LAND USE PATTERN, CLIMATE CHANGE AND ITS IMPILICATION ON FOOD SECURITY IN GURAGHE ZONE:

BY

SHAFI HUSSEN

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A THESIS SUBMITTED TO THE DEPARTMENT OF ECONOMICS, COLLEGE OF BUSINESS AND ECONOMICS, SCHOOL OF GRADUATE STUDIES WOLKITE UNIVERSITY IN PARTIALS FULFILLMENT OF THE REQUIREMENTS FOR MASTER OF DEGREE IN ECONOMICS

JANURY, 2019

WOLKITE, SOUTH ETHIOPIA

WOLKITE UNIVERSITY

SCHOOL OF GRADUATE STUDIES

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Declaration

I, Shafi Hussen, declare that this thesis entitled: **"Land Use Pattern, Climate Change and its Implications on Food Security in Guraghe Zone,SNNPR, Ethiopia"** is outcome of my own effort study that all sources of materials used for the study have been dulyacknowledged. To the best of my knowledge, this study has not been submitted for any degree in this Universityor any other University. It is offered for the partial fulfillment of the degree of Masters ofBusiness Administration.

By: (Shafi Hussen)

Signature---

Date--

ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "***Land Use Pattern, Climate Change and its Implications on Food Security in Guraghe Zone , SNNPR, Ethiopia"*** submitted in partial fulfillment of the requirements for the degree of **Master's**in Economics**,** the Graduate Program of the **Department/School of Economics,** and has been carried out by Id. No 138/09, under my/our supervision. To the best of my knowledge, is an original work and not submitted earlier for any degree either at this University or any other University.

Therefore I recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

Name of major advisor-Bedassa Wolteji (PhD)

Signature------ ---

Date 08/01/2019

Name of Co- advisor Biruk Birhanu (MSC**)**

Signature

Date 08/01/2019

EXAMINERS' APPROVAL SHEET

==

We, the undersigned, members of the Board of Examiners of the final open defense by Shafi Hussen have read and evaluated his/her thesis entitled "***Land Use Pattern, Climate Change and its Implications on Food Security: A Case of Guraghe Zone, SNNPR, Ethiopia***", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree .of Master in Developmental Economics.

Name of the Chairperson -------------------------------------Signature-------- Date-------

Name of Major Advisor Bedassa Welteji(PhD) Signature - Date 08/01/2019

Name of Internal Examiners-Solomon F.(PhD candidate) Signature______________ Date---

Name of External examiner-Admasu(PhD) Signature ------ Date------------------------

SGS Approval Signature------------------------------------ Date--------------------------

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

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ACRONOMY

AEM	Agronomic-Economic Models
AEZM	Agro-Ecological Zone Models
CO2	Carbon Di Oxide
CSA	*CENTRA STASTICS AGEINCY*
EA	Enumeration Area
EMA	ETHIOPIA METROLOGICAL AGEINCY
FAO	Food and Agricultural Organization
GDP	Growth Domestic product
IFPRI	International Food Policy Research Institute
IAM	Identify Access Management
IPCC	Intergovermental Panel on Climate Change
LULCC	Land use land coverage change
SNNPR	Southern Nations Nationalities & PeoplesRegion
UNDP	United Nations DevelopmentProgram
UNFP	United Nations PopulationFund
UNIDO	United Nations Industrial Development Organization

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Abstract

It is widely recognized that climate variability and frequent droughts resulting from El-Nino phenomenon are among the major risk factors affecting agricultural production that might contribute to hunger and food insecurity in East Africa in general and Ethiopia in particular. The objectives of the present study were to examine the implication of land use pattern climate change and its implication on food security in Guraghe Zone, SNNPRS, Ethiopia. This study is based on Zonale level data of the study area based on major seasonal crops- Maize, Wheat, Barely, Sorghum, Teff and Potato which comprise of food crops for the time span of 2000 to 2010 (CSA). Using secondary data both descriptive statistics (mean, standard devotion, and t-test) and liner regression model were used to analyze the data. Crop productivity in quintals per hactar is chosen to be the Dependent variable whereas cropping area, yield, average annual maximum and minimum temperatures, rural house holders, total forest area, average annual rainfall are the Explanatory variables. Rainfall positively contributed to the production of maize crop and was significant. Maximum humidity contributed positively, it showed a significant influence on maize yield. The results of study also indicate a positive influence of rainfall on overall productivity. A 1% increase in the rainfall leads to a 0.889% increase in the yield of crops. However, the adjusted R^2 value showed 47% variability in the production of maize crop. According to this study, the observed mean yield of the six crops in ascending order is as follows:sorghum, barley, maize,teff, wheat, and potato. In the case of average production, maize ranked first, potato ranked second, barely ranked third and wheat,teff and sorghum fourth , fifth and six place, respectively.

The linear regression that adoption of soil conservation, small-scale irrigation and employing different agronomic practices are important factors influencing household crop productivity. Moreover, land holding and forest are positively and significantly affected household'scropproductivity. The results further showed that population pressure was important factors affecting crop productivity in the inverse direction. This study further highlighted the significance of cropping area in attaining crop productivity under changing climate. The findings call for action based on growing improved crop seed to increase food crop productivity.

Key words: Land use pattern, food securityand climate change.

1. INTRODUCTION

1.1. Background of theStudy

Land use and land cover change (LULCC) is an important factor responsible for observed global environmental changes (Foley 2005, Pongtraz 2010, Ellis 2011).There is no internationally agreed definition of the term climate change, which has resulted in differences of opinion on the issue. Climate change can refer to long term changes in average weather conditions covering all changes in the climate system, including the drivers of change, the changes themselves and their effects.

According to World Food Summit of 1996, Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Although there is a strong link between climate and LULCC, the dynamics of land use change is not explicitly represented in regional and global climate models, partly due to the difficulties in formulating the human decision-making processes influencing anthropogenic land use (Pielke 2011, Rounsevell 2014). Also because of their rather complex modeling framework with different sources of uncertainties involved, it is difficult to engageidentify access managementin assessing relative roles played by climate and socioeconomic changes in projected LULCC (Ackerman, 2009&Rounsevell, 2014).

While agricultural land use is directly responsible for the human-induced land cover change, implication of zonal climate change on future crop productivity can play an important role in crop area expansion influencing local and zonal agricultural practices. Therefore, assessment of climate change implication on crop yield and the consequent changes in the distribution of crop area in zone is great importance in evaluating the land-atmosphere interaction on a local or zone scale. Many agricultural regions across the globe have already observed significant changes in crop yield variability over the past few decades (Osborne and Wheeler, 2013). Nevertheless, previous studies projecting the climate change implication on agriculture have overwhelmingly focused on the mean yield of various crops, with little attention paid to how the inter-annual variability of crop yield might change in futureclimate.

Sub-Saharan Africa is extremely vulnerable to climate change implication because of its large dependence on natural resources, fragile economic infrastructure and limited capacityfor mitigation and adaptation. Although local crop production provides the majority supply of staple foods, mostly rain fed agricultural system in east Africa is not prepared to adapt to projected future climate. Various studies predicted significant reduction in productivity of the major crops in the region under the changed climate scenario unless new technology and adaptation policy can counteract the adverse effect of climate variability (Schlenker and Lobell 2010, Knox 2012, Ahmed et al. 2015). Also in Ethiopia, more than 80% of the agricultural growth since 1980 was attributed to crop area expansion instead of increase of productivity over already existing agricultural land (The World Bank, 2008).

Considering the vulnerability of agricultural infrastructures in the SNNP region, despite the potential scope of improving yield to minimize land use change, addition of new crop area is likely to be a prevailing strategy for agricultural growth in the near future. Therefore, comprehensive analysis of crop response to regional climate changes should be included in investigating future land use changes, and the resulting feedback to regional climate. Directly addressed the climate change implication on crop yield and crop area distribution in evaluating land use- climate interaction in Guraghe Zone.

Guraghe Zone has densely populated area and subsistent farming system. The problem of Deforestation and have less use of drought resistant seeds of crops. Even it has river resources it is not use irrigation by full potential of small scale irrigation system. Due to this the study area has problem of food insecurity, Poor soil and water conservation skill & practice, Deforestation, Drought porne area, Environmental vurnalability, low intensity of rain fall, Low practice of moisture conservation mechanisms and Stugnant children development and also malnutrition of children due to this my study has the contributions and set policy recommendation to address the mentioned problems.

The motivation of this study stems from the several gaps of knowledge identified above which need to be filled for comprehensive assessment and quantification of land use- climate feedback in the context of potential climate-induced changes in future crop yield and agricultural land use in Guraghe Zone.

1.2. Statement of theproblem

Agriculture has played a crucial role in the growth and economic well-being of the nation. Even though the share of agriculture sector has reduced in the total GDP, the sector still stands strong and is of utmost importance to all the other sectors. It is also mentioned that the increasing dependence of the farmers on uncertain makes agriculture productivity in Ethiopia vulnerable Abebe Tadeg (2008). Climate change not only influences the eco system including the forests, sea levels and rivers but also the socio-economic system consisting of agriculture. Further, there is a dire need to produce sufficient amount of food grains to meet the demands of the multiplying population and to save the farmers who solely depend on agriculture for their livelihood. Thus, it is imperative to carry out a research on effect of land use pattern climate change on food crop production due to the drastic changes in precipitation and temperature (IPCC,2007).

The problem of Deforestation and have less use of drought resistant seeds of crops, it has river resources is not use irrigation by full potential of small scale irrigation system, Poor soil and water conservation skill & practice, Environmental vurnalability, low intensity of rain fall, Low practice of moisture conservation mechanisms.

An important premise behind this study is that, while peoples are not yet in a position to focus on how climate may change (either on the short or on long term) one can estimate the potential consequences of each of a number of possible climate changes. By considering the range of implication on crop productivity in the study area it is possible to improve both on techniques of implication analysis and armory of potential responses. Ayele (2000) states that, the starting point for understanding the effect of future climate variables needs understanding of the current situation. The above author emphasizes that we have the tools. Hence, more effort is needed to make the data available, build climate analysis into every agricultural project and bring relevant and accurate climate information to farmers.

This study makes an attempt to analyze the implication of land use pattern climate change and its implication on majior food crop productivityin Guraghe Zone. It examines the implications of climate change for food crop productivity. The expected crop yield losses due to climate change would therefore implication on their already low level of income, and left without any alternative source of income, the situation would lead to increased poverty and foodinsecurity. Climate variability, specifically rainfall patterns resulting from climate change may result in decrease yield of crops. The reduction in crop yields may lead to higher prices for food, which could trigger zonale food crises. These would lead to greater food insecurity causing political instability, increasing the stakes for control over productive agricultural land. Consequently, climate change by redrawing the map of water availability, food security and disease prevalence and loss of income source could increase forced migration, raised tensions and trigger conflict. Therefore the pattern of vulnerability to climate change on land use and food security is worrisome.

This lead to the following research questions:

1.3. Research Question

1) What is the implication of climate change on majior crop production in Guraghe Zone?

2) Does the implication of climate change on productivity differ in the type of crop in the study area?

3) How land use pattern linked to crop productivity?

4) Do households associate crop productivity with climate variability?

1.4. Objective of the Study

1.4.1. General Objective

The general aim of this study was to analyze land use ,climate change and its implication on food security in Guraghe Zone.

.1.4.2 Specific objectives

1. To identify the implication of climate change on majior crop production in Guraghe Zone.

2. To examine the effect of land use pattern on foodcrop productivity in the study area.

3. To see the relation how climate change and land use pattern linked with foodcrop productivity?

1.5. Significance of the Study

The study is expected to be highly significant because problems related to crop productivity are the current development issue of the country and therefore studying the land use pattern climate change and its implication to food security of the study area in general are extremely relevant which require timely and appropriate response to bring about sustainable development through working for meeting the livelihood and crop productivity needs of the area.To recommend policy issue related to land use pattern climate change and its implication for food security.

After studying these issues, it is aimed to show the access level of levlielihood resources, their crop productivity status, their livelihood strategies and related issues to the governmental and nongovernmental organizations, stakeholders and to development planners so that they will take policy intervention measures.

Furthermore, the work will also give clear picture of Guraghe Zone general profile in social, physical, and economic aspects which is expected to invite development actors and stakeholders to the area to play roles for promoting the required development efforts needed to reach the final development goals which are useful for the study area in particular and the country in general. The motivation of this study stems from the several gaps of knowledge identified above which need to be filled for comprehensive assessment and quantification of land use- climate feedback in the context of potential climate-induced changes in future crop yield and agricultural land use in Guraghe Zone.

1.6. Scope and Delimitation of the study

The study would focus on the land use pattern, climate change and its implication on food security in Guraghe Zone. The thematic boundaries of the study are challengesof land use pattern, climate change and its implication on food security.Delimitation of these studies is their modeling of land use change which is often done at the country, Agro ecological zones or coarse grid level. Such an aggregated approach fails to capture the local level determinant of land use change, such as infrastructure, population density, elevation, and soil quality is not able present spatially explicit outcomes (maps) to measure and use in Ethiopia.

1.7 ORGANIZATION OF THE STUDY

The thesis had five chapters. Chapter one is organized as Background of the study, statement of the problem, research question, objectives of the study, significance, scope, Limitations of the study, organization of the study. Chapter two discusses the key concepts usedIn the paper to place the problem in a theoretical and empirical perspective as well as conceptualFramework and related studies. Chapter three is focuses on methodology, and method of data analysis. Chapter four describes the Result and discussion of the data. Finally, chapter five summarizes the main findings, conclusions as well as commendations.

2. LITERATURE REVIEW

2.1. Definition and concept

Land cover refers to the physical and biological cover over the surface of the land.Much of the world's natural land cover has been transformed by human activities (Morton *et al.*, 2006), resulting million km^2 of grassland areas and 6 million km^2 of forest/woodland have been converted to cropland worldwide since 1850 (Lambin *et al.*, 2003), and the main purpose for land use change is to obtain food and other essentials. In Ethiopia, land use can be seen from the perspective of human activities such as agriculture, forestry, building construction, and recently, industrialization which has led to increased human population within urban areas and depopulation of rural areas. The driving forces behind land use pattern include all factors that influences human activity, including local culture (food preferences), economics (demand for specific products, financial incentive), environmental condition (soil quality, terrain and moisture).

In Ethiopia, biodiversity is an important resource having a dual purpose of utilization; consumptive use (food, fiber, fuel, shelter, medicine and wild life trade) and non-consumptive use (ecosystem services and economically important tourism industry). Given the heavy dependence of Ethiopia on natural resources, many communities are vulnerable to the biodiversity loss that could result additionally due to climate change. The use of fire as a management tool for slash-and-burn agriculture and other purposes results in at least a third of the savanna being burned every year (IPCC, 2000). Forest fires contribute to climate change and may result to significant ecosystem change that could affect biodiversity significantly. Land use pattern therefore contributes to global warming, leads to habitat conversions and fragmentation which directly implicationbiodiversity. The implication of climate change on biodiversity would be further compounded by the climate induced alterations of agriculture (FAO,1999).

The implication of climate change on biodiversity would be further compounded by the climate induced alterations of agriculture (FAO,1999)

2.1.1. Land use effect on small holder production

In Ethiopia crop production is increased recently through intensive and extensive agriculture systems. The intensification of agriculture and the expansion of croplands into marginal lands which is dominated by the traditional system/practices have led to severe land degradation (Hurni, 1988). Several studies have been done at the national level; theHighland Reclamation Studies: Ethiopia (EHRS-FAO 1986), the National Conservation Strategy Secretariat (Sutcliffe 1993) and Ethiopian Forestry Action Plan (1993) all to estimate the level of land degradation. The studies show that, 30,000 ha is lost annually due to water erosion with over 2 million ha already severely damaged (National Review Report, 2002), United Nation Development Project in 2002 reported a nutrient depletion of 30kg/ha of Nitrogen and 15-20kg/ha of phosphorus, while a loss of 62,000 ha of forest and woodland annually have been reported by World Bank in 2001. All physical and economic evidence show that land degradation and the loss of land productivity is an important problem in Ethiopia.

2.2. Concepts and definitions of climate change

Most people define "climate change" as the alteration of the world's climate that humans are causing, through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. However, scientists often use the term for any change in the climate, whether arising naturally or from human causes.

Climate change inintergovernmental panel on climate change usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (IPCC, 2007). Each of these two definitions is relevant and important to keep in mind.

When dealing with issues of climate change, it is important to understand the different terms used as "packages" in understanding the system. Accordingly, "climate variability" is the fluctuation in climatic parameters from the normal or baseline values, whereas "climate change" is a change in the long-term mean value of a particular climate parameter (Abebe Tadege, 2008).

2.2.1. Components of climate and climate system

Climate involves variations in which the atmosphere is influenced by and interacts with other parts of the climate system and external forcing (Lovejoy and Hannah, 2005).The internal interactive components in the climate system include the atmosphere, the oceans, sea ice, the land and its features(including the vegetation ,albedo ,biomass and ecosystems), snow cover ,land ice, and hydrology(including rivers, lakes and surface and subsurface water). The components normally regarded as external to the system include the sun and its output; the earth's rotation; sun -earth geometry and slowly changing orbits; and the physical components of the earth system. Rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth's atmosphere (UNFCCC, 2007). Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human implication on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions (IPCC, 2007)

There are also seasonal and longer time scale linkages due to the earth's rotation which are often referred as climate system tele-connections. According to(Lovejoy and Hannah, 2005) the best known of tele-connectios is the El Nino phenomenon; a major redistribution of planetary heat andoisture occurs in the atmosphere and ocean about every three to seven years through a phenomenon centered in the equatorial pacific and its opposite phase as Lalina. El Nino is the dominant cause of droughts and floods in various parts of the world. It also plays important role in modulating carbon dioxide exchange with the atmosphere. Moreover El Nino is accompanied by change in the atmospheric pressure and winds throughout the tropics and subtropics called southern oscillation which is combined with ElNino and give rise to coupled mode of climate system called

El Nino-Southern oscillation (ENSO).This in turn has implication on atmospheric convection and rainfall and thereby change atmospheric heating patterns.

The atmosphere connects all weather systems and all climates, it is sometimes useful to describe the atmosphere, oceans and Earth surface as the "global climate system" (UNISDR, 2008). Because the climate system is in a constant state of flux and has always exhibited natural fluctuations and extreme conditions, it is not possible to argue that any single extreme event is attributable to climate change. Only after a sufficient period and with hundreds of extreme events recorded can scientists determine if a specific event is within normal historical variation or is due to some other cause such as climate change.

2.2.2. Causes of climate change

Climate change occurs as a result of both internal variability within the climate system and external factors. The external causes may be natural or induced by human activity. The primary cause of climate change is increase in the concentration of carbon dioxide and other greenhouse gases in the atmosphere because of human activities mainly fossil fuel burning and removal of forests (Lovejoy and Hannah,2005). At global scale, the main cause of greenhouse gas (GHG) emissions is from carbon dioxide (70%), primarily from burning of fossil fuel (petroleum) imported from industrialized countries, while the other sources for GHG are methane(CH_4) and nitrous oxide(N_2O) caused by deforestation and agricultural activities, particularly the use of pesticides(Yohannes Gebre Michael and Mebratu Kifle, 2009).

Rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth's atmosphere (UNFCCC, 2007). Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human implication on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions (IPCC, 2007)Humans are increasingly influencing the climate and the earth's temperature by **burning fossil fuels, cutting down rainforests and farming livestock**.

This adds enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming.

Greenhouse gases

Some gases in the Earth's atmosphere act a bit like the glass in a greenhouse, trapping the sun's heat and stopping it from leaking back into space.

Many of these gases occur naturally, but human activity is increasing the concentrations of some of them in the atmosphere, in particular:

- carbon dioxide (CO_2)
- methane
- nitrous oxide
- fluorinated gases

CO_2 is the greenhouse gas most commonly produced by human activities and it is **responsible for 64% of man-made global warming**. Its concentration in the atmosphere is currently 40% higher than it was when industrialisation began.

Other greenhouse gases are emitted in smaller quantities, but they trap heat far more effectively than CO_2, and in some cases are thousands of times stronger. **Methane** is responsible for 17% of man-made global warming, **nitrous oxide** for 6%.

Causes for rising emissions

- **Burning coal, oil and gas** produces carbon dioxide and nitrous oxide.
- **Cutting down forests (deforestation).** Trees help to regulate the climate by absorbing CO_2 from the atmosphere. So when they are cut down, that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding to the greenhouse effect.
- **Increasing livestock farming.** Cows and sheep produce large amounts of methane when they digest their food.
- **Fertilisers containing nitrogen** produce nitrous oxide emissions.

- **Fluorinated gases** produce a very strong warming effect, up to 23 000 times greater than CO_2. Thankfully these are released in smaller quantities and are being phased down by EU regulation.

Global warming

TThe current **global average temperature is 0.85ºC higher** than it was in the late 19th century. Each of the past three decades has been warmer than any preceding decade since records began in 1850.

The world's leading climate scientists think human activities are almost certainly the main cause of the warming observed since the middle of the 20^{th} century.

An increase of 2°C compared to the temperature in pre-industrial times is seen by scientists as the threshold beyond which there is a much higher risk that dangerous and possibly catastrophic changes in the global environment will occur. For this reason, the international community has recognised the need to keep warming below 2°C.

The greenhouse effect causes the atmosphere to retain heat

When sunlight reaches Earth's surface, it can either be reflected back into space or absorbed by Earth. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). Greenhouse gases like water vapor (H_2O), carbon dioxide (CO_2), and methane (CH_4) absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the "greenhouse effect."

The role of the greenhouse effect in the past

Over the last several hundred thousand years, CO_2 levels varied in tandem with the glacial cycles. During warm "interglacial" periods, CO_2 levels were higher. During cool "glacial" periods, CO_2 levels were lower.[2] The heating or cooling of Earth's surface and oceans can cause changes in the natural sources and sinks of these gases, and thus change greenhouse gas concentrations in the atmosphere.[2] These changing concentrations are thought to have acted as a positive feedback, amplifying the temperature changes caused by long-term shifts in Earth's orbit.[2

The recent role of the greenhouse effect

Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. These greenhouse gas emissions have increased the greenhouse effect and caused Earth's surface temperature to rise. The primary human activity affecting the amount and rate of climate change is greenhouse gas emissions from the burning of fossil fuels.

The main greenhouse gases

The most important GHGs directly emitted by humans include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several others. The sources and recent trends of these gases are detailed below.

Carbon dioxide

Carbon dioxide is the primary greenhouse gas that is contributing to recent climate change. CO_2 is absorbed and emitted naturally as part of the carbon cycle, through plant and animal respiration, volcanic eruptions, and ocean-atmosphere exchange. Human activities, such as the burning of fossil fuels and changes in land use, release large amounts of CO_2, causing concentrations in the atmosphere to rise.

Atmospheric CO_2 concentrations have increased by more than 40% since pre-industrial times, from approximately 280 parts per million by volume (ppmv) in the 18th century to over 400 ppmv in

2015. The monthly average concentration at Mauna Loa now exceeds 400 ppmv for the first time in human history. The current CO_2 level is higher than it has been in at least 800,000 years.[2]

Some volcanic eruptions released large quantities of CO_2 in the distant past. However, the U.S. Geological Survey (USGS) reports that human activities now emit more than 135 times as much CO_2 as volcanoes each year.

Human activities currently release over 30 billion tons of CO_2 into the atmosphere every year.[2] The resultant build-up of CO_2 in the atmosphere is like a tub filling with water, where more water flows from the faucet than the drain can take away.

Methane

Methane is produced through both natural and human activities. For example, natural wetlands, agricultural activities, and fossil fuel extraction and transport all emit CH_4.

Methane is more abundant in Earth's atmosphere now than at any time in at least the past 800,000 years.[2] Due to human activities, CH_4 concentrations increased sharply during most of the 20th century and are now more than two-and-a-half times pre-industrial levels. In recent decades, the rate of increase has slowed considerably.[2]

For more information on CH_4 emissions and sources, and actions that can reduce emissions, see EPA's Methane page in the Greenhouse Gas Emissions website. For information on how methane is impacting the Arctic, see the EPA report Methane and Black Carbon Impacts on the Arctic.

Nitrous oxide

Nitrous oxide is produced through natural and human activities, mainly through agricultural activities and natural biological processes. Fuel burning and some other processes also create N_2O. Concentrations of N_2O have risen approximately 20% since the start of the Industrial Revolution, with a relatively rapid increase toward the end of the 20th century.[2]

Overall, N_2O concentrations have increased more rapidly during the past century than at any time in the past 22,000 years.[2] For more information on N_2O emissions and sources, and actions that can reduce emissions, see EPA's Nitrous Oxide page in the Greenhouse Gas Emissions website.

Other greenhouse gases

- Water vapor is the most abundant greenhouse gas and also the most important in terms of its contribution to the natural greenhouse effect, despite having a short atmospheric lifetime. Some human activities can influence local water vapor levels. However, on a global scale, the concentration of water vapor is controlled by temperature, which influences overall rates of evaporation and precipitation.[2] Therefore, the global concentration of water vapor is not substantially affected by direct human emissions.
- Tropospheric ozone (O_3), which also has a short atmospheric lifetime, is a potent greenhouse gas. Chemical reactions create ozone from emissions of nitrogen oxides and volatile organic compounds from automobiles, power plants, and other industrial and commercial sources in the presence of sunlight. In addition to trapping heat, ground-level ozone is a pollutant that can cause respiratory health problems and damage crops and ecosystems.
- Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), together called F-gases, are often used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. Unlike water vapor and ozone, these F-gases have a long atmospheric lifetime, and some of these emissions will affect the climate for many decades or centuries.

2.2.3. Manifestations of climate change

The knowledge of climate change manifestations is of paramount importance to understand its implication on different sectors. The increase in average temperature of the planet and change in hydrological cycle are major manifestations of climate change (Lovejoy and Hannah, 2005).The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity – due to seawater absorbing heat and carbon dioxide from the atmosphere (UNFCCC, 2007).Global temperature increases signify increases in the water-holding capacity of the atmosphere, and, together with enhanced evaporation, this means that the actual moisture should increase. It follows that naturally occurring droughts are likely to be exacerbated by enhanced drying. Globally there must be an increase in precipitation to balance the enhanced evaporation.

Most of the moisture in extra tropical storm comes from moisture stored in the atmosphere when it began. This increased moisture provides fuel for storms and enhances rainfall and snow intensity, increasing risk of flooding. According (Love joy and Hannah, 2005), the average surface air temperature of the planet is probably the single most widely used indicator of the state of global climate while other bio-geophysical phenomena that should be measurable: for example, sea level, glacier mass balance, sea -ice thickness and/or extent, and snow cover duration are supplementary evidences.

Accordingly Climate change issues differ from place to place and not all climate change issues are equally manifested in all countries. Climate change will affect all countries, but people in the poorest countries and poor people in richer countries are more likely to suffer the most. They tend to live in high-risk areas such as unstable slopes and flood plains, and often cannot afford well-built houses. Many of them depend on climate-sensitive sectors, such as agriculture, and have little or no means to cope with climate change, for example owing to low savings, no property insurance and poor access to public services. Climate change is expected to reduce already low incomes and increase illness and death rates in many developing countries. Africa, small island states, and the Asian and African mega-deltas are likely to be particularly affected by climate change (UNISDR, 2008).

According to the IPCC (2007), Europe would need to cope with retreating glaciers and extent of permafrost, reduced precipitation in Southern Europe and the possibility of more droughts in some areas, as well as increased risk of flash floods, Wild fires and rising sea levels are likely. In Latin America water scarcity, increased salinization, desertification of agricultural land, flooding in low-lying coastal areas and productivity of some crops and livestock would decrease, with adverse consequences for food security. North America would experience altered seasonal availability of water, forest fires, longer and hotter heat waves, with a greater potential for adverse health implication. Australia and New Zealand may face more frequent extreme events such as heat waves, droughts, fires, floods, landslides and storm surges. Small island states, coastal systems and other low-lying areas are especially vulnerable to the effects of climate change, rising sea levels and extreme weather events. Asia's sustainable development would be challenged as climate change compounds the pressures that rapid urbanization, industrialization, and economic development have placed on natural resources. Some of the main issues would be the availability of adequate fresh water, increased flooding because of both rising sea levels and river flooding at coastal areas.

Africa is particularly vulnerable to the effects of climate change because of multiple stresses and low adaptive capacities, arising from endemic poverty, weak institutions, and complex disasters and associated conflicts. Drought would continue to be a primary concern for many African populations. The frequency of weather- and climate-related disasters has increased since the 1970s, and the Sahel and Southern Africa have become drier during the twentieth century. Water supplies and agricultural production would become even more severely diminished. By 2020, in some African countries agricultural yields could be reduced by as much as 50%. By the 2080s, the area of arid and semi-arid land in Africa would likely increase by 5-8 %(IPCC, 2007). Generally, increasing food insecurity, water scarcity, drought, spread of diseases to new areas, damage from floods and forced migration due to desertification of previously arable land or sealevel rise are some of the likely issues in developing countries (Solomon *et al*., 2007).

In Ethiopia, researches conducted indicate that in the past few years, the rainfall pattern has shown a decreasing trend in amount and distribution, even though the significance of the change differ among different climate types. Moreover recurrent droughts and floods in Ethiopia are definitive sign that climate change is indeed implicating on Ethiopia. Discussion held with farmers also revealed that late start and early cessation of the main rainy season are recent changes in the rainfall regime in the past few years. More over climate change has caused change in the land use pattern, change in crop mix such as the introduction of lowland crops (including maize, haricot bean, pepper and sugarcane) to the areas where they were not traditional known in the area are typical indicator of the change in the different parts of the country. Most crops produced in the main cropping season also encounter moisture deficiency at their maturity period, which brings about decline in productivity (Green Forum, 2007).

2.3. Implication of climate change on crop production

Agricultural systems worldwide over the last 40 – 50 years have responded to the effect of the interacting driving forces of population increase, income growth, urbanization, and globalization on food production, markets and consumption (Von Braun, 2007). To these forces can be added the twin elements of climate variability and climate change which have a direct effect on food production and food security (Parryl *et al.*, 2004).

Ethiopia relies on rain-fed agriculture. As a result it is highly vulnerable to changes in climatic condition, seasonal shifts and precipitation patterns. Crop production and livestock husbandry account for about half of a household income, and the poorest members of the society are those who are most dependent on agriculture for jobs and income (FAO, 1999). The rural populace for whom agriculture is the primary source ofdirect and indirect employment would be most affected due to the vulnerability to global change processes (Ringler, 2008). Additionally the human alteration of land use patterns, elimination of wetlands and other biophysical changes could affect the water cycle ability to support the needed food production. Gregory *et al.*, (1999) reported a decreased crop duration (and hence yield) of wheat as a consequence of warming and a reduction in the yield of rice of about 5% per ^{0}C rise above 32^{0}C. Using a simulation model of production for cropping systems, Tubiello *et al.*, (2000) showed that the combined effect of increased carbon dioxide and climate change would depress crop yields by 10 – 40% if current management practices were not amended. Therefore new cropping systems which are resilient and adaptable to changing climatic conditions are required. More recently, elements of crop adaptation to extreme weather events have been explored with genotypic variation and adaptability to cope with several of the negative implication on unadapted productivity (Fuhrer,2006).

While Ethiopia has always suffered from great climatic variability, including droughts that have contributed to hunger, climate change is set to make the lives of the poorest even harder. Small scale farmers are more vulnerable and likely to bear the brunt of the negative implication of climate change. This is partly due to the traditional management practices that they adopt. The expected crop yield losses due to climate change would therefore implication on their already low level of income, and left without any alternative source of income, the situation would lead to increased poverty.

2.4. Climate change and food security implications forEthiopia

Food insecurity is an integral part of poverty in Ethiopia. At present agriculture dominates the Ethiopian economy, accounting for nearly 35% of gross domestic product (GDP), dominated by small scale farmers who employ largely rain-fed and traditional practices, therefore the consequence of land use change and the negative implication of climate change would have a far reaching implication on food security. Desertification, brought on by human land use pressures and recurrent drought has consumed significant land area and continue to threaten arable land. Climate change is projected to reduce yields of crops like wheat by 33%. Agro-pastoral and pastoral households, which are reliant on livestock for their livelihoods also suffer severe losses during droughts couple with seasonal reoccurring shortages due to diminishing grazing lands. Ethiopia has experience at least five majornational droughts since 1980 (World Bank, 2007).

Although Ethiopia has relatively abundant water, it has one of the lowest storage capacities in the world: 50 cubic meters per person (UNDP, 2007). Climate change is projected to cause the drying up of wetlands and run-off to Nile tributaries (Abay and Awash Rivers) would be reduced by up to one third (World Bank, 2007). These would have serious implication on the farmers' productivity due to watershortages.

One of the most strategically important issues in the context of environment - human relationship is the geography of insecurity in terms of resource availability and utilization; both latent (hidden danger) and realized (as currently being experienced in the form of conflicts among communities), posed by climate change. This has the potential to undermine the economic and political stability of some regions. An important question in this regard is "In which regions are the threats of climate change greatest"? Climate variability, specifically rainfall patterns resulting from climate change may result in decrease yield of crops. The reduction in crop yields may lead to higher prices for food, which could trigger regional food crises. These would lead to greater food insecurity causing political instability, increasing the stakes for control over productive agricultural land. Consequently, climate change by redrawing the map of water availability, food security and disease prevalence and loss of income source could increase forced migration, raised tensions and trigger conflict. Therefore the pattern of vulnerability to climate change on land use and food security isworrisome.

Landusechangeis one of the driving force for climate change , implicating agriculture and deforestation and intensive agriculture a causal factor The vulnerability of the regions in Ethiopia would be determined by the level of exposure to drought and climate extremes, level of technology, socio- economic and infrastructural development. There is the need therefore to mainstream climate change mitigation and adaptation into rural development process. Some practical steps for mainstreaming climate change would include setting aside existing bio-diverse habitats as conservation reserves, afforestation, avoidance of overgrazing, improvement in technology such as change in crop management practices and the encouragement of land use change in places where the threat of climate change makes the continuation of economic activity impossible or extremely risky such as returning cropland to pasture, forest or other uses may be found.

2.5. Theoretical framework

Climate change, land use and crop productivity is now a subject of global concern. This is evident from the number of empirical literature that is currently available on the subject matter. However, most seem to focus on the industrial countries where the economic implication are likely to be less harmful because of better adaptation techniques and technology than the developing nations. Not with standing, these studies laid the foundation for the increasing number of developing countries studies that are emerging.

Conventionally, there are some models that have been widely used to assess the economic implicationof climate change on agriculture. These are, Production Function Approach, Agronomic-Economic Models (AEM), Agro-Ecological Zone Models (AEZM), and the Ricardian Cross-Sectional Model (RM). In the Production function approach, the production function is specified and the yields of different species of crops are examined under different climatic conditions (Reinsborough, 2003). The model assumes that the different species of crop don‘t have any means of adapting to the changing climate condition. It also assumes that land used in a giving year for a specific crop would be used for that same crop in other years. This makes the model to under estimate the agricultural benefits of the changing climaticconditions.

The AEM employs a combination of: (i) controlled experiments on specific crops grown in field or laboratory settings under different climate scenarios such as temperatures, precipitations, and or carbon-dioxide; (ii) agronomic modeling; and, (iii) economic modeling, to predict climate implications (Adams and McCarl, 2001). The estimated changes in the experimental crops from the agronomic models are then entered into an economic model to predict crop choice, production, and market prices (Seo et al. 2005). One major advantage of the AEM is that it directly predicts the way climate change affects crop yields since it requires carefully calibrated controlled experiments. However, disadvantages which limits its applicability to the developing countries include amongst others; (i) agronomic estimates do not control for adaptation to changing climates (Mendelsohn and Dinar, 1999); and, (ii) lack of sufficient controlled experiments to determine agronomic responses in several developing countries (Seo et al. 2005). Studies that have adopted this technique include those of: Adams et al. (1989, 1990, 1993, & 1999); Easterling et al. (1993); Kaiser et al. (1993); Rosengweig and Parry, (1994); El-Shaer et al. (1997); Kapentanaki and Rosengweig (1997); Iglesias et al. (1999); Darwin, 1999; Kumar and Parikh (2001)etc.

The AEZM on the contrary, assigns crops to agro-ecological zones as implicit in the name and their crop yields predicted (FAO, 1996). Underlying this model is the simple fact as climate changes, the agro-ecological zones and the crops changes, which makes it possible to predict the effects of alternative climate scenarios on crop yields (Mendelsohn and Dinar, 1999). However, just like the AEZM, changes in the experimental crops derived from the different agro-ecological zones are fed into an economic model to predict rather overall supply and market effects (Darwin et al. 1995). The greatest strength of this model is that it can easily be applied to the developing countries because the geographical distribution of zones in this region is available (Mendelsohn, 2000).

Disadvantages include: (i) it is not clear how tightly climate zones can predict which crops should be grown or what their yields would be (Mendelsohn, 2000); and, (ii) estimates do not control for adaptation to changing climates as the case with the AEZM. For the RM, its theoretical basis is deeply rooted in the famous theory of economic rents by David Ricardo (1815) however, much of its application to climate-land value analysis, draws extensively from the work of Mendelsohn et al. (1994). The RM(Ricardian model) simple examines how climate in different places affects the net revenue or value of land. As Seo et al. (2005) note, by doing so, the RM accounts for the direct implications of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities.

Land use- refers to utilization of land resource by human various socio – economics purpose. Land coverage- indicates the type of physical materials at earth surface.Anthropogenic land use pattern have direct implication on land coverage type strong links between climate and LULCC, the daynamics of land use change is not explicitly represented in regional and global climate models using intergrated assement models is an approach to combine the socio economics aspects and the climatic systematic in to analytical frame work.They Use cellular models. Agent-based modeling approach, climate projection models.

2.6. Empirical Review

According to hamza et al (2012) Land uses pattern climate change, its implication for food security in Ethiopia. Climate change is perhaps the greatest challenge facing the world today. Climate change has the potential to adversely affect net farm revenues of small holders with increasing land fragmentation due to population growth translating to worsening food security situations. Since food security brings in additional socio-economics, geographical and political factors, focusing on measures of vulnerability, adaptation options and the development of adaptive capacity to reduce the adverse impacts of climate change in the rural areas of Ethiopia, this paper therefore reviewed the effect of climate change on land use pattern and the implication for food security inEthiopia.

AccordingtoVanDijk,andetal(2014)analyzeimpactsofuncertainandcomplexfuturesonVietnam'seconomyviachangesinlandusepattern key variable that may affect land use in Vietnam are climate change , international trade, population growth, technological change. He used global-to-local model frame work.

According to Jawad, etal (2013) examined the impact of climate and land use change on water and food security in Jordan. The study show the per capita share of water is less than 145m cubic/year. The study focused on crop production and water resource under trends of anticipated climate change and population change on country. Remote sensing data were used to determine land use /cover changes and rates of urbanization. They were used regression analysis to estimate the projected increase in agricultural water demand under the scenarios of increased air temperature and reduced rainfall. Results showed that problems of water scarcity food insecurity would be exacerbated by climate change and increased population growth.

According to Belaye, etal (2013) examined adapting to climate variability and change experiences from cereal based farming in the central rift and kobo valleys, Ethiopia. The study based on a household questionare, interviews with key stakeholder, and group discussion. The study result revealed that about 99% of the respondents at the central rift valley and 96% at the kobo valley perceived an increase in temperature and 94% at central rift valley and 91% at the kobo valley perceived decrease in rain fall over the last 20-30 years. The study areas are characterized by a bi-modal rain fall pattern.

In addition to quantitative descriptive stastics, and qualitative information in the form of narrative experience and observation. K.F.Ahmed et,al (2016) potential impact of climate and socio economic changes on future agricultural land use in West Africa. In this study we will compare the contribution of climate changes and socio economic development to potentials future changes of Agricultural land use projection algorithm.

Land use- refers to utilization of land resource by human various socio – economics purpose. Land coverage- indicates the type of physical materials at earth surface.Anthropogenic land use pattern have direct impact on land coverage type .strong links between climate and LULCC, the daynamics of land use change is not explicitly represented in regional and global climate models .using intergrated assement models is an approach to combine the socio economics aspects and the climatic systematic in to analytical frame work. Abebe Tadege , (2008) Accordingly, “climate variability” is the fluctuation in climatic parameters from the normal or baseline values, whereas “climate change” is a change in the long-term mean value of a particular climate parameter.

Alemu B, Kidane D (2014). The Implication of Integrated Watershed Management for Rehabilitation of Natural Resource.Fuhrer, J. (2006). Agricultural Systems: Sensitivity to Climate Change, CAB Reviews: Perspective in Agriculture, Veterinary Science, Nutrition and Natural Resources. Garedew, E., Sandewall, M., Sodaberg, U., and Cambell, B. M. (2009). Land Use and Land Cover Dynamics in the Central Rift Valley of Ethiopia. Environmental Management.Eid et al., (2006). Estimates from two climate change scenarios

showed that high temperatures would constrain agricultural production in Egypt almost 46.7 per cent in output value.

Mano and Nhemachena (2006) finds that when farm revenue in Zimbabwe is regressed against various climates, soil, hydrological and socio-economic variables in a Ricardian framework, the net effect of climate change on agriculture in Zimbabwe is quite significant. Sensitivity analysis of alternative climatic scenarios that is, 2.5^0 C and 5^0 C increases in temperature resulted to decrease in net farm revenues of approximately US$0.3 and US$0.3 billion respectively. In Kenya the results were not much different. Mariara and Karanja (2006) find that climate change also affects agricultural productivity using a seasonal Ricardian analysis. The results showed that increased winter temperatures are associated with higher crop revenue, but increased summer temperatures have a negative impact. Increased precipitation is positively correlated with net crop yield. The result further suggests that there is a non-linear relationship between temperature and revenue on the one hand and between precipitation and revenue on the other. For Cameroon, Molua and Lambi, (2006) finds that a 3.5 per cent increase in temperature associated with a 4.5 per cent increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon‘s agriculture, leading to a loss of almost 46.7 per cent in output value. This would negatively affect the economy as a whole, since close to 30 per cent of Cameroon‘s national GDP comes from agriculture.

In Egypt, empirical results from four variants of the standard Ricardian model showed that a rise in temperature would have negative effects on farm net revenue in Egypt (Model 1). In the second, third, and fourth models, adding the linear term of hydrology, the linear and quadratic terms of hydrology, and the hydrology term and heavy machinery to the analysis improved the adaptability of farm net revenue to high temperature. Marginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis. Also, estimates from two climate change scenarios showed that high temperatures would constrain agricultural production in Egypt (Eid et al., 2006). Other studies in this series include (Sene et al. 2006),who assessed the implicationof Climate Change on the revenues and adaptation of farmers in Senegal and finds that farmers have several ways of adapting to climatic constraints in Senegal. These include amongst others diversifying crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, and praying etc. For Seo and Mendelsohn, (2006), using two variants of the standard Ricardian model, results suggest that the livestock net revenues of large farms in Africa fall as temperatures rise but that small farms are not temperature sensitive (Model 1), while in the second model the authors find that higher temperatures reduce both the size of the stock and the net revenue per value of stock for large farms. In Kurukulasuriya and Mendelsohn, (2006), assessing the impact of climate change on African cropland from 11 countries involving over 9000 farmers, the authors find that net farm revenues fall as precipitation falls or as temperatures warm across all the surveyedfarms.

In Burkina Faso, Ouedraogo et al. (2006) find that if temperature increases by 1°C, farm revenue wold fall by 19.9 US$/ha, while if precipitation increases by 1 mm/month, net revenue increases by 2.7 US$/h using a standard Ricardian model. The elasticity shows that agriculture is very sensitive to precipitation in Burkina Faso. In Ethiopia, the results were not much different, Deressa (2006), also finds that net farm revenue would fall in summer and winter if temperature increases whereas increase in precipitation during spring would increase net farm revenue. Simulation of uniform scenarios that is increasing temperature by 2.5^{0}C and 5^{0}C; and decreasing precipitation by 7 per cent and 14 per cent suggest that increasing temperature and decreasing precipitation are both damaging to Ethiopian agriculture. However, the author concludes that decreasing precipitation appeared to be more damaging than increasing temperature. Also in Zambia, Jain (2006), finds that an increase in the November–December mean temperature and a decrease in the January–February mean rainfall have negative implication on net farm revenue in Zambia, whereas an increase in the January–February mean temperature and mean annual runoff has a positive implication.

It is however; surprising, that despite the vastness, population, and position of Nigeria in the Sub-Saharan region coupled with its different climatic conditions, she was left out of the multi-country studies. Some individual research efforts have however been geared toward ascertaining the implication of climate change on Agricultural productivity and profitability in Nigeria. For example, Davis and Sadiq, (2010) carried out a research on the effect of climate change on cocoa yield. The study revealed that there is a weak inverse correlation in rainfall (0.0073), meaning that increase in rainfall result in decrease in yield. While positive weak correlation (0.2196) was established for temperature on yield. The study also revealed a strong positive correlation between yields and temperature. They concluded that a combination of optimal temperature (29°c) and minimal rainfall (900 to 1000mm) would give a better yield and improve production and the economy of both Cocoa farmers and Nigeria at large. Lawal and Emaku, (2007) during their own study on the effect of climate change on cocoa production in Nigeria found out that there is a weak negative correlation for both rainfall and relative humidity on cocoa yield over the years while they established positive correlation for temperature on yield.

On the same study, they found out that the incidence of black pod disease has a positive correlation with temperature and relative humidity but a negative correlation with rainfall. Just like Davis and Sadiq, they concluded that a better yield and reduced incidence of black pod disease on cocoa in Nigeria require an optimal temperature of 29°c and minimal rainfall of 1,125mm and relative humidity of about 74%. . In line with the above findings, Ajayi et al, (2010) revealed that rainfall has a constraining ability on cocoa yield in the core cocoa production areas of Ondo state, Nigeria. They found that Cocoa yield was also shown to be the inverse of annual rainfall level as cocoa yield increased in the early and latter months of the year when the rains are yet to fully come, and suffered in the mid-year at the heart of rain season. Contrary to the negative correlation between rainfall and cocoa yield, Omolaja et al, (2009) found that high rainfall and favorable temperature promote flowering intensity of cacao inNigeria.

2.7. Threats of climate change for developing countries and food insecure people

Emissions of GHGs between 2000 and 2006 have increased on average by 3.1 percent per annum, compared to 1.1 percent in the previous decade, and are likely to continue to grow rapidly in view of high economic growth and lack of effective mitigation strategies (Garnaut Climate Change Review 2008). There is high confidence that natural systems are affected by changes in climate, especially by rising temperatures (IPCC 2007). The effects of climate change are heterogeneous and region-specific. Some positive effects of climate change such as CO2 fertilization of plants could contribute to increasing production and security. Climate change could lead to increased water stress, decreased biodiversity, damaged ecosystems, rising sea levels, and potentially, to social conflict due to increased competition over limited natural resources. Small-holder agriculture, pastoralist, forestry, and fisheries and aquaculture are among the systems most at risk (FAO2008).

2.8. Conceptual frame work

2.8.1Land use pattern, climate change and biodiversity

Land cover refers to the physical and biological cover over the surface of the land. Land use and land cover change is a term used for the human modification of the earth terrestrial surface. Much of the world's natural land cover has been transformed by human activities (Morton *et al.,* 2006), resulting in ecosystem degradation and biodiversity loss worldwide (Green *et al.,* 2005). An estimated 4.7 million km^2 of grassland areas and 6 million km^2 of forest/woodland have been converted to cropland worldwide since 1850 (Lambin*et al.,* 2003), and the main purpose for land use change is to obtain food and other essentials. In Ethiopia, land use can be seen from the perspective of human activities such as agriculture, forestry, building construction, and recently, industrialization which has led to increased human population within urban areas and depopulation of rural areas. The driving forces behind land use pattern include all factors that influences human activity, including local culture (food preferences), economics (demand for specific products, financial incentive), environmental condition (soil quality, terrain and moisture).

Land use change is largely driven by the decision of the people and population growth, declining household farm size and income. There have been many studies on land use and cover changes both at regional or local levels (Tsegaye*et al.*, 2009; Garedew*et al.*, 2009; Gete and Hurni, 2001), but most often they deal with quantifying land use/change using remote sensing tools, which give quantitative descriptions but do not explain or provide understanding of the relationship between the pattern of change and there driving forces (Olson *et al.*, 2004). However, studies linking land cover changes with drivers are scarce. In Ethiopia few attempts have been made outside the range land. Tsegaye*et al.*, (2009) reported a rapid reduction in woodland (97%) and grassland (88%) between 1972 and 2007, while the size of cultivated land increased more than eightfold in the Northern Afar region. Similarly, Gete (2000) observed a reduction in forest cover in Central Gojamfrom27%in1957to0.3%in1994.Same trend was recorded in the western part of Ethiopia. Land degradation by overgrazing and intensive agriculture on marginal lands is a major cause of soil loss.

Ethiopia is a country with high biodiversity and distinctive ecosystem, and the natural resource base is critical to the economy and livelihood of a greater percentage of the population (Hurni, 1993). However rising population has increased pressure on land resulting in reduced farm outputs and increase demand for more agricultural land. When a land is transformed from a primary forest to a farm the loss of forest species is immediate and complete and indirectly affects wild life. Land use plays a major role in climate change at global, regional and local scales. It is responsible for releasing greenhouse gases, and the major driver of this change is deforestation and agriculture which causes the release of soil carbon in response to disturbance by tillage (Ellis,2010).

In Ethiopia, biodiversity is an important resource having a dual purpose of utilization; consumptive use (food, fiber, fuel, shelter, medicine and wild life trade) and non-consumptive use (ecosystem services and economically important tourism industry). Given the heavy dependence of Ethiopia on natural resources, many communities are vulnerable to the biodiversity loss that could result additionally due to climate change. The use of fire as a management tool for slash-and-burn agriculture and other purposes results in at least a third of the savanna being burned every year (IPCC, 2000). Forest fires contribute to climate change and may result to significant ecosystem change that could affect biodiversity significantly. Land use pattern therefore contributes to global warming, leads to habitat conversions and fragmentation which directly impacts biodiversity. The impact of climate change on biodiversity would be further compounded by the climate induced alterations of agriculture (FAO,1999).

2.8.2 Land use effect on small holder production

In Ethiopia crop production is increased recently through intensive and extensive agriculture systems. The intensification of agriculture and the expansion of croplands into marginal lands which is dominated by the traditional system/practices have led to severe land degradation (Hurni, 1988). Several studies have been done at the national level; the Highland

Reclamation Studies: Ethiopia (EHRS-FAO 1986), the National Conservation Strategy Secretariat (Sutcliffe 1993) and Ethiopian Forestry Action Plan (1993) all to estimate the level of land degradation. The studies show that, 30,000 ha is lost annually due to water erosion with over 2 million ha already severely damaged (National Review Report, 2002), United Nation Development Project in 2002 reported a nutrient depletion of 30kg/ha of Nitrogen and 15-20kg/ha of phosphorus, while a loss of 62,000 ha of forest and woodland annually have been reported by World Bank in 2001. All physical and economic evidence show that land degradation and the loss of land productivity is an important problem in Ethiopia, impacting on the rurallivelihood.

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3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Geographic Location of the StudyArea

The Gurage Zone in the north Oromia region to the south east Hadya zone and yem special woreda. The mountains form a watershed between the Omo-Gibe River basin in the west and the Oromia region in the east. The Wabe River catchment is a sub catchment of the Omo-Gibe River basin in the Gurage Zone.

The Gurage Mountain (Zebidar) make up the highest area in the catchment and the lowest altitude is found in the Gibe valley of the study area. The catchment covers a drainage area of about 1860 km2. The maximum temperature in the catchment during the last 20 years ranges from 20 °C (during the wet season) to 27- 39 °C (during the dry. season), while the minimum temperature is in the range of 0–19 °C. The average temperature is 18 °C. The mean annual rainfall ranges from 1200 to 1320mm (NMA, 2016). Pellic vertisols are the dominant soil type.

Table 3.1 : Description of the identified LULC in Study Area

LULC	Description
Bare land	Areas of land that have been degraded either due to erosion or over-grazing and cultivation.
Grazing land	All areas covered with grass and used for livestock grazing
Cereal crop	Areas of land prepared for growing cereal crop. This category includes areas ently cov with crops and land prepared for cereal cultivation
Forest	Areas covered by trees, natural or planted, with a minimum size of 0.5 ha.
Woodland.	Area with open stands of trees, mainly dominated by Acacia spp
Built up	Urban fabric of residential, commercial, industrial, transportation, and other land
Shrub land	Area covered by small trees shrubs and mixed with grasses; less dense than forests
Wetland	Areas that are waterlogged and swampy during the wet season and relatively dry durin

	dry season
Enset-based forestry	Areas dominated by Enset crops mixed with fruit trees, vegetables, Khat, coffee, etc. growing within a home garden
Afro-alpine vegetation	High altitude vegetation dominated by the shrub Erica arborea, herbs and grasses.

3.1.2. Demographic changes

Based on the 2007 census conducted by the Central Statistical Agency (CSA) of pia, the Gurage zone had a total population of 1279,646 with an area of 5893 sq. km and a population density of 217 per sq. km. From this, only 119,822 (9.4%) were urban inhabitants. The population growth rate of the region is 2.9%. There were 286,328 households in the Gurage zone in 2007, indicating the presence of an average of 4.47 persons per household (CSA, 2009). Although the relationship between population growth and the degradation of ecological resources is still being vigorously debated (Boserup, 1965; Lopez- Carr et al., 2006; UNU-IAS and IR3S/UTIAS, 2016), the vailable evidence suggests that increasing demand for food, energy, and housing in both rural and urban locations has significantly altered land-use practices and degraded the most productive landscapes across the Africa continent (Christiaensen et al., 2006).

landless farmers were obliged to farm every piece of land continuously without fallow. Land shortage also pushed farmers to convert forests, shrubs and Afro-alpine vegetation covers in their own land into crop land.

3.1.3. Economic activities

The Gurage community live a sedentary life based on agriculture, involving a complex system of crop rotation and transplanting. Enset is their main staple crop, but others are grown according to the AEZs, such as cereal crops (barely, wheat, beans, peas, teff (Eragrostis tef), sorghum, etc.), non-cereal crops (like potato), and vegetables (like cabbage). Cash crops which include coffee and chat are also grown.

Animal husbandry is practiced and the number of livestock per household is large, even though the area of their own land is small.

According to the statistical abstract report of the Gurage zone, for each district (woreda), the number of average livestock per hectare was 27(GZFED, 2015). Currently, farmers are planting eucalyptus trees and stimulant crops like chat in their home garden to increase their income. As a result, most of the farmer's land parcels have been converted to eucalyptus plantations in all agro-ecological zones of the catchment. This type of economic characteristics makes the land use land cover to become dynamics in the Wabe River catchment.

3.2. Data Sources

This study is based on secondary data covering the period from2000 to 2010, based on country, region and zonal level data of Guraghe Zone major six food crops- Maize, Sorghum, Barely, Wheat, Teff, Potato which comprise of Food and Cash crops for the period obtained from various sources. Thirteen Woreda with varied climatic conditions have been considered for the study in Guraghe Zone. The data obtained can be divided into two parts: agricultural and meteorological variables. These have been obtained from the following sources:

Agricultural Data- Crop productivity in Quintal per hectare, cropping area in thousand m^2 or hectares, total forest area in hectares, total number of households lived in farming land and yield are the agricultural variables taken into account. These data for the major crops has been taken from Central Statistics Agency (CSA).

Meteorological Data- Zonale Annual Rainfall and maximum and minimum temperatures have been taken into consideration as the climate variables. Zonale Annual rainfall data for the respective years (2000- 2010) has been obtained from the database of the Ethiopia Meteorological Agency (EMA).

This study incorporated the data of 13 Woredas in Guraghe Zone belonging to different districts as well as different geographical locations.

3.3. Model

The relationship between climate change and agricultural productivity for the years 2000-2010 is assessed by running an econometrics model using Liner Regression. Crop productivity in quintals per M^2 is chosen to be the Dependent variable whereas cropping area, yield, average annual maximum and minimum temperatures, rural house holders, total forest area, average annual rainfall are the Explanatory variables. The theory related to panel regression and its application is explained in the following section.

Consider the panel regression equation:

$$Ysn=\beta 1Xsn+ \beta 2Lsn+ \beta 3Tsn+ \beta 4Wsn+ un+ vsn$$

Where,

$[vsn|Xsn,Lsn,Tsn,Wsn]=0$

In case explanatory variables are observed, in all the above equations; coefficients can be computed using multiple regression. However, in case when the explanatory variable is unobserved, an external variable Zs is introduced which relates to the endogenous variable, say, Xsn. In this case however it is uncorrelated to all exogenous variables (Lsn, ,) and the idiosyncratic error term vsn.

$(Zsn,vsn)=0$

$(Zsn,Xsn)\neq 0$

By using panel data we can control for the sources that cannot be measured or are not observable and are sources of heterogeneity that vary between individuals but do not differ with time. It can also control for omitted variables. The panel data has three basic models: the random effects model, the fixed effects model and the OLS model. The random effects model exists when there exists heterogeneity over the years and within the cases. The fixed effects on the other hand does not vary with time but there is variability within the cases. The OLS, which is the third model does not take into account the time factor.

This regression analysis has been conducted using SPSS and STATA to find out the best fit in our model. Linear regression with panel-corrected standard errors (PCSEs) has been used in the model to remove the effect of heteroskedasticity and multicollinearity. Linear regression with panel-corrected standard errors is used in time series model for cross sectional data using OLS to calculate the values for the parameters. This model by default assumes that the errors are heteroskedastic and correlated. According to research, panel regression for micro econometric data is usually over estimated since it shows all kinds of temporal and cross sectional correlations. These dependencies can lead to biased results. To avoid these biases and to get valid results, linear regression with panel-corrected standard errors has been introduced to avoid possible correlation in residuals.

In literature, the relationship between climate change and agriculture productivity has been commonly estimated by using two methods: the production function method and the Ricardian method. The production function approach uses the production function and accommodates various environmental inputs to examine the implication of these inputs on the production (Callway et al., (1982); Decker et al., (1986); Adams et al., (1988), (1990); Adams, (1989); Rind et al., (1990); Rosenzweig and Parry, (1993). The major drawback of the production function method is that it fails to take into account the substitutions that farmers make in order to cope up with the uncertain climate shocks. The Ricardian approach on the other hand, incorporates value of farmland or net rent on which the implication of climate is assessed (Mendelsohn et al., 1994). This approach takes into consideration both, the implication of climate change on productivity of crops as well as the substitutions that farmers resort to as an adaptation strategy towards change in the climate. However, according to De Salvo et al.(2013), the production function approach is used to estimate the effect of climate change on one particular crop, a group of crops or a particular ecosystem in both short and long term, whereas the Ricardian approach is applied to estimate the implication on the whole agricultural sector or a particular branch. This regression analysis first show the implication of climate change on each food and cash crop and then on the productivity of all the crops using the production function approach.

Cobb Douglas production function is incorporated in this model to analyze the effect of climate change on agricultural productivity. The functional form of the equation may be written as:

$(TProd)sn$={$GAIsn$,$AWsn$,$FARsn$,} (3.5)

Where, TProd stands for total productivity for each crop.

S denotes the number of states for every crop and n is the considered time period.

GAI stands for gross cropping area,

AW is the total number of agricultural workers(HH).

FAR is the crop share of forest area and.

Climate factors are assumed to be an input factor for growth of crop in Cobb Douglas production model. Thus we can write it in the functional form as:

$(TProd)sn=\{FCsn,GAIsn,AWsn,Tractsn,FARsn,HPsn,RFsn,MAXTsn,MINTsn\}$

Where, MAXT and MINT are annual average maximum and minimum temperatures and RF denotes annual average rainfall, respectively. The above equation can be written in the Cobb Douglas production form as:

$\ln(T\quad rod)sn=\beta 0+\beta 1\ln(FC)sn+\beta 2\ln(GAI)sn+\beta 3\ln(AW)sn+\beta 4\ln(Tract)sn+$
$\beta 5\ln(FAR)sn+\beta 6\ln(HP)sn+\ \beta 7\ln(RF)sn+\beta 8\ln\ (MAXT)sn+\ \mu s$

Where, $\beta 0$ is constant coefficient; $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$, $\beta 6$, $\beta 7$ and $\beta 8$ are the coefficients for the respective variables and µs is the intercept term . Cobb Douglas Production Function's functional form is given by the above equation.

The hypothesis is given in the table below:

Table 3.1: Hypothesis - Panel Data Regressions

Hypothesis	Variable	Method of Testing
Higher the cropping area higher productivity.	CA	Linear regression with panel-corre standard errors (PCSEs)
Higher the yield, higher productivity	HY	Linear regression with panel-corre standard errors (PCSEs)
Higher the HH number, higher productivity.	HH	Linear regression with panel-corre standard errors (PCSEs)
Higher the temperature, higher productivity of the crop	HT	Linear regression with panel-corre standard errors (PCSEs)
Higher the forest area, higher productivity of the crop	FA	Linear regression with panel-corre standard errors (PCSEs)
Higher the RF , higher the product of the crop	HRF	Linear regression with panel-corre standard errors (PCSEs)

Several economists have worked using a similar approach to analyze agricultural productivity in different countries. Nastis et al. (2012) did one of such research to estimate the effect of climate change on agricultural output in Greece. Gupta et al. (2012) has also written a paper that investigates the climatic bearing on millet, sorghum and rice yield. This thesis follows the methodology and the empirical model of the first section of the paper by Kumar et al. (2013) based on the topic 'Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India'. He emphasizes on the effect of climate change on the yield of major food grain and nonfood grain crops.

The second section of the thesis shows the relationship between agriculture and food security due to the effect of climate change on the productivity. There can be two approaches to prove that climate change is gradually resulting in food security problems resulting in poverty:

1. By taking the socio economic factors into consideration so as to prove an implication of climate change on food security that is resulting in poverty. We can make use of a similar model projected by Kumar et al. (2013)

2. Theoretically, using several references prove that variations in the climate can result in the problem of food insecurity affecting the poor sections of the society.

Many studies in the past have assessed the effect of climate change on different factors of food security- availability, accessibility and utilization, however, due to limited resources and paucity of time, the scope of this research is restricted to analyzing the implication of climate change on only one dimension of food security – food availability. This research aims at analyzing the implication of land use pattern climate change and its result on food crop production making an inference from the results and relating it to food security based on the present literature.

4. RESULT AND DISCUSSION:

4.1. Descriptive Results

Increasing agricultural productivity can improve food availability and is therefore an important step towards achieving sustainable food security. Agriculture, as we know, is strongly influenced by weather and climate. Thus, to ensure food availability, it is important to assess the implication of land use pattern climate change on food crop productivity. In order to study this effect Linear Regression with the regression results of different major crops of the study area evaluated by ordinary least square (OLS) used. The summary of the data is presented in the table below. The first table indicates the common factors that affect the productivity. The second table shows the summary pertaining to factors related to specific crops.

.**Table 4. 1. Descriptive statistics, 2000 to 2010.**

Variables	Crops	Mean	Std. Deviation	Minimum	Maximum
Croppingarea (ha)	Barley	1108185.2880	52105.81917	1040998.90	1148498.60
	Maize	1145082.9050	107855.19536	1040998.90	1419881.82
	Sorghum	998335.4610	189902.38210	465788.80	1148489.07
	Teff	1050581.2870	105658.66537	783164.51	1148498.60
	Wheat	977046.2160	326577.66636	104849.02	1148498.60
	Potato	898656.0650	427883.85594	104849.02	1148498.60
Production (quintal)	Barley	14149.0000	2933.28049	9000.00	16428.00
	Maize	15415.7000	3012.50099	9000.00	20739.00
	Sorghum	12202.4720	2962.89732	6662.72	16428.00
	Teff	13863.2720	2218.21518	9000.00	16428.00
	Wheat	14135.7240	2569.07361	9000.00	16428.00
	Potato	15221.6450	1749.46231	11855.73	16428.00
yield (quintal/m)	Barley	.012698997140	.0022444844454	.0085640372	.0143040107
	Maize	.024962638560	.0370854266670	.0085640372	.1303924400
	Sorghum	.012322094280	.0020620438260	.0085640372	.0143041653
	Teff	.025889902590	.0411960607954	.0085640372	.1430417960
	Wheat	.026236309070	.0410786673744	.0085640372	.1430417960

	Potato	.026939065700	.0407974102308	.0128118866	.1430417960
max. Temp (^{o} C)	Barley	26.0350	2.25488	20.25	28.80
	Maize	25.7950	2.04592	20.25	27.20
	Sorghum	27.2300	.83407	26.30	28.80
	Teff	27.2000	1.21747	25.50	29.00
	Wheat	24.1000	.98995	23.00	26.20
	Potato	26.0000	1.33000	24.00	28.20
min temp. (^{0} C)	Barley	9.7400	1.62289	6.90	12.10
	Maize	9.7400	1.62289	6.90	12.10
	Sorghum	12.5500	1.07316	11.20	14.10
	Teff	11.9100	.97917	10.20	13.10
	Wheat	11.9000	.58689	10.90	12.60
	Potato	10.3200	1.23630	8.00	12.10
RF (mm/year)	Barley	15.1600	25.81142	.00	75.40
	Maize	173.9900	48.95437	109.10	234.30
	Sorghum	41.3900	56.25036	.00	185.10
	Teff	98.0600	80.82662	6.10	262.60
	Wheat	131.4200	92.91566	31.00	324.80
	Potato	144.3900	77.47247	34.00	274.60

As it can be seen in the above table 4.1 , In the case of yield, it was found that among the six crops, the mean yield of potato was the highest. According to this study, the observed mean yield of the six crops in ascending order is as follows:sorghum, barley, maize,teff, wheat, and potato. In the case of average production, maize ranked first, potato ranked second, barely ranked third and wheat,teff and sorghum fourth , fifth and six place, respectively.

. In addition to this , according to the average production area, maize ranked first, barley ranked second, teff ranked third and sorghum, wheat, and potato stood fourth , fifth and six place, respectively. Regarding to climate variables, the highest maximum temperature was noticed in the sorghum growing season and the lowest maximum temperature was observed in the wheat growing season. Meanwhile , the highest minimum temperature was observed in the sorghum growing season, In contrast the lowest minimum temperature were noticed both in barely and maize growing season.

For rainfall, maize received the highest rainfall in growing season; potato, in the second, wheat in the third , teff in the fourth , sorghum and barley in the fifth and six place respectively. This study was also determine which climatic variable affect food crops the most severely in the study area.

Rainfall positively contributed to the production of maize crop and was significant. Maximum humidity contributed positively, it showed a significant influence on maize yield. However, the adjusted R^2 value showed 47% variability in the production of maize crop .

4.2. Regression Results of different Major Crops

Table 4.2 The regression results of different major crops evaluated by ordinary least square (OLS)

Variables	Major Crops			
	Wheat	Maize	Barley	Teff
Max Temp	0.778***	0.732***	0.819**	0.732 ***
Min Temp	0.541**	-0.193*	0.062	0.193 *
Rainfall	0.781***	0.944***	0.890**	0.944***
Constant	0.287*	0.44**	0.0698	0.44**
F	0.163*	0.865**	1.824**	0.865**
Wald chi2	2.219***	2.119**	1.870*	2.119**
Adjusted R^2	0.387*	0.47**	0.215**	0.47**
* represents level of statistical significance*** *p<0.01*, ** *p<0.05*, * *p<0.1 spss v.*				

4.2.1 Climate and Maize Crop

To determine the influence of the climatic variables on the maize crop yield OLS method was employed. The results are presented in table 4.2, which showed that the effects of all the climatic parameters were observed to be significant for the production of the maize crop. Minimum temperature caused a negative effect and insignificant influence on the yield of the maize crop.

explained by climatic factors. Based on the result of the above table, maize productivity. 1% increase in maximum temperature increases the maize productivity by 0.7% whereas a 1% increase in minimum temperature decreases the productivity by 0.1%.

A study was conducted in which it was found that climatic variables significantly affect the yield of maize, butvary among different maize crops. Moreover, the effects of maximum temperature and minimum temperature are pronounced as compared to rainfall. It is confirmed that rising maximum mean temperature would result in an increase in maize production, while the increase in minimum temperature would lead to anenhancement in the production.

4.2.2. Climate and Wheat

Wheat is an important food crop and a raw material for many products. The findings in table 4.2. revealed that both maximum temperature and minimum temperature were found to be positive andsignificant.

Rainfall showed a statistically significant contribution to the yield of wheat crop, but it negatively influenced the yield of crops. However, the adjusted R^2 value showed 39% variability in the production of wheat crop is explained by climatic factors in the model.

4.2.3. Climate and teff Crop

Teff is one of the important food crops of the study area. The productivity of teff reduced from 1.43 quinta/m2to 0.08quintals/m2 during 2000 to 2010 in the study area. Teff is planted in the study area in mehir season, mostly under rain fed conditions.

OLS method was used to obtain the contribution of the climatic variables to the yield of teff. The results indicated that maximum temperature is statistically significant and has a positive influence on the crop yield. Maximum temperature and rainfall showed a statistically significant relation and positively influenced the yield. Minimum temperature showed a negative influence on teff crop yield.

		crop land	built up area	bar land	wood land	Forest Land	population	production
Pearson Correlation	**Cropland**	1	.972	-.806	-.965	-.533	.929	.998*
	built up area	.972	1	-.644	-1.000*	-.717	.990	.953
	bar land	-.806	-.644	1	.624	-.072	-.529	-.845
	wood land	-.965	-1.000*	.624	1	.735	-.993	-.945
	Forestland	-.533	-.717	-.072	.735	1	-.808	-.473
	Population	.929	.990	-.529	-.993	-.808	1	.901
	Production	.998*	.953	-.845	-.945	-.473	.901	1
Sig. (2-tailed)	**Cropland**		.151	.403	.168	.642	.241	.044
	built up area	.151		.555	.017	.491	.090	.195
	bar land	.403	.555		.571	.954	.645	.359
	wood land	.168	.017	.571		.475	.074	.212
	Forestland	.642	.491	.954	.475		.401	.686
	Population	.241	.090	.645	.074	.401		.285
	Production	.044	.195	.359	.212	.686	.285	
N	**Cropland**	3	3	3	3	3	3	3
	built up area	3	3	3	3	3	3	3
	bar land	3	3	3	3	3	3	3
	wood land	3	3	3	3	3	3	3
	Forestland	3	3	3	3	3	3	3
	Population	3	3	3	3	3	3	3
	Production	3	3	3	3	3	3	3
	*. Correlation is significant at the 0.05 level (2-tailed).							

For the case of data interpretation of correlation values, the following guide was used

.

Pearson's *(r)* and	**Spearman *(ρ)* are correlation coefficients**
Range from -1 to 1	
-1 = Perfect Negative relationship	± (0.1 – 0.3) = Weak
0 = No relationship	± (0.4 – 0.7) = Moderate
1 = Perfect Positive relationship	± (0.7+) = Strong

As it can be seen in table 4.4, population growth had a strong positive relationship with crop production. Increase in population demanded changes in land use where more land was converted to crop cultivation for more food production. Forestland had a strong postive correlation relationship with crop production since forest created conducive environment for agriculture as soil fertility was increased due to making the land furrow and adequate rainfall but if no forest the opposite is true. Built up area had a strong positive relationship with crop production as farmland was reduced due to land subdivisions, village settlements, and shopping centers and towns.

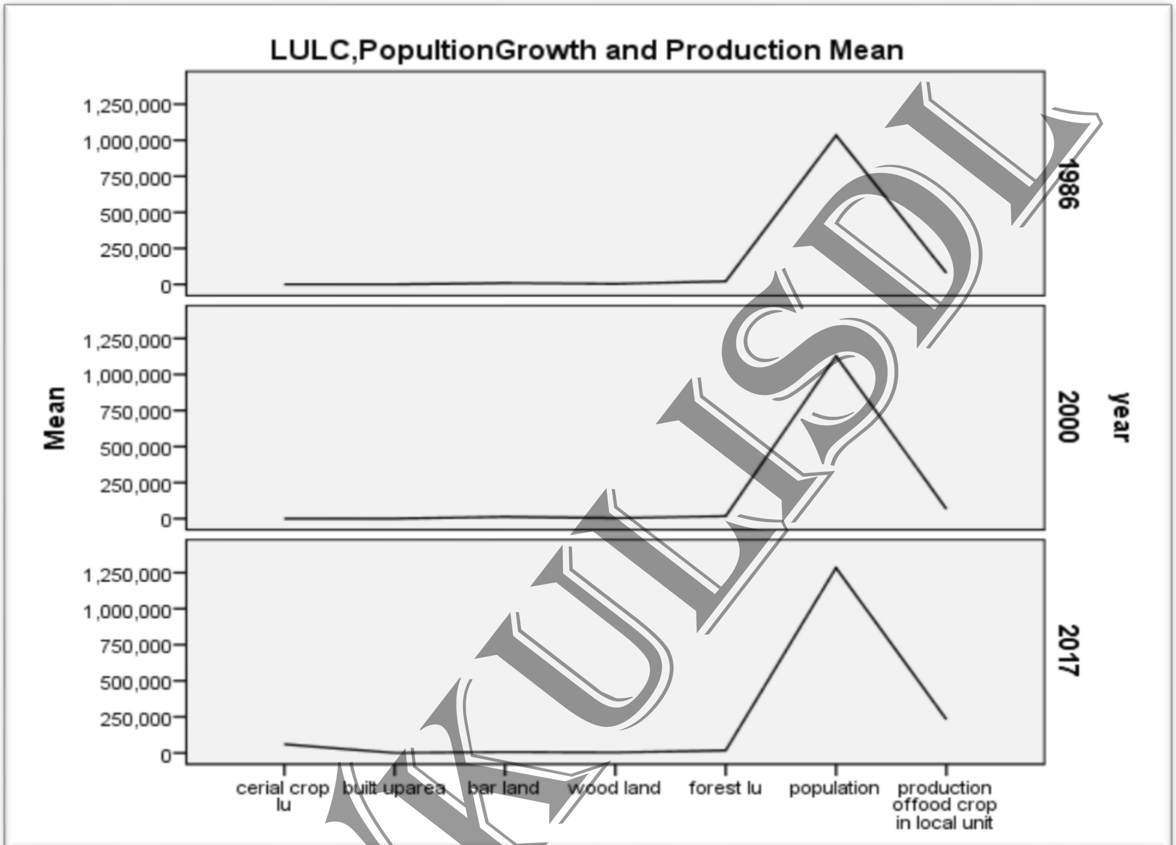

Figure 1. LULC , Population and Production trend 2000-2010

4.4. Food crops and Production

It was found out that most of agricultural land was under crops. In small scale holder areas, an average of 1.2 parcels of land had been put under food crops and the majority (36%) of the households had two parcel of land under food crops.(GZAO, 2010). In the earlier 2000s most people had two to four parcels of land under food crops but this reduced with time paving way for cash crops and built up area as population increased. *Maize, Sorghum, Wheat ,teff, Barley and P*otatoes, were the commonly and most grown food crops in every agricultural household in Guraghe Zone. This could be because these food crops do not require any further processing and so Households find them convenient to grow. Due to reduced agricultural land, households have adopted mixed cultivation on small pieces of land so as to maximize the land production in quintals per hectare was computed for two year data points basing on the available statistics (table 4.5).

Year	measurement	maize	sorghum	wheat	barley	Teff	Potato
2000	Cropping land(ha)	6150	767	2503	731	311	6175
	Production(quintal)	230625	19175	55056	13158	28044	28200
2001	Cropping land(ha)	4269	422	5565	784	3049	5213
	Production(quintal)	136608	9706	133560	14112	36588	27892
2002	Cropping land(ha)	6720	750	2396	655	3136	6765
	Production(quintal)	231770	21000	57491	16035	45570	240013
2003	Cropping land(ha)	6308	771	2509.5	607	3168.75	6387
	Production(quintal)	334324	23130	66501.75	137182	38025	334400
2004	Cropping land(ha)	5043	1003	2148	532	3459	5121
	Production(quintal)	220245	26579.5	63100	956	43203.5	222145
2005	Cropping land(ha)	5043	1003	2148	532	3459	5100
	Production(quintal)	313773	25568	61820.5	8967.5	52762	314705
2006	Cropping land(ha)	6209	503	2402	624	3266	6300
	Production(quintal)	334300	18166	574506	16009	37029	334500
2007	Cropping land(ha)	4296	418	2246	601	2908	4387
	Production(quintal)	137600	9700	63200	13700	46562	138600
2008	Cropping land(ha)	6472	740	2144	522	3370	6500
	Production(quintal)	341322	20150	618816	9567	44196	342322

2009	Cropping land(ha)	5120	774	2560	522	3107	5220
	Production(quintal)	313780	23140	55090	9061	45562	315680
2010	Cropping land(ha)	6814	1004	5802	730	3501	6912
	Production(quintal)	240670	26591.5	133598	13066	51792	241654

Table 4.5. Productivity Data form 2000-2010

There was a general decline in land (ha) under cultivation of these main crops. The table further shows that maize was mostly consumed by study area households, it was the most highly grown crop. This could be due to the fact that maize can mix with various crops, take shorter period to grow and do not take too much space than teff. Households preferred to put more land under maize which matures faster.

4.5. Annual and seasonal rainfall and temperature from 2000 -2010 Guraghe Zone

4.5.1. Trend analysis of rainfall and temperature

The daily rainfall and temperature data for the period 2000-2010 from the Ethiopia meteorological agency for Guraghe zone was aggregated into monthly and yearly totals. The results were then analyzed for trend changes and presented in the figures below.

4.5.1. Minimum, Maximum temperature and Rainfall analysis (2000-2010)

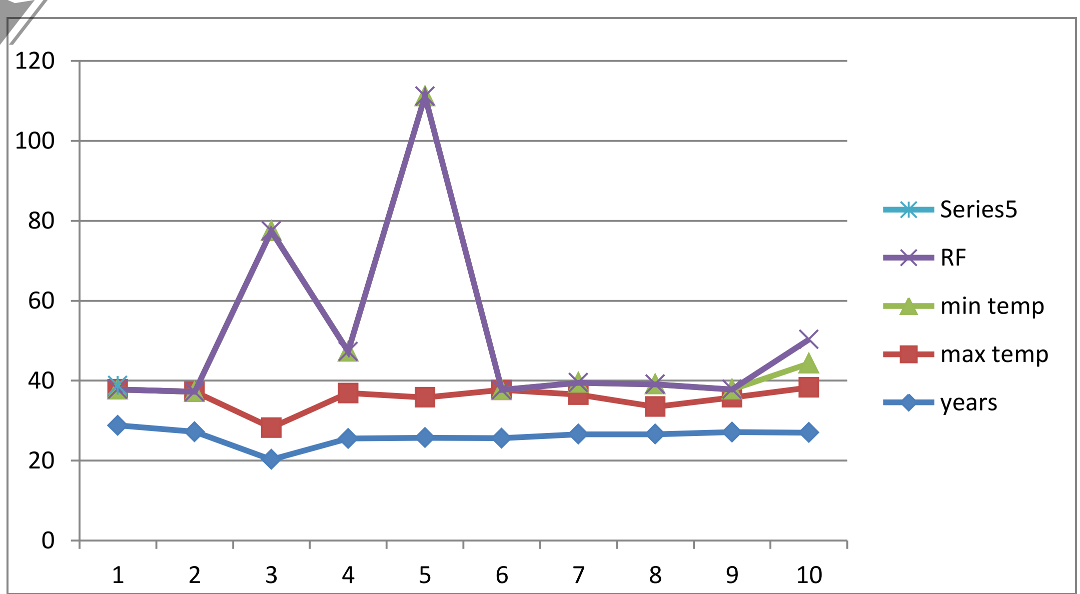

Figure 2.Minimum , Maximum temperature and Rainfall analysis(2000-2010)

Figure 2 shows the annual rainfall, minimum and maximum temperature variability of the study area. The main rainy season at local level between 2000-2010 revealed that the study area received variable rain. It is therefore apparent from the findings that there is no consistent rainfall trend observed overtime in Guraghe Zone suggesting that the yearly rainfall trends were likely to be unpredictable.

Minimum and Maximum monthly temperature for the study area was obtained in figure 2, above showed that from 2000 to 2010, the lowest mean annual temperature was observed in 2003,(8.90^{0}C) and the highest annual temperature was in 2000 with (28.80^{O}C).

4.6. Implications of Climate Change on Food Security

The rising magnitude of weather and climate change across Guraghe Zone economy has affected food productivity in numerous ways- both directly and indirectly. Significant alterations in the production cycle and the agricultural eco-system are the common direct implication of such climate variations. On the other hand, the effect on the demand of crops, implicating the economic growth can be regarded as an indirect implication. Agricultural prices have a major indirect effect due to climatic shocks, not only in the study area but also the country level.

The World Bank data as shown above clearly projects a steep rise in agricultural prices globally by about 17%, with approximately 23% and almost 77% rise in agricultural prices in South Asian economies and Sub Saharan Africa, respectively. In line with these projections and increasing distortion in climatic stability, there has been an upward pressure on the agricultural prices, especially in Ethiopia particularly in the study area. With majority of the population in the study area living below or at the poverty line, such rise in agricultural prices due to climatic shocks, poses a grave challenge for Guraghe Zone, even Ethiopia at large to ensure food security for its masses.

Agriculture forms a major source of livelihood for around 85 percent of the rural population in Ethiopia. Small farmers possess approximately 80 percent of the landholdings in the rural areas. With growing uncertainty in the food production due to changes in the climatic conditions, the poor sections of the society become the most vulnerable in the country economy. A study carried out by CSA, (2011) predicts that Ethiopia would be affected by severe droughts in the years to come, leading to acute food shortages.

Furthermore, industrialization and the mounting reliance of manufacturing sector on agriculture have resulted in a slow shift from food crop production towards cash crop production across Ethiopian economy. This continuously increasing pressure of the industrial sector on agriculture for cash crops with the simultaneous rise in negative externalities from industrialization is another major driver of food insecurity in the rural as well as urban areas. According to FAO, Ethiopia would suffer from a nutritional deficiency in the coming three decades.

All these above defined direct and indirect effects of climatic shocks coupled with the results of the regression analysis clearly establish an inverse relationship between climate change and food productivity in the study area. The analysis of study indicates a negative affiliation of maximum temperature with the overall agricultural productivity of the crops taken into consideration. For a 1% increase in the maximum temperature, there is a 0.765% fall in the overall productivity. Soil transpiration and productivity are likely to be disrupted owing to the fluctuations in the rainfall and rise in the maximum temperature. Additionally, due to extreme and unsuitable weather conditions in the study area there exist high chances of soil infertility leading to a decline in the quantity and quality of the crop. The study suggests that an increment in the temperature is expected to increase the risk of land degradation making it unsuitable for agricultural production. All these factors along with the inverse relationship identified by the study holds a far more significant implication for the question of 'foodcrops production' for the study area economy.

The results of study also indicate a positive influence of rainfall on overall productivity. A 1% increase in the rainfall leads to a 0.889% increase in the yield of crops.This outcome has a positive effect on food security. An increasing rainfall will result in surplus production of food crops. Since rainfall is a seasonal phenomenon, it cannot be regulated by the government. For the supply of water, the responsible bodies in the study area with the government should focus on the development of advanced irrigation systems, in order to reduce the dependence of farmers on rainfall.

Giving emphasis the magnitude of the situation, there holds an indispensable need to focus on the issue of food security, before it worsens. The government of Ethiopia has been working on addressing the food security issues by providing subsidies for fertilizers, high yielding varieties, pesticides and manures and installing better irrigation systems. It has also launched, 'The 2nd MDG Plan' (2010-2014) that concentrated on reviving the production of crops through the operation of National Food Security. This programme aimed at providing incentives to the regions to plan adequate strategies in case of sudden natural hazards. Some of the other initiatives by the Ethiopian government to address the problem of low agricultural productivity, food security and poverty are; the introduction of the 'Watershed Development and Micro Irrigation Plan', 'Protection of Plant Varieties and Farmers' Rights Act', Establishment of 'National Rain-fed Area Authority' and the commencement of ' National Rural Health Mission'.

In general, countering the various challenges faced by the study area economy, including low productivity of the agricultural sector, health problems, poor infrastructure, endangered forests and wild life, rising sea levels, increasing pressure on the land with the growing population and lack of technology intervention of the government, public and private institutions is most importance.

5. CONCLUSIONS AND RECOMMENDATION

5.1. Conclusion

Climate change is a global environmental threat to all economic sectors—specifically the agricultural sector. Guraghe Zone has faced extreme weather events like untimely and heavy rainfall and flash floods in mountainous areas affecting huge damage to the major crops and properties of farmers. It is expected that the above-mentioned situation will increase as a function of climate change.

Paying attention to the significance of agriculture to the study area economy and rural livelihoods, the importance of climate change adaptation approaches is critical. Even though the adaptation strategies are very important, all farmers do not use such strategies. The majority of rural households and connected urban populations in the study area are highly dependent on agriculture. Therefore, adaptation to the negative implication due to climate variability may be essential to encourage food security for the country and to protect the subsistence of rural households.

The prime aim of this study was to analyze the implication of land use pattern climate change (e.g., maximum temperature, minimum temperature, rainfall, etc) on major food crops of Guraghe zone , including wheat, maize, sorghum, teff, barely and potato. The OLS methods were employed to achieve the objectives and obtained mixed results. Some climate variables affect thecrop yield negatively and significantly, while others are not significant. The most influential climatic variables for Maize crop production in the study area were observed to be maximum temperature, minimum temperature and RF. The finding confirmed that maximum temperature is significant andpositiveinfluenced the yield of Maize crop, while rainfall and minimum temperature are bothsignificant andpositivelyinfluenced wheat crop yield. The influence of maximum temperature is significant for the maize crop. Both temperature and relative humidity displayed positive interrelation with teff crop yield.

Overall, climate change has adverse implication on the yield of major food crops. Moreover, the population is growing rapidly and the Gurage zone will face the problem of food security in the near future. The government needs to take firm action to overcome this problem and ensure sufficient food forthe masses.

In this way, measures combating population growth and resource utilization would be determined. This would reduce the risks ahead of human life in terms of land and food availability.

5.2. Recommendation

All three key issues highlighted in this study- land use pattern , climate change and food security - are majorly linked to agricultural productivity. Owing to the growing population and the limited resources of the country, there is an immediate requirement to raise the productivity levels.

Advanced farming techniques should be used in order to cope in a better fashion, with the climatic shocks.

Improved irrigation systems should be introduced along with the cultivation of different types of crops which are not very sensitive to the climate changes.

Improving the adaptive capacity by changing agricultural practices, upgrading livestock and crops by breeding and spending in latest know-hows and infrastructure' will be of greatest significance.

Increase the land holding size of the farmers and to as such, expand the area under cultivation. Special emphasis should also be given to agriculturally rich areas and those that are prone to natural calamities like floods and droughts by advancing the infrastructure of these areas.

Increasing the farmer's awareness by providing basic education in rural villages can also be a useful step contributing towards advancement of technology.

Agricultural policies should promote organic farming to bring about sustainable agriculture, thereby reducing the effects of agriculture on climate and ensuring higher yield and profits.

Providing Basic Necessities to the Poor

Flourishing industries and low productivity in the agriculture sector has led to a large rural population migrating to urban areas in search of job opportunities. The government must ensure the smooth working of the population. Food should be readily available to the poor at subsidized rates to solve the problem of food availability. More Viable plans and acts should be introduced by the government agencies aiming at reducing poverty levels by generating more jobs and increasing the minimum wage level so that each household has sufficient income to meet their basic needs.

Several other programs such as, Integrated Rural Program exist but unfortunately, they are not very actively followed and should as such be re-implemented

New contingency plans should be developed in order to spread awareness about the occurrence of natural calamities among the low skilled workers and to prepare them for mitigation and adaptation in case of emergency.

Improvement of Public Health Services

Preserving Natural and Biodiversity:- Forests are very strongly linked with the agriculture productivity. Promoting afforestation and preserving the natural habitat will not only reduce the chances of global warming by reducing pollution levels but will also provide fuel and other benefits to the rural population, thus, increasing their income and standard of living. Programs that prevent deforestation and forest fires should be initiated to improve the land use and increase sustainability of agricultural land

Wise utilization and Conserving Water Resources :-

Finally, the research has room for improvement when the following factors are considered;

1) Land use land cover data collected should include farming methods used by farmers in order to map and analyze the land use/ cover changes and implications for food production if the living conditions and standards of rural livelihoods are to be improved and maintained at current levels.

2) The food production data should include livestock products and animal population data in order to map adequately the relationship between land use land cover changes, population growth and food security.

References

Abebe Tadege, (2008). Accordingly, “climate variability” is the fluctuation in climatic parameters from the normal or baseline values, whereas “climate change” is a change in the long-term mean value of a particular climate parameter.

Abera Y, Belachew T (2011). *Effects of land use on soil organic carbon and nitrogen in soils of Bale, South Eastern Ethiopia*. J. Trop. Subtrop. Agroecosyt. 14, 229-235.

Ackerman (2009). Assessing relative roles played by climate and socioeconomic changes in projected LULCC.

Adamsetal. (1989, 1990, 1993, & 1999),Darwin (1999),Easterling et al. (1993),El-Shaer et al. (1997),Iglesias et al. (1999),Kaiser et al. (1993), Kapentanaki and Rosengweig (1997),Kumar and Parikh (2001),Rosengweig and Parry, (1994) , Seo et al.(2005).Lack of sufficient controlled experiments to determine agronomic responses in several developing countries.

Aerts R, Wagendorp T, November E, Mintesinot B, Deckers J, Muys B (2004). *Ecosystem thermal buffer capacity as an indicator of the restoration status of protected areas in the Northern Ethiopian Highlands*. Restoration Ecology 12, 586-596.

Agbede TM (2010). *Tillage and fertilizer effects on some soil properties, leaf nutrient concentrations, growth and sweet potato yield on an Alfisol in southwestern Nigeria*. Soil & Tillage Research 110(1), 25-32.

Ajayi et al, (2010). Revealed that rainfall has a constraining ability on cocoa yield in the core cocoa production areas of Ondo state, Nigeria.

Alemu B, Kidane D (2014). *The Implication of Integrated Watershed Management for Rehabilitation of Natural Resource.*

Ali, A.; (2017). *Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in South Africa* . Clim. Risk Manag. **2017**, 16, 183–194.

Bandara, J.S.; Cai, Y(2014). *The impact of climate change on food crop productivity, food prices and food security in South Asia.* Econ. Anal. Policy **2014**, 44, 451–465

Belaye, etal (2013). Examined adapting to climate variability and change experiences from cereal based farm.

Berry, L. (2003). *Land Degradation in Ethiopia: Its Extent and Impacts*. A Pilot Case Study Analysis on Ethiopia Commissioned by the GMwith WB Support, Pp 24.

Cline (2007). Agricultural output in developing countries may decline by 20 percent due to climate change, while output in industrial countries is expected to decrease by 6 percent .

CSA (2009)There were 286,328 households in the Gurage zone in 2007, indicating the presence of an average of 4.47 persons per household.

daba, S. (2003). *An Assessment of the Physical and Socioeconmic Detriments of Soil Erosi.on in the Hararghe Highlands East Ethiopia, Land Degradation and Development,* 14, 69-81.

Daka(2009)*Climate Change on Poverty and Economic Growth and Options of Coping with Adverse Effects of Climate Change in Bangladesh*; Policy Study: Dhaka, Bangladesh, 2009.

Darwin et al (1995)Changes in the experimental crops derived from the different agro-ecological zones are fed into an economic model to predict rather overall supply and market effects.

Davis and Sadiq, (2010) Carried out a research on the effect of climate change on cocoa yield.

Deressa (2006). Finds that net farm revenue would fall in summer and winter if temperature increases.

Deressa, T., Hassan, R. M., and Ringler, C.(2008). *Measuring Ethiopian Farmers Vulnerability to Climate Change Across regional States*, IFPRI Discussion paper 00806.

Devereux, S, and Maxwell, S, Eds (2001). Food Security in Sub-Saharan Africa. London UK: Intermediate Technology Development Group Publishing

EHRS-FAO (1986). Several studies have been done at the national level; the Highland Reclamation Studies: Ethiopia.

Eid et al., (2006). Estimates from two climate change scenarios showed that high temperatures would constrain agricultural production in Egypt almost 46.7 per cent in output value.

FAO, (1986). *Highland Reclamation Study Ethiopia*, Final Report Vol I and II, Rome, Italy.

FAO, (1999) crop production and livestock husbandry account for about half of a household income, and the poorest members of the society are those who are most dependent on agriculture for jobs and income.

FAO, (1999). *The State of Food Insecurity in the World.* Food and Agricultural Organization of the United Nations

Fischer et a l (2005) .Due to climate change, yields in developing countries could further decrease by 15 percent on average by 2080

Fuhrer, (2006). More recently, elements of crop adaptation to extreme weather events have been explored with genotypic variation and adaptability to cope with several of the negative implication on unadapted productivity.

Fuhrer, J. (2006). *Agricultural Systems: Sensitivity to Climate Change,* CAB Reviews: Perspective in Agriculture, Veterinary Science, Nutrition and Natural Resources, No 052.

Garedew, E., Sandewall, M., Sodaberg, U., and Cambell, B. M. (2009). *Land Use and Land Cover Dynamics in the Central Rift Valley of Ethiopia*. *Environmental Management*, 44, 683-694

Gete Zeleke. (2000). *Landscape Dynamics and Soil Erosion Process*. Modelling in the North Western Ethiopian Highlands.

Green Forum, (2007). Most crops produced in the main cropping season also encounters moisture deficiency at their maturity period, which brings about decline in productivity.

Green, R. E., Cornell, S. J., Scharlemann, J. P. W.,and Balmford, A (2005). *Farming and the Fate of Wild Nature.* Science 307, 550-555

Gregory *et al.,* (1999).Human alteration of land use patterns, elimination of wetlands and other biophysical changes could affect the water cycle ability to support the needed food production.

Gregory, P. J., Ingram, J. S. I, Cambell, B., Gourdriaan, J., Hunt, L. A.,Landsberg, J. J., Linder, S., Stafford Smith, M., Sutherst, R. W., and Valentin, C. (1999).

GZFED (2015).According to the statistical abstract report of the Gurage zone, for each district (woreda), the number of average livestock per hectare was 27.

Hamza et al (2012). Land uses pattern climate change, its implication for food security in Ethiopia.

Hurni, (1988).The intensification of agriculture and the expansion of croplands into marginal lands which is dominated by the traditional system/practices have led to severe land degradation.

Hurni, H. (1988). Degradation and Conservation of the Resources in the Ethiopian Highlands. *Mountain Research and Development*, 8 (23), 123-130

Hurni, H. (1993). Land Degradation, Famine and Land Resource Scenarios in Ethiopia. In: Pimentel, D., editor, World Soil Erosion and Conservation. Cambridge, UK, Cambridge University Press, Pp 27-61.

In Burkina Faso, Ouedraogo et al. (2006). Find that if temperature increases by 1°C, farm revenue will fall by 19.9 US$/ha, while if precipitation increases by 1 mm/month, net revenue increases by 2.7 US$/h using a standard Ricardian model.

IPCC, (2000).The use of fire as a management tool for slash-and-burn agriculture and other purposes results in at least a third of the savanna being burned every year.

IPCC, (2007). The human implication on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

IPCC. (2001). Climate Change: Impacts, Adaptations and Vulnerability. IPCC Working Group II. 3rd Assessment Report (McCarthy, J. J.,Canziani, N. A., Leary, D. J.,Dokken and K. S. White (eds), Cambridge University Press.

Jawad, etal, (2013). Examined the impact of climate and land use change on water and food security in Jordan.

K.F.Ahmed et,al (2016). Potential implication of climate and socio economic changes on future agricultural land use in West Africa.

Kumar et al. (2013). Based on the topic *'Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India'.*

Lambin *et al(*2003).An estimated 4.7 million km^2 of grassland areas and 6 million km^2 of forest/woodland have been converted to cropland worldwide since 1850 and the main purpose for land use change is to obtain food and other essentials.

Lambin *et al., (2003*).Million km^2 of grassland areas and 6 million km^2 of forest/woodland have been converted to cropland worldwide since 1850.

Lambin, E. F., Geist, H. J., and Lepers, E. (2003). Dynamics of Land Use and Land Cover Change in Tropical Regions. *Annual Review Environmental*

Lawal and Emaku, (2007) .During their own study on the effect of climate change on cocoa production in Nigeria found out that there is a weak negative correlation for both rainfall and relative humidity on cocoa yield over the years while they established positive correlation for temperature on yield.

Lovejoy and Hannah, (2005). The increase in average temperature of the planet and change in hydrological cycle are major manifestations of climate change.

Managed Production Systems. In: Walker, B., Steffen, W., Candell, J, and Ingram, J. S. I.(eds). *The Terrestrial Biosphere and Global Change*: Implications for Natural and Managed Systems. Cambridge University Press, Cambridge, Pp 229- 270.

Mano and Nhemachena (2006). Finds that when farm revenue in Zimbabwe is regressed against various climates, soil, hydrological and socio-economic variables in a Ricardian framework, the net effect of climate change on agriculture in Zimbabwe is quite significant. Sensitivity analysis of alternative climatic scenarios that is, 2.5^0 C and 5^0 C increases in temperature resulted to decrease in net farm revenues of approximately US$0.3 and US$0.3 billion respectively.

Mendelsohn and Dinar, (1999). Agronomic estimates do not control for adaptation to changing climates.

Molua and Lambi, (2006) finds that a 3.5 per cent increase in temperature associated with a 4.5 per cent increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon‘s agriculture, leading toMarginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis.

Molua and Lambi, (2006). Finds that a 3.5 per cent increase in temperature associated with a 4.5 per cent increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon‘s agriculture, leading toMarginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis.

Morton *et al., (2006*).Land cover refers to the physical and biological cover over the surface of the ofthe world’s natural land cover has been transformed by human activities.

Nastis et al. (2012). Did one of such research to estimate the effect of climate change on agricultural output in Greece.

National Review Report,(2002).The studies show that, 30,000 ha is lost annually due to water erosion with over 2 million ha already severely damaged Ethiopia is a country of small holder agriculture.

Negatu, (2005). In the year 2000 cropping season, 87.4% of rural households operated less than two hectares, 64.5% cultivated farms less than one hectare while 40.6% operated farm of less than 0.5 ha or less.

Omolaja et al (2009). Contrary to the negative correlation between rainfall and cocoa yield, found that high rainfall and favorable temperature promote flowering intensity of cacao inNigeria.

Osborne and Wheeler (2013).Many agricultural regions across the globe have already observed significant changes in crop yield variability over the past few decades.

Parryl *et al(*2004). Twin elements of climate variability and climate change which have a direct effect on food production and food security.

Pielke (2011). Dynamics of land use change is not explicitly represented in regional and global climate models, partly due to the difficulties in formulating the human decision-making processes influencing anthropogenic land use.

Reinsborough, (2003). In the Production function approach, the production function is specified and the yields of different species of crops are examined under different climatic conditions

Resource Degradation in the North- Western Ethiopian Highlands. *Journal of Mountain Research and Development,* 21(2), 245 – 257.

Ringer, (2008). The rural populace for whom agriculture is the primary source ofdirect and indirect employment would be most affected due to the vulnerability to global change processes.

Rounsevell 2014).Assessing relative roles played by climate and socioeconomic changes in projected LULCC

Samuel, (2005).Small farms were fragmented on average into 2.3 plots.

Seo et al. (2005). Lack of sufficient controlled experiments to determine agronomic responses in several developing countries.

Solomon *et al*., (2007).Generally, increasing food insecurity, water scarcity, drought, spread of diseases to new areas, damage from floods and forced migration due to desertification of previously arable land or sealevel rise are some of the likely issues in developing countries.

UNDP (2007). Climate change shocks also erode the long-term opportunities for human development and could exacerbate inequalities within countries

UNDP, (2007). Although Ethiopia has relatively abundant water, it has one of the lowest storage capacities in the world: 50 cubic meters per person.

UNFCCC, (2007).Rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth's atmosphere.

UNISDR, (2008). The atmosphere connects all weather systems and all climates, it is sometimes useful to describe the atmosphere, oceans and Earth surface as the "global climate system".

VanDijk,andetal, (2014). AnalyzmplicationofuncertainandcomplexfuturesonVietnam'seconomyviachangesinlandusepattern key variable that may affect land use in Vietnam are climate change , international trade, population growth, technological change.

Von Braun(2007). Agricultural systems worldwide over the last 40 – 50 years have responded to the effect of the interacting driving forces of population increase, income growth, urbanization, and globalization on food production, markets and consumption.

World Bank, (2007). Climate change is projected to cause the drying up of wetlands and run-off to Nile tributaries would be reduced by up to one third.

World Bank,(2008). Agricultural growth since 1980 was attributed to crop area expansion instead of increase of productivity over already existing agricultural land.

World Food Summit (1996). Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Appendix

Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
bararea	10	1040998.90	1148498.60	1108185.2880	52105.81917	-.494	.687	-2.243	1.334
barpro	10	9000.00	16428.00	14149.0000	2933.28049	-1.234	.687	.118	1.334
baryield	10	.0085640372	.0143040107	.012698997140	.0022444844454	-1.537	.687	.901	1.334
barmaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
barmintem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
barRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
maarea	10	1040998.90	1419881.82	1145082.9050	107855.19536	1.979	.687	5.317	1.334
mapro	10	9000.00	20739.00	15415.7000	3012.50099	-.625	.687	2.364	1.334
mayield	10	.0085640372	.1303924400	.024962638560	.0370854266670	3.149	.687	9.940	1.334
mamaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
mamimtem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
maRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
soarea	10	465788.80	1148489.07	998335.4610	189902.38210	-2.976	.687	9.251	1.334
sopro	10	6662.72	16428.00	12202.4720	2962.89732	-.787	.687	-.126	1.334
soyield	10	.0085640372	.0143041653	.012322094280	.0020620438260	-1.413	.687	.859	1.334
somaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
somintem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
soRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
tefarea	10	783164.51	1148498.60	1050581.2870	105658.66537	-1.920	.687	5.099	1.334
tefpro	10	9000.00	16428.00	13863.2720	2218.21518	-.854	.687	1.821	1.334
tefyield	10	.0085640372	.1430417960	.025889902590	.0411960607954	3.153	.687	9.956	1.334
tefmaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
tefmintem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
tefRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
wharea	10	104849.02	1148498.60	977046.2160	326577.66636	-2.570	.687	6.876	1.334
whpro	10	9000.00	16428.00	14135.7240	2569.07361	-.928	.687	.074	1.334
whyield	10	.0085640372	.1430417960	.026236309070	.0410786673744	3.151	.687	9.950	1.334
whmaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
whmintem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
whRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
poatea	10	104849.02	1148498.60	898656.0650	427883.85594	-1.573	.687	.872	1.334
popro	10	11855.73	16428.00	15221.6450	1749.46231	-1.146	.687	-.336	1.334

poyield	10	.0128118866	.1430417960	.026939065700	.0407974102308	3.161	.687	9.996	1.334
pomaxtem	10	20.25	28.80	26.0350	2.25488	-2.044	.687	5.646	1.334
pomintem	10	6.90	12.10	9.7400	1.62289	-.264	.687	-.556	1.334
poRF	10	109.10	234.30	173.9900	48.95437	-.075	.687	-1.587	1.334
Valid N (listwise)	10								

Correlation pop,LULC and food crop production

Correlations

		cerial crop lu	built uparea	bar land	wood land	forest lu	population	production offood crop in local unit
cerial crop lu	Pearson Correlation	1	.972	-.806	-.965	-.533	.929	.998*
	Sig. (2-tailed)		.151	.403	.168	.642	.241	.044
	N	3	3	3	3	3	3	3
built uparea	Pearson Correlation	.972	1	-.644	-1.000*	-.717	.990	.953
	Sig. (2-tailed)	.151		.555	.017	.491	.090	.195
	N	3	3	3	3	3	3	3
bar land	Pearson Correlation	-.806	-.644	1	.624	-.072	-.529	-.845
	Sig. (2-tailed)	.403	.555		.571	.954	.645	.359
	N	3	3	3	3	3	3	3
wood land	Pearson Correlation	-.965	-1.000*	.624	1	.735	-.993	-.945
	Sig. (2-tailed)	.168	.017	.571		.475	.074	.212
	N	3	3	3	3	3	3	3
forest lu	Pearson Correlation	-.533	-.717	-.072	.735	1	-.808	-.473
	Sig. (2-tailed)	.642	.491	.954	.475		.401	.686
	N	3	3	3	3	3	3	3
Population	Pearson Correlation	.929	.990	-.529	-.993	-.808	1	.901
	Sig. (2-tailed)	.241	.090	.645	.074	.401		.285
	N	3	3	3	3	3	3	3

Model Summary[b]

del	R	R Square	justed R Square	Std. Error of the Estimate	Change Statistics				urbin-Vatson
					Square Change	F ange		ig. F hange	
	.691[a]	.477	.215	2598.18838	.477	1.824		.243	1.870

'redictors: (Constant), barRF, barmaxtem, barmintem

)ependent Variable: barpro

Coefficient Correlations[a]

Model			barRF	barmaxtem	Barmintem
1	Correlations	barRF	1.000	-.077	-.252
		barmaxtem	-.077	1.000	-.132
		barmintem	-.252	-.132	1.000
	Covariances	barRF	338.721	-552.014	-2592.520
		barmaxtem	-552.014	152148.770	-28769.798
		barmintem	-2592.520	-28769.798	311827.192

a. Dependent Variable: barpro

production offood crop in local unit	Pearson Correlation	.998*	.953	-.845	-.945	-.473	.901	1
	Sig. (2-tailed)	.044	.195	.359	.212	.686	.285	
	N	3	3	3	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

Linear Regression

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	11235.8252	17816.4961	14149.0000	2025.77044	10
Residual	-3133.79077	2603.11694	.00000	2121.41192	10
Std. Predicted Value	-1.438	1.810	.000	1.000	10
Std. Residual	-1.206	1.002	.000	.816	10

a. Dependent Variable: barpro

Correlations

		tefpro	mamaxtem	mamimtem	maRF	whmaxtem	whmintem	whRF	tefmaxtem	tefm
Pearson Correlation	Tefpro	1.000	-.204	-.535	-.127	-.204	-.535	-.127	-.204	
	Mamaxtem	-.204	1.000	.157	.115	1.000	.157	.115	1.000	
	Mamimtem	-.535	.157	1.000	.266	.157	1.000	.266	.157	
	maRF	-.127	.115	.266	1.000	.115	.266	1.000	.115	
	Whmaxtem	-.204	1.000	.157	.115	1.000	.157	.115	1.000	
	Whmintem	-.535	.157	1.000	.266	.157	1.000	.266	.157	
	whRF	-.127	.115	.266	1.000	.115	.266	1.000	.115	
	tefmaxtem	-.204	1.000	.157	.115	1.000	.157	.115	1.000	
	tefmintem	-.535	.157	1.000	.266	.157	1.000	.266	.157	
	tefRF	-.127	.115	.266	1.000	.115	.266	1.000	.115	
Sig. (1-tailed)	tefpro	.	.286	.055	.363	.286	.055	.363	.286	
	mamaxtem	.286	.	.332	.376	.000	.332	.376	.000	
	mamimtem	.055	.332	.	.229	.332	.000	.229	.332	
	maRF	.363	.376	.229	.	.376	.229	.000	.376	
	whmaxtem	.286	.000	.332	.376	.	.332	.376	.000	
	whmintem	.055	.332	.000	.229	.332	.	.229	.332	
	whRF	.363	.376	.229	.000	.376	.229	.	.376	
	tefmaxtem	.286	.000	.332	.376	.000	.332	.376	.	
	tefmintem	.055	.332	.000	.229	.332	.000	.229	.332	
	tefRF	.363	.376	.229	.000	.376	.229	.000	.376	
N	tefpro	10	10	10	10	10	10	10	10	

Coefficients[a]

mamaxtem	10	10	10	10	10	10	10	10
mamimtem	10	10	10	10	10	10	10	10
maRF	10	10	10	10	10	10	10	10
whmaxtem	10	10	10	10	10	10	10	10
whmintem	10	10	10	10	10	10	10	10
whRF	10	10	10	10	10	10	10	10
tefmaxtem	10	10	10	10	10	10	10	10
tefmintem	10	10	10	10	10	10	10	10
tefRF	10	10	10	10	10	10	10	10

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig Char
1	.549[a]	.302	-.047	2269.96961	.302	.865	3	6	

a. Predictors: (Constant), maRF, mamaxtem, mamimtem

b. Dependent Variable: tefpro

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13367735.086	3	4455911.695	.865	.509[b]
	Residual	30916572.133	6	5152762.022		
	Total	44284307.219	9			

a. Dependent Variable: tefpro

b. Predictors: (Constant), maRF, mamaxtem, mamimtem

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B		Correlations	Collinearity Sta		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance
1	(Constant)	23803.983	9379.779		2.538	.044	852.490	46755.476				
	mamaxtem	-122.400	340.787	-.124	-.359	.732	-956.277	711.477	-.204	-.145	-.123	.970
	mamimtem	-714.476	487.873	-.523	-1.464	.193	-1908.257	479.305	-.535	-.513	-.500	.913
	maRF	1.178	16.079	.026	.073	.944	-38.167	40.523	-.127	.030	.025	.924

a. Dependent Variable: tefpro

Coefficient Correlations[a]

Model			maRF	mamaxtem	mamimtem
1	Correlations	maRF	1.000	-.077	-.252
		mamaxtem	-.077	1.000	-.132
		mamimtem	-.252	-.132	1.000
	Covariances	maRF	258.548	-421.355	-1978.887
		mamaxtem	-421.355	116136.106	-21960.167
		mamimtem	-1978.887	-21960.167	238019.643

a. Dependent Variable: tefpro

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	mamaxtem	mamimtem	maRF
1	1	3.934	1.000	.00	.00	.00	.00
	2	.047	9.164	.01	.01	.03	.99
	3	.016	15.655	.04	.08	.96	.01
	4	.003	34.458	.94	.91	.01	.00

a. Dependent Variable: tefpro

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	12296.4521	15813.9326	13863.2720	1218.73045	10
Residual	-3296.45215	2862.44702	.00000	1853.42242	10
Std. Predicted Value	-1.286	1.601	.000	1.000	10
Std. Residual	-1.452	1.261	.000	.816	10

a. Dependent Variable: tefpro

Model Summary[b]

Model	R	R	Adjusted R	Std. Error of the	Change Statistics	Durbin-

		Square	Square	Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Watson
1	.275[a]	.075	-.387	3025.57525	.075	.163	3	6	.917	2.219

a. Predictors: (Constant), maRF, mamaxtem, mamimtem

b. Dependent Variable: whpro

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4476619.261	3	1492206.420	.163	.917[b]
	Residual	54924633.726	6	9154105.621		
	Total	59401252.987	9			

a. Dependent Variable: whpro

b. Predictors: (Constant), maRF, mamaxtem, mamimtem

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF

1	(Constant)	14601.302	12502.030		1.168	.287	-15990.063	45192.667					
	Mamaxtem	-133.777	454.226	-.117	-.295	.778	-1245.227	977.673	-.089	-.119	-.116	.970	1.031
	Mamimtem	421.328	650.271	.266	.648	.541	-1169.827	2012.484	.216	.256	.254	.913	1.095
	maRF	-6.244	21.432	-.119	-.291	.781	-58.686	46.198	-.062	-.118	-.114	.924	1.082

a. Dependent Variable: whpro

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	12912.8340	15069.0859	14135.7240	705.26742	10

Residual	-4210.32861	3415.16602	.00000	2470.37185	10
Std. Predicted Value	-1.734	1.323	.000	1.000	10
Std. Residual	-1.392	1.129	.000	.816	10