Climate change has brought a very big impact on teff production	
•	Variations in climate has caused an increase in incidences of floods during the raining season	
•	Shifts in rainfall seasonality have caused crop failures and low yield.	
•	Some crop varieties have no longer been productive due to persisted droughts in the area.	
•	Climate change has led to crop pest and diseases infestation due to droughts	
•	Climate change has led to rural-urban migration.	
•	Excessive rainfall contributes to destruction of buildings and infrastructures	
•	Flood does not contribute to soil erosion	
•	Water becomes scarce and dried due to droughts and low rainfall	
•	Yield loss of crops is the results of drought	
•	Climate variability has impact on rain fed production	
•	Decrease in rainfall reduce water stored in bands	
•	Climate change has led to the deforestation	
•	The cost of food crops are increasing because of climate change.	

Part 3: Farm level characteristics and Soil indicators. /encircle the choice/

1. What type of production system are you using?
   1=Rain fed 2= Rainwater harvesting
   3= Irrigation 4= Rain fed supplemented with irrigation
2. Do you have a farm experience? 1= Yes 2= No
3. For how long have you been involving in crop cultivation?
   1= Less than 5 years 2 = 5 to 10 years 3= More than 10 years
4. Type of soil texture in your farm
   1= sandy 2=clay loam
   3=sandy clay 4= Clay 5= Loam
5. What is the soil colour of your farm?
   1= Reddish 2= Brown
   3= Black 4= Gray
6. Is it suitable for production? 1. Highly suitable 2= Suitable 3= Not suitable
7. If yes, what is the extent of water holding capacity 1= High 2= Low 3= Moderate
8. Do you have a reliable supply of seeds for the crops you grow? 1= Yes 2= No.
9. If NO, what makes it difficult for you to obtain the type of seeds you want? ....
10. What type of teff seeds are you using? (* Please name the seed)
    1= improved 2= moderate
    3= poor 4=Local

Part 4: Adaptations and constraints of Adaptations/encircle the choice/

1. Have you made any adjustments to reduce the impacts of climate change on specific for teff production? 1. Yes 2. No
2. What strategies you adapting to fluctuations in climate specific to teff production?

1. Grow drought tolerant crops	6. Changing to irrigation farming
2. Early mature crops	.7. The use of chemical fertilizer
3. Crop diversification	8. Improve in water maximization

4. Switching from farm to off farm activities   9. Changing in plant dates

5. Mulching   10. Use of Compost

11. Others (Specify) ………………….

3. What are the perceived hindrances to adaptation of modern techniques of combating climate change (with reference to teff production)

1. Lack of improved seeds   5. Lack of capital to acquire modern techniques

2 .Lack of access to water for irrigation   6. Lack of Credit access

3. Lack of current knowledge on adaptation methods   7. There are no hindrances

4. Lack of information on weather incidence   8. Others (Specify)………………

Part 5: Plot Level Information (Yield, Costs of production, for the season (2012/13):

1. Total Farm size(2012/13) ________ (hectares)

Plot no.	Size (ha)	Land tenure	Ownership (who owns)	GPS Points			Other main Crops grown	Adaptation measures					Yield/plot		Seasonality	Amount sold(kg)		Market price		Amount consumed (kg)	
								Agriculture Water management		Other measures			Teff	Other main crops	1.Good 2.Normal 3.Bad	Teff	Other crops	Teff	Other main crops	Teff	Other main crops
				Alt.	Lat.	Long.		Water Harvesting	Irrigation	Rain fed	SWC	Mention (**others**)									
1																					
2																					

3																					

Table information:

- Land tenure: 1.owned –inherited 2.Owned-bought 3.Owned-gifted 4.Not owned-borrowed 5.Not owned –rented in.
- Ownership; 1=husband 2=wife 3=joint (husband and wife) 4.children 5.family.
- Soil water conservation: 1.Rainfed 2. Tillage 3.Bunds 4.Ripping (deep tillage)
- Others:

1. Drought tolerant 6. Planting different crop varieties
2. Early mature crops 7. Mulching
3. Crop diversification 8.Changing to irrigation farming
4. Off farm activities 9. Use of chemical fertilizer
5. Shortening growing season 10. Cultivating different crops
6. Improve in water maximization 11. Changing in planting dates

2. Seasonal Information

Plot No.	BAS (Below average season) Year (EC):				AVS (Average season) Year (EC):				ABS (Above average season) Year (EC):			
	Crop	Yield (Qunt.)	Price (Br)	Revenue(Br)	Crop	Yield (Qunt.)	Price (Br)	Revenue (Br)	Crop	Yield (Qunt.)	Price (Br)	Revenue(Br)

Bad Vs
Season Reve

3. Production Costs

Direct cost and Family labour inputs: Family labour=people (A.E)*Effective days *Effective hours
A.E=Adult Equivalent(1=A person of 15 and above years of age; A child of 10-14 years of age will be equated to 0.5 of an adult equivalent

Plot no	Activity								
		Type of labour	Famil	Number	Number of	Cost of	Qty/Amount	Cost/Unit	Total cost

		1=Family 2.Exchange 3.Hired labour 4.Both family and hired	y labour	of persons	days used	labour per plot.	(bags/kg/litre	eg. Br/bag	
1.	Bands construction								
	Land renting								
	ploughing								
	Planting								
	cultivating								
	Seeds								
	weeding								
	fertilization								
	spraying								
	Harvesting								
	Storage								
	Water fees								
	Transportation								
2.	Bands construction								
	Land renting								
	ploughing								
	Planting								
	cultivating								
	Seed								
	weeding								

	fertilization								
	spraying								
	Harvesting								
	Storage								
	Water fees								
	Transportation								
	Bands construction								
	Land renting								
	ploughing								
	Planting								
3.	cultivating								
	Seed								
	weeding								
	fertilization								
	spraying								
	Harvesting								
	Storage								
	Water fees								
	Transportation								

4. Is this production sufficient for your household for a year?
   i) Sufficient ii) Not Sufficient
   iii) Surpluses iv) I don't know
5. Are you able to feed yourself from own produced food throughout the year until the next harvest? 1= Yes 2= No
6. Compare the period before and after involvement in /use of Improved Varieties of Teff /other adaptation strategies , is your household
   1= more secure food 2= no change 3= less food secure
7. Changes in your agricultural income after commencement of adaptation strategies like use of improved varieties of teff, irrigation scheme?
   1= increased 2= remained the same 3= declined
8. For either answer, provided above give an explanation (Why?) ____________
9. Did you experience any problems in producing Teff last year? 1. Lack of Improved Varieties 2. Capital constraints 3.Animal damage 4.theft of produce
   5. Other specify ________________

Part 6: Farm Productive and Livestock assets:

1. For how long have you been involved in livestock husbandry?
   1= Less than 5 years,
   2= 5 to 10 years
   3= More than 10 years

Why do you keep livestock?

1= For commercial

2= For domestic purpose

3= Both above

Please indicate the type and number of non- working livestock the household owns.

Type of livestock	Number		Value(Average price)		Type of produce(eg. eggs)	Amount produced (Specify units)	Amount sold (Specify units)	Selling price per unit (Specify units e.g. Br/litre)	Amount consumed
	Young animals	Adult animals	Young animal	Adult animal					
Cattle									
Sheep									
Goats									
Horse									
Poultry									

Other(specify)									

Part 7: Off-farm Activities:

1. What is the main source of income;
   1. Crop production 2. Livestock keeping
   3. Off farm activities 4.others specify
2. How much money does your household earn from the following income sources on a monthly basis?

Source of income	Monthly income in Br.(ETB)
Business	
Wages and salary	
pensions	
Income from renting land	
Remittances from family/friends(monetized &in-kind terms)	
Salary from employment	
Other(specify)	

Part 8: Assets based wealth:

1. What is your form of financial asset 1.Savings 2. Money from credits 3. Support

2. A. Please provide information on the following key productive assets

Type of assets	Number owned	Working status: 1=most of them working properly 2=working moderately 3=working improperly 4=not working	Total value (Monetary value)
Land			
Machete /knife			
Ox-plough, weeder,riper			
Wheel barrow			
Oxen			
Tractor			

Sprayer			
Watering can			
Irrigation pump/Treadle pump			
Pick-up/lorry			
Warehouse/storage structure			
Hand hoe			
Slasher			
Rake			
BBM(Broad Bed Maker)			
Other(specify)			

3. Activities Vs Family Responsibility

Activities	Husband	wife	both	children		family
				boys	girls	
Land ownership						
Farming activities						
Cost of production						
Accrued benefit						
Livestock ownership						
Production asset						
Family labour						
Hired labour						

4. Consumable assets and amenities for measuring long-term wealth (to be used to develop wealth index based filmer and pritchet)

- What is the roofing material of the main house?

1. Mud/cow dung
2. Corrugated iron sheets
3. Leaves/Grass
4. Timber/wood
5. Other specify

____

- What is the wall material of the main house?

1. Mud/cow dung/
2. raw bricks
3. Wood/bamboo
4. Stones
5. Iron/material sheets
6. Burnt bricks
7. Cement blocks
8. Other (specify)

____

- How many sleeping rooms does this main house contain ___________
- Is there any other dwelling apart from this main house which is used for sleeping?
  1. Yes 2. No

- What is floor material of the main house?

1. Earth
2. Cement
3. Other (specify)

____

- What kind of toilet is mostly used?

1. No any toile
2. Pit latrine uncovered
3. Pan/bucket
4. Own flush toilet
5. Pit latrine covered
6. Shared flush toilet
7. Other(specify)

____

- What is the main source of energy for cooking?

1. Firewood
2. Electricity
3. Charcoal
4. Crop residues
5. Paraffin
6. Animal dung
7. Gas
8. Other (specify)

____

- What is the main source of energy for lighting?

1. paraffin
2. Gas
3. Electricity
4. Generator
5. Candles
6. Battery
7. Firewood
8. other (specify)

- What is the major source of water for drinking?

1. piped in dwelling
2. piped outside dwelling
3. public tap
4. bore-hole
5. protected well/spring
6. unprotected well/spring
7. rain water
8. vendor/tanker truck
9. river/lake /stream
10. other (specify)

- Does the household own any of the following items?

No.	Item	Quantity
1	lorry/pickup/ luxurious car	
2	Motorbike	
3	Television	
4	Bicycle	
5	Radio	
6	Bed	
7	Iron	
8	Mobile phone	
9	Landline phone	
10	Sofa	
11	Spongy mattress	
12	Wrist/wall watch	
13	Other(Spec.)	

‘‘THANK YOU VERY MUCH FOR SHARING US FROM YOUR VALUABLE TIME’’!!

- Name of the enumerator: ______________________________
- Signature: ________________ Date(GC): ____________________