ADDIS ABABA UNIVERSITY
COLLEGE OF BUSINESS AND ECONOMICS
SCHOOL OF COMMERCE
OFFICE OF GRADUATE STUDIES

# ECONOMIC IMPACT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION AND FOOD SECURITY IN SUB-SAHARAN AFRICA

**BY**

**BATRU WOLDE MULETA**

A THESIS SUBMITED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN THE PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE IN DEVELOPMENT ECONOMICS

**June, 2021**
**Addis Ababa, Ethiopia**

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**Advasior: - Aregawi Gebremedhin(PhD)**

**June, 2021**
**Addis Ababa, Ethiopia**

## DECLARSATION

I hereby declare this thesis to the senate of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Development Economics that fulfills the regulation of the university and meet the required standards for its originality and quality

**Approved by Examiners**

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| Advisor | Date |
| ______________________ | ______________ |
| Internal Examiner | Date |
| ______________________ | ______________ |
| External Examiner | Date |

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| | |
|---|---|
| **ADF** | Augmented Dicky-Fuller test |
| **AGRA** | Alliance for a Green Revolution in Africa |
| **CIGI** | Centre for International Governance Innovation |
| **FAO** | Food and Agricultural Organization |
| **FAOSTAT** | Food and Agriculture Organization of United Nation Statistics Division |
| **GHG** | Green House Gas |
| **FEM** | Fixed Effect Model |
| **IAASTD** | International Assessment of Agricultural Knowledge, Science and Technology for Development |
| **IFAD** | International Fund for Agricultural Development |
| **IFPRI** | The International Food Policy Research Institute |
| **IPBES** | Intergovernmental Science-policy platform on Biodiversity and Ecosystem Service |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPS** | Im, Pesaran and shin |
| **ISS** | Institute for Security Study |
| **NEPAD** | New Partnership for Africa's Development |
| **NESDIS** | National Environmental Satellite Data and Information Services |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NPFA** | United Nations Population Fund |
| **OECD** | Organization for Economic Co-orporation Development |
| **OLS** | Ordinary Least Square |

| | |
|---|---|
| **REM** | Random Effect Model |
| **SSA** | Sub-Saharan Africa |
| **UNDESA PD** | UN Department of Economic and Social Affairs, Population Division |
| **UNDESA** | United Nations Department of Economic and Social Affairs |
| **UNEP** | United Nations Environment Programme |
| **UNFCC** | United Nations Framework Convention on Climate Change |
| **UNICEF** | United Nations International Children's Emergency Fund |
| **US** | United States |
| **VIF** | Variance Inflation Factor |
| **WFP** | World Food Programme |
| **WHO** | World Health Organization |
| **WRI** | World Resources Institute |

# ABSTRACT

*Agriculture is the main livelihood in Sub-Saharan Africa, but land degradation due to improper agricultural practice and climate change seriously causing decline in yields. Climate change impact agricultural production and food security directly through temperature level and water availability and indirectly through its impact disease vectors and pests. This paper investigates the economic impact of climate change on agricultural production and food security in SSA. Country level panel data of SSA countries is used to analyze the impact of temperature and precipitation on agricultural production and food security. Temperature and precipitation deviations from long term average are used to analyze their impact on agricultural production and their coefficient of variations are used to analyze their impact on food security. The results from the analysis indicate that, slight deviation in temperature from its long term average impact agricultural production positively and significantly. However, its square(larger) deviation affects the production negatively if adaptation method not used. The use of pesticide included in production as adaptation method, reverses the negative impact of temperature on agricultural production. Both the slight and large deviation in precipitation impact agricultural production negatively. All agricultural production input variables has significant effect on agricultural production in the region. Coefficient of variation of both temperature and precipitation affect food security negatively. The climate variables impact food security directly through its impact on food production and indirectly through its impact on other food security indicators. To overcome its impacts the study suggest that; appropriate land use policy formulation, appropriate use of irrigation, planting agro-forest tree, investment on agricultural research and number of population must be maintained at optimum level.*



***Key Word:*** *Sub-Saharan Africa, Climate change, Agriculture, Food security*

## CHAPTER ONE

# 1. INTRODUCTION

### 1.1 Back Ground

Sub-Saharan Africa (SSA) covers total surface area of 2456 million ha with areas considered to be useful is 1532 million ha after deduction of continental water cover 65 million ha, settlement area 3 million ha and non-cultivatable land 856 million ha (Séronieand Jacquemot, 2020). Out of 790 million ha potentially available land, only 240 million hectares already exploited with annual and perennial crop cultivation and 445 million ha is used for prairies and permanent pasture in the region (OECD/FAO, 2016).

The region is a home for more than 950 million people (OECD/FAO, 2016)is known by fast population growth which is 2.5% per annum compared to 2017-2019 base period(OECD/FAO, 2020). About 50% of total populations are engaged in agriculture for their livelihood and small farms constitute about 80% of all farms in the region (OECD/FAO, 2016). On average the sector accounts for 16% of the total Gross Domestic Product (GDP) of the region though the contribution reach more than 50% in countries like in Chad (OECD/FAO, 2020).

However, more than half of available land for agriculture would be affected by land degradation, seriously causing decline in yields in the region (IFAD, 2019). Soil degradation is greater in Africa than in the rest of the world. Improper agricultural practice and climate change jointly have accelerated both arable and pastures land degradation in the region (Séronieand Jacquemot, 2020).

As defined by IPCC, Climate change “refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer” (IPCC, 2013). Climate changes happen due to natural processes as well as by anthropogenic induced pollution and its impact on natural resources, biodiversity, and land use etc.(Kaur & Kaur, 2017).

Climate change can worsen land degradation by increasing drought frequency and severity, dry spells, heat stress, rainfall intensity, flooding, sea-level rise, wind, and wave action adapted by land management. Climate change affects food security due to changing precipitation patterns, warming and higher frequency of extreme events. Its occurrences results either an increase or decrease in crops yield, animal growth rates and productivity, as well as agricultural pests and diseases infestations (IPCC, 2019).

These occurrences of climate change cause to increase the intensity and number of disasters, threaten food security and human health, reduce fresh water availability, reduce industrial production and damage the physical infrastructure, resulting in decline development. Furthermore, changes in rainfall and river sensitivity to climate variation cause changes in rainfall with decreased river basin runoff and less water available for agriculture and hydropower generation (IPCC, 2019).

Climate change impact agricultural production directly through temperature level and water availability and indirectly through changes in other species such as pollinators, disease vectors, pests and invasive species even though, the indirect impact difficult to predict by simulation and modeling (FAO, 2016). Climate change and its variability as well as extremes have been affecting agricultural productivity, natural resources, with impacts on food securities and rural livelihoods that decline in the number of farmers. All of these forces to major shifts in food production, distribution and consumption methods worldwide and to new food security, nutrition and health challenges (FAO, 2019).

The effect of climate change on the global ecosystem and its impact on agriculture and food security makes a challenging in ending hunger and malnutrition. Though there is considerable progress, people that live under chronically undernourished reach about 800 million and stunted children less than five years old are estimated to 161 million. Similarly 500 million people are obese and 2 billion lack the essential micronutrients they need to lead healthy lives (Gitz *et al.*, 2016).

Fruit and vegetables highly affected by climate change due to its potential cause for disease and pest infestation (Tripathi *et al.,* 2016) and impact on pollinators that contribute up to 35% of worldwide crop production (IPBES, 2016). It also impacts livestock production systems specially pastoralists in decreasing animal feeds, productivity, poor animal health and access to water (Egeru, 2016).

**1.2 Statement of the problem**

Sub Saharan Africa's population which was 950 million in 2016, is projected to reach 2.1 billion by 2050 (OECD/FAO, 2016). However, this increase impose burden in increasing rate of urbanization that cause decline in agricultural land as well as increase food demand (Olasehinde-

Williams *et al.*, 2020). The number of undernourished people estimated to 218 million in the region in 2016 (OECD/FAO, 2016) and projected to increase to 355 million by the year 2050 (AASR, 2014). Hence, to solve difficulty of undernourishment and to fulfill the food demand, agricultural productivities are likely to increase significantly (Adedoyin *et al.*, 2020).

However, as a result of climate change, cereal yield projected to decline by net 3.2% in 2050 in SSA. This decline in yield projected to causes an increase in food price up to 20% that projected to decline nutrition consumption of the family by 1.3% or 37 kilocalories per capita per day. Consequently that expect to result 0.6 million more malnourished children in the region (Ringler *et al.*, 2011).

Agriculture depends on natural resources like water, soil and biodiversity, but agricultural policies, mostly neglect to manage ecosystems that results huge loss of wealth due to natural disasters(erosion, landslides, drought) that arise from fail to integrate agriculture and environmental management policies (Ching *et al.*, 2011).

It is very crucial to assess the impacts of climate change on agriculture and food security in SSA. Unfortunately, there have been limited studies on the impact of climate change on agriculture and food security till date in the region. Especially researches conducted on food security were very scant. Some research conducted at district level by using micro level data of a single or few crops effects, and tried to conclude for large area that cover various agro climate. There is also time gap since some of the researches conducted not in recent time. In addition the recommendations forwarded from the researches do not consider the link between climate change, agriculture and food security.

Thus, this research contributes in filling the gap that not addressed yet in the region through the empirical evidence obtained and forwarded recommendations including policy issues. These also help to give clear insight on how to adapt and mitigate climate change as well as coordinate resources to tackle the problem based on the link between climate change, agriculture and food security.

## 1.3 Objective of the study

### 1.3.1General objective

The general objective of the research is to examine the impact of climate change on agricultural production and food security in SSA.

### 1.3.2 Specific objectives

i. To determine the impact of temperature and precipitation on agricultural production and food security in SSA

ii.To determine the vulnerability level of agricultural production and food security to temperature and precipitation in SSA

## 1.4 Research question

i. What are the temperature and precipitation impacts on agricultural production and food security in SSA?

ii. What is the vulnerability level of agricultural production and food security to climate variables in SSA?

iii. How is Agricultural productivity linked to food security?

### 1.5 Hypothesis of the study

Ho: Climate change has no impact on agricultural production and food security in SSA

### 1.6 Significance of the study

This study assessed the possible economic impact of climate change on agricultural production. It intended to provide important insight and contribute to efforts aimed at ensuring food security through sustainable production and increased income from agricultural production. The output of the research help policymakers so that they understand the severity of climate change and give attention to the environmental protection that promotes sustainability.

### 1.7 Scope and limitation of the study

The study totally depends on the aggregate macro data to analyze the impacts of climate change on agricultural production and food security in SSA. This is due to lack of individual crop, different livestock species and soil characteristics data at the micro-level. Different crop types respond to climate change differently and hence further disaggregation is important. Given that different crops and livestock have different climate requirements, future studies need to be focused on specific crop and livestock responses and adaptations in SSA.

In addition the study do not incorporates future climate change impact predictions. Thus, future research recommended to include near and far future climate change damage on agricultural production and food security prediction.

### 1.8 Definition of terms

**Adaptation:** The process of modification to climate effects, to decrease harm or increase useful opportunities (IPCC, 2012).

**Anthropogenic:** The impact of human population on ecological pattern and terrestrial biosphere (Ellis, 2011).

**Disaster:** Severe alterations of harmful physical measures leading to prevalent adverse effects that need instant emergency response for recovery (IPCC, 2012).

**Ecosystem:** is living organisms interacting with each other and together their environment as one component (Ellis, 2008; Balasubramanian, 2008).

**Exposure:** The existence of assets in adversely affected situation(IPCC, 2012).

**Extreme climate event:** Weather or climate variable value manifestation above (or below) a threshold value (IPCC, 2012).

**Malnutrition:** is a condition of nutrition imbalance in which shortage or extra of nutrients causes significant effects on body composition and reduced function (Soeters *et al.*, 2016).

**Microbial:** is a group of microorganism of the one or more species (Sattley & Madigan, 2015).

**Pastoralism:** is a branch of agriculture engaged in animal reproduction using open grazing land (Dong, 2018).

**Resilience:** The capability of a system and its constituent portions to recover from the effects of a dangerous incident in an appropriate and efficient way(IPCC, 2012).

**Vulnerability:** The tendency or susceptibility to be harmfully affected (IPCC, 2012).

### 1.9 Organization of the paper

The rest of the paper organized as follows. Chapter two covers theoretical and empirical literature review and conceptual framework. Chapter three covers the methodology part that includes research design, data source and data nature, method of data analysis and model specification. Chapter four covers discussion and presentation of both descriptive and econometric results. Lastly, chapter five summarizes the main findings in the study and forward recommendations and possible policy options.

# CHAPTER TWO

## 2. REVIEW OF THEORETICAL AND EMPERICAL LITERATURE

### 2.1Theoretical Literature

#### 2.1.1 Climate change and Agriculture in SSA

Climate change is a complex and uncertain problem that involves natural resources, the environment, and peoples interactions which likely to change the ecological and influence agricultural production (Devendra, 2012). Changes in climate elements such as precipitation, temperature, and humidity, are likely to affect crop plants and livestock production, hydrologic balances, input supplies and many parts of agricultural systems (Easterling & App, 2002).

Agriculture is the science, art and business of cultivating plants, raising animals, cultivation of fungi and other living organisms for producing food, feeds, fiber, bio fuel and other products used to sustain human life. It provides the primary sources food and nutritional security together with forestry and fisheries for the welfare of the people (Fazal &Wahab, 2013).

However, agriculture is a complex multi-dimensional and multi-faceted sector not just about food production alone rather it concerns the efficient use of the natural resources, preservation of the ecosystems and productivity enhancement in a way that can sustain the needs and enhancements of human livelihoods in the future (Devendra, 2012).

Agriculture is one of the most climate sensitive sectors of an economy that impacted positively or negatively by climate changes, as a result of natural cause or human activities (Wheeler & Braun, 2013). Crops need an optimum amount of heat, water and nutrients, which are climatic in nature for the photosynthetic process (Molua, 2008). Carbon dioxide, temperature and rainfall required for crop survival and to increase their productivity (Khan & Tahir, 2018). However, extreme natural events such as drought, floods, windstorms, frost, heat spells and erratic rainfall threats agricultural productivity and production (IPCC, 2012).

Climate change seriously affects both annual and perennial crop production. An increase in temperature; affect length of growing season, flowering, sterility and protein content of the crop. Amount and distribution of precipitation increases erosion, flood, storm damage, water lodging and pest infestation rate. Under successive droughts condition crops either have reduced yields or not grown at all (Devendra, 2012). As described by Kurukulasuriya and Rosenthal (2013) climate would have a physical effect on crops in four ways;

***(i). Changes in temperature and precipitation:*** Will change the agro-ecological zones; affect soil moisture and content, and the timing and length of growing seasons in various ways(Kurukulasuriya & Rosenthal, 2013).

Tropical crops grown under normal temperatures that approach theoretical optima for photosynthesis are sensitive to warming. Any additional warming beyond optimum temperature is harmful, even when accompanied by increased precipitation. Slight warming stimulates higher productivity of temperate crops that adapt at lower temperature. However, as temperate warming proceeds beyond certain threshold level it is detrimental to the crops (Easterling*et al.,* 2007; Adams *et al.,* 1998). This is due to the fact that an increase in temperature lead to higher respiration rates and shorten seed formation periods that results smaller and lighter grains with lower quality (Adams *et al.*, 1998).

Climate change causes soil degradation by increasing soil erosion and rate of nutrient leaching. Warmer temperatures stimulate microbial activity that increase the natural decomposition of organic matter and minimize nutrient conservation. During winter time when plant nutrition demand is low or plants are absent, rising soil temperature causes nitrogen mineralization rate that exceeds plant nutrient up take. If the process followed by increased precipitation and loss of snow cover, lead to nutrient leaching consequence (Lotze-Campen & Schellnhuber, 2009).

Severe rainfalls and shifting from snow to rain, which is likely to increase under climate change, increase the rate of erosion. Dry soils are sensitive to wind and water erosion in arid and semi-arid regions (Nearing *et al.*, 2004).

***(ii)*. *Carbon dioxide*:** Higher levels of carbon-dioxide enhance greater water use efficiency and higher rate of photosynthesis that have a positive yield impact. An increase in atmospheric $CO_2$ concentrations reduce evapo-transpiration, improve water use efficiency of crops and increase the rate of photosynthesis, but the net result may be moderated by costly pest and weed infestations as it favors them in the same way (patterson *et al.*, 1999.)

Rise in temperature and elevated carbon dioxide concentration increases plant damage by pest and disease (Easterling *et al.*, 2007; Ziska *et al.*, 2018). Similar to crops, weeds show positive response to carbon dioxide concentration due to their greater genetic diversity (patterson *et al.*,1999; Ziska *et al.*, 2018). An increase in carbon dioxide concentration also alters the pant defense mechanism against pathogen. Higher temperature increases plant disease infestation and favors insect growth and geographical distribution in cooler region (Ziska *et al.*, 2018; Patterson *et al.*, 1999).

***(iii). Water availability (*****or** ***runoff):*** is a critical factor in determining the impact of climate change in many places, particularly in Africa. A number of studies suggest that precipitation and the length of the growing season are critical in determining whether climate change positively or negatively affects agriculture (Kurukulasuriya & Rosenthal, 2013). Severe rainfalls and shifting from snow to rain, which is likely to increase under climate change, increase the rate of erosion. Dry soils are sensitive to wind and rain erosion in arid and semi-arid regions (Nearing *et al.*, 2004).

***(iv). Frequency of extreme events:*** an increase in climate variability and frequency of extreme events results agricultural yield loss. A higher frequency of droughts is likely to increase pressure on water supplies. In contrast, increases in rainfall intensity in other regions can lead to higher rates of soil erosion, leaching of agricultural chemicals, and runoff that carries nutrients into water bodies (Kurukulasuriya & Rosenthal, 2013).

As with crops climate changes will have a significant effect on livestock production, productivity and the resilience of animal production systems. Climate change cause a number of potential effects prevailing livestock production systems through its impact on forage yields, feedstuff quality, availability and costs, water availability, heat stress and pest and disease spread (Thornton *et al.*, 2009; Rojas-downing *et al.*, 2017).

Climate change affect livestock production, both directly and indirectly through impacting productivity, animal health and the quality and amount of feed supply, biodiversity, carrying capacity of pastures, drinking water, an increased incidence of livestock pests and diseases. Heat Stress due to high temperature reduced feed intake and lowers animals' resistance to pathogens, parasites and vectors that cause lowered productivity and mortality (Thornton *et al.*, 2009; IPCC, 2019; Niag *et al.*, 2014; Gitz *et al.*, 2016). Climate change and water management threats fisheries and aquaculture caused from water temperatures, sea level rise, decreased pH, oxygen deficit and changes in productivity patterns (Porter *et al.*, 2014; Gitz *et al.*, 2016).

### 2.1.2 Climate Change and Food Security in SSA

#### 2.1.2.1 Food Security and Dimensions

Food security is a multi-part observable fact resulting from numerous causes (FAO, 2013). Its definition contains four key dimensions of food supplies (Byerlee *et al*., 2008). World food summit defines food security as;

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

According to this definition the four food security dimensions availability of food, Accessibility, Utilization (the way it used and assimilated by human body) and stability dimensions established.

***i. Availability:*** it refers to the quantity, quality and diversity of available food in type. This means sufficient amount of food that has appropriate quality with important nutrition contents that supplied through domestic production or import(food aid) (Chijioke *et al.*, 2011). It can be determined by domestic production, storage, distribution, import and export (Gitz *et al.*, 2016; FAO, IFAD and WFP, 2014; Byerlee *et al*., 2008).

FAO noted that, availability of agricultural product affected by climate change directly or indirectly (Gitz *et al.*, 2016). It affected directly through its impact on crop yield, soil fertility, water holding potential and crop pests and diseases, and indirectly through its impact on economic growth, agricultural product demand and income distribution (Edame *et al.*, 2011; Pedercini *et al.*, 2012). Its impact through ecological change affects land suitability, potential yield and varieties currently under production (Alagidede *et al.*, 2015).

***ii. Access:*** refers to the ability of communities, individuals and countries to purchase food in sufficient quantities and quality. Physical access to food impacted by climate change through production declines and transportation infrastructures; economic access that represented by domestic food price, declining of purchasing power and incidence of undernourishment (FAO, IFAD and WFP, 2014).

Food access determined not only by physical and economic factors, but also by social and political factors. Physical availability of food not guaranty to individual to access food due to poverty, poor infrastructure, high price, and high transaction cost etc.(Ericksen *et al.*, 2011).

***iii. Utilization:*** comprises variables that determine the ability to utilize food, particularly access to water and sanitation. The other is the outcome of poor food utilization like nutritional failures of children less than five years age such as wasting, stunting and underweight (FAO, IFAD and WFP, 2014). Climate change negatively affects food utilization through effects on human health and the spread of diseases and pests (Edame *et al.*, 2011). It negatively affects food safety and increases the pressure from vectors, water and food borne diseases. It affects the ability of individuals to use food effectively(Hossain *et al.*, 1998; Schmidhuber & Tubiello, 2007).

In addition to food availability and access to food, food utilization determined by other factors such as food preparation, nutrition content, access to clean drinking water, health care, women and child care and women's role (Negin *et al.*, 2009).It relates to hygiene, sanitation, proper food processing and sufficient knowledge about nutrition (Chijioke *et al.*, 2011).

***iv. Stability:*** relates to the stable access to adequate amounts of food at all times by population, household or individuals. It covers indicators that measure food security risk, such as cereal dependency ratio, area under irrigation and value of staple food imports as a percentage of total merchandise exports. Additionally, stability to food all the time affected by; domestic food price volatility, fluctuations in domestic food supply, and political instability that interlinked with variable weather conditions and climate change(FAO, IFAD and WFP, 2014).Climatic fluctuations are likely to reduce crop yields and livestock numbers and productivity that further cause fluctuation in yields and local food supplies and adversely affect the stability of food supplies (Hossain *et al.*, 1998).

To meet its food needs any country faced with a choice between food self-sufficiency and food self-reliance strategies. Food self-sufficiency relates to meeting country's food need by producing in the country by mobilizing domestic resources while food self-reliance relates to availability of the food regardless of the origin of the food. It relates to the ability of the domestic economy to import food to fill domestic food deficiency in production (Mkandawire *et al.*, 2014).

Climate change affects all dimensions of food securities in complex ways. Climate change and harsh climatic conditions such as excessive rainfall, lack of rain, temperature and humidity cause significant pre-harvest and postharvest food loss (chuster *et al.*, 2017).Infestation by pests and infections by disease are important cause of food loss and waste that consequently affect food availability negatively (chuster *et al.*,  2017; John, 2014).

Climate change negatively affects both physical as well as economic access to food. It affects transportation through infrastructural damages creating time gap among diverse stages of the food supply chain. This increases the risk of damaged or loss of perishable food products (FAO, 2019). Agriculture is an important source of food and income for agrarian society to access sufficient quantities and qualities of food. Decline in agricultural yield cause rise in food price that consequently decrease purchasing power of people to purchase sufficient and nutritious food with more protein, micronutrients, and vitamins (Schmidhuber & Tubiello, 2007).

Frequency and severity of extreme event reduce crop yields livestock numbers and productivity, and cause greater fluctuations in local food supplies that adversely affect the stability of food supplies and thus food security (IPCC, 2007; Schmidhuber &Tubiello, 2007).

Climate change alters infectious disease pressure from vector, water, and food-borne diseases and affects the ability of individuals to use food effectively. It results substantial decline in labor productivity, poverty and mortality through its impact on food safety and security (IPCC, 2007; Schmidhuber & Tubiello, 2007).

## 2.2 Empirical Literature Review

### 2.2.1 Effect of Climate change on Agriculture & Food Security in SSA

The number of world population overwhelmingly increasing and is projected to reach 9.8 billion by 2050 and by 2100 projected to reach 11.2billion (UNDESA, 2017).To feed these all people sufficiently the total food production will have to be increased by 70% to 100% (Byerlee *et al.*, 2008; Ray *et al.*, 2014). However, in the face of climate change increasing food production to feed this increasing population in a sustainable way is a great challenge. This is due to the sensitivity nature of agriculture to climate change and variability, as a result of natural causes and human activities (Wheeler & Braun, 2013).

As noted by the different reports climate change has been identified considerable threat to Africa, its ecosystems and many of its species. It is predicted that Africa will experience high extreme temperature, increase in disease and pest infestation, shift in crop and livestock growth, an increase in desertification in SSA, erosion and floods are all signs of climate change that cause environmental degradation and will displace millions of people in Africa (Tadesse, 2010).

In Sub-Saharan African agricultural sector performance is constrained by naturally low soil fertility, governance problems, insufficient transport and storage, poor access to inputs such as improved seeds and fertilizer, and lack of output markets infrastructure (AGRA, 2014).Among other developing regions SSA face worst problem due to high temperature in the region and reliance of inhabitant's livelihood on rein-fed agriculture (Ching *et al.*, 2011). Only 4 percent of cultivated land in the region is irrigated that increases yield loss due to rising temperature and decrease in precipitation (Ching *et al.*, 2011; IAASTD, 2009).

In SSA, high food price makes food security challenging for farmers in the region that rely on rain fed agriculture, pastoralism and do not have a good asset base hence have considerable financial constraint. This is because farmers in the region are net food buyers and high priced lead them failure to access food. Moreover, it forced them to reduce the quantity and quality of food they consume and allocate food for certain household members only that lead to malnutrition (Chijioke *et al.*, 2011).

In SSA about 80% of all the farms are small holder farmers that cultivate degraded small plot of land and lack reliable irrigation. They lack input and financial credits and categorized as resource poor farmers that practice rain-fed low yield subsistence agriculture with below global average yield. Average value added per worker is US$ 318 in 34 countries of SSA which is far less compared to world average US$ 1,000. Income is also less than US$1.00 per day which is due to low productivity of agriculture and spends about 60% of their income on food (AGRA, 2014; Ching *et al.*, 2011; Rosen & Shapouri, 2012).

The outcome of climate change; high temperature, extreme weather events, water shortage, raising sea level, ocean acidification, land degradation, levels and frequency of precipitation, disruption of ecosystem and loss of biodiversity adversely threat agricultural production that consequently challenge global food security. Agriculture is both source of food and income for the majority of the population. It plays a critical role for food securities since it is a means to get monetary and non-monetary resources that are sufficient to allow everyone to access ample quantities and qualities food (FAO, 2006).

Sub-Saharan Africa is already experiencing significant changes in average temperature, rainfall amount and distribution and occurrences of extreme weather events such as drought and floods. This climate change decrease production potential that reduce yield significantly and increase risk of hunger and further affect all food security dimensions (Kotir, 2011).

Across the SSA region climate change impacts are not uniform. Severe flood impacts West Africa; extended and increased droughts in east Africa; depletion of equatorial rain forest at equatorial parts of Africa and ocean acidification problems are the major problems intensified in the region. These extreme events threaten agricultural production and food security. The impacts also affect health, water access, infrastructure damages and increase potential consequences for political instability and conflicts (Tadesse, 2010; Besada *et al.*, 2015).

FAO revealed that 25 percent of the economic impact caused by climate-related disasters falls on the agriculture sector and among damage and loss caused by drought 84 percent is to agriculture. In sub-Saharan Africa region between 1980 and 2014 over 363 million people affected by droughts, of whom 203 million were in eastern Africa, 86 million in southern Africa, 74 million western Africa and less than 1 million in central Africa (Baas *et al.*, 2015).

According to the FAO estimation, annual world production of crops and livestock will need to be 60 percent higher than it was in 2006 to meet demand for food in 2050. Of required increase about 80 percent of the required increase will need to come from higher yields and 10 percent from increases in the number of cropping seasons per year (Alexandratos & Bruinsma, 2012). However, widespread land degradation and increasing water scarcity due to climate change hamper yield increase and eradication of hunger, malnutrition and poverty (FAO, 2016).

The prediction shows that climate change will affect food and water securities over the coming decades in a significant and uncertain way. The effect on developing countries highly detrimental because of; the widespread poverty level, high vulnerability levels, and low adaptation capacities of the region. This is due to the fact that in developing countries the majority of populations engaged in agriculture directly or indirectly as a main means of employment and income-generating livelihood (Ringler *et al.*, 2010).

Projection shows the impact of climate change decrease crop yield compared to world without climate change and with the absence of mitigation mechanisms. By 2100 decrease in crop yield ranges between 5 and 50% for wheat, between 20 and 45% for maize, between 30 and 60% for soybean and between 20 and 30% for rice (Rosenzweig *et al.*, 2013; FAO, 2016).

In SSA of all currently cultivated land about 128 million hectare is suitable for growing maize with a production potential of 882 million tones under current climate conditions and high levels of input. However, the projection show that the region would lose 11% of its potentially cultivable land and 7% of its grain maize production potential, by 2080 compared with current climate conditions, even under the use of fertilizer and adaptation the best and most productive grain maize varieties (Edame *et al.*, 2011).

Lobell *et al.*, (2011)revealed that for each degree crop spends above $30^0$C depresses yield by 1 percent if the plant gets sufficient amount of water and yield decreased by 1.7 percent for each day spent over $30^0$C under drought condition in Africa. In addition temperature increase causes agricultural pest infestation and their ability to survive as well as damage rate that cause yield reduction (Chijioke *et al.*, 2011).

Kabubo-Mariara and Karaja (2007) revealed that due to climate change Kenya will experience an increase in average temperature between 3.5°C to 4°C and a 20% decrease in rainfall by 2030. According to the prediction a change in temperature would result in a 1% (US$3.54 per hectare) gain in high potential zones but a 21.5% (US$54 per hectare) loss in medium and low potential zone. The result further suggest that losses of up to US$178 per hectare in country by the year 2030.

The prediction shows that, due to climate change temperature increases in 2.5°C and 5°C causes $0.65 billion and $1.8 billion respectively in Cameron. In the same manner an increase in precipitation causes a yield loss 6.5% per hectare and further decrease in precipitation by14% predicted to cause a loss of $4.56 billion in Cameron (Molua & Lambi, 2007).

Dell, Jones, and Olken(2012) find that high temperature reduces economic growth and growth rate in poor countries in reducing agricultural output, industrial output and political stability. According to their research finding on 136 countries an increase in temperature by $1^0$C reduces economic growth by 1.3 percent on average.

Abidoye and Odusola (2015) revealed that due to climate change, many African countries experience from $1^0$ to over $3^0$ Celsius temperature increase and a rise $1^0$ Celsius cause from 0.27 to 0.35 percent GDP reduction. An increase in temperature of 1.5°C and 3.6°C estimated to reduce net revenue $1,453.41 and 3,488.18 per hectare respectively if adaptation is not incorporated. However, reductions in net revenue minimized to $116.67 and $280.01 per hectare for 1.5°C and 3.6°C increases temperature respectively if farm machinery used as an adaptation mechanism. Irrigation use could also increase farm net revenues by $39.26 and $94.21 per hectare for the same level temperature increases (IAASTD, 2009).

Globally Rice, Wheat and maize price projected to increase by 48, 36 and 34 percent respectively during 2000 to 2050 period due to climate change. As projected by (Ringler *et al.*, 2010)due to climate change a price of wheat, Rice and Maize projected to increase by 15, 7 and 4 percent respectively in 2050 in Africa (Chijioke *et al.*, 2011). High food price has long term human capital effect. Studies revealed that due to undernourishment people at early childhood have more than 10 percent lower lifetime earnings due to physical and mental impairment (World Bank, 2011; Chijioke *et al.*, 2011).

Sub-Saharan Africa shows low level of progress in improving food security in all types of indicators. The greatest food security challenge, especially low improvement in food access in sluggish income growth, high poverty rate poor infrastructure, which hinders physical and distributional access. Food utilization indicated by the high anthropometric prevalence of stunted and underweight children less than five years of age also a major concern (FAO, 2018).

The region faces low improvement in access to drinking water, sanitation facilities, dietary quality and diversity of the poor. Of the four dimensions food stability dimension shows least progress mainly due to political instability, war and civil strife (FAO, 2018; FAO, IFAD & WFP, 2014). Food availability necessary but not sufficient condition for access and access is necessary but not sufficient for utilization (Chijioke *et al.*, 2011).

Climate change impact the four dimensions of food security, availability, access, utilization and stability, directly and indirectly (Gitz *et al.*, 2016). Evidences since 1990 showed that the impact of climate change on food security dimensions, availability, access, utilization and stability being represented by 70%, 11.9%, 13.9% and 4.2%, respectively.

As asserted by different literatures, still about 700 million people live in extreme poverty, and about 815 million suffer from chronic hunger (FAO, 2017; FAO, IFAD, UNICEF, WFP &WHO,

2017). FAO revealed that, by 2030 more than 650 million people will be suffering from undernourishment. This is due to depletion of land, water and biodiversity jointly with climate change threat agricultural production need to meet the food demand (FAO, 2017).

Although progress has been made against hunger globally, it tends to be concentrated among the landless and farmers with small plots in SSA region due to the slow growth of agricultural outputs and expanding population (IAC, 2004). In the region the number of undernourished were about 33% and 31% of people 1990-92 and 2001-2003 respectively (IAASTD, 2009). Among food insecure peoples in African continent 97% live in SSA where 34% is categorized as undernourished (NEPAD, 2003).

Climate change increases the number of malnourished child by 11 percent by 2050 in low income developing countries in comparison to no climate change or perfect mitigation scenario. The number of malnourished children worsened due to climate change in SSA and projected to be 1 million more in 2030 and 600,000 more in 2050 relative to no climate change scenario (Ringler *et al.*, 2010 ; Chijioke *et al.*, 2011).

In SSA both climate variability and land degradation are expected to increasingly hinder food production growth, and access to both agricultural inputs and markets for outputs will be continuously constrained by poor infrastructure development in the region (Ringler *et al.*, 2010).

Climatic change events that damage road and decrease road networks in Africa, mostly cause food shortage and economic shock for exposed society (Cervigni *et al.,* 2016). Erosion, severe drought, and coastal flooding have displaced millions of people (Abebe, 2014). Abebe (2014) observed that, due to weather condition severe flooding and landslides were temporarily displaced around 48,000 people in Uganda and 55,000 in Kenya, Namibia, Rwanda and Zambia in 2010.

Projections on African development clarify that, due to climate change yield reductions in some countries could be reach 50% by 2020, and net revenues from crops could fall by as much as 90% by 2100, with small-farm holders being the most affected. Water stress will also be aggravated in Africa and the population at risks projected to be between 350-600 million by 2050 while in sub-Saharan Africa between 25 and 40 percent of mammal species will become endangered in national parks due to ecosystem damage (IPCC, 2007).

Africa is highly vulnerable to climate change impacts that threaten its efforts on food security and economic development (Fankhauser & Ward, 2010). However, Africa contributes less than 7% greenhouse gas emission which very low in global emission history. World Bank (2010) estimates that developing countries and SSA need between US$75 - 100 billion and US$14-17 billion per year respectively to adapt temperature change that reaches $2^0$C by 2050.

In addition, its stress increases the manifestation and the incidence of pest and diseases (Ringler *et al.*, 2010). Spread of malaria increases during the past four decades in the regions where the phenomenon was not common and the climate was cooler before 50 years (Besada *et al.*, 2015). In Sub-Saharan Africa, malaria and other vector-borne diseases can have such a large effect on labour productivity, which could make many countries to be trapped in a vicious cycle of disease, low productivity, poverty and deficient health care (Gallup *et al.*, 1999).

**2.3 Conceptual framework**

As revealed in the preceding parts, there is a lot of issue about the GHGs emissions from human activities into the atmosphere that cause alters in temperature and precipitation. Alteration in the level of these climate variables for longer period of time results into climate conditions that is not suitable for agricultural production. Increase and fall in temperature and precipitation above or below the optimum level negatively impact the agriculture.

The distribution and amount of rainfall across the country together with occurrence of extreme weather events cause serious damages on agriculture. Similarly an increase or fall in temperature above or below the optimum level negatively impact agricultural production. The damage level and type depend on the interaction of these climate variables.

The impacts can be addressed by effective adaptation measures at community and institutional levels in order to achieve good outcomes; otherwise it will lead to poor national development. The following conceptual framework provides further understanding on climate change impacts and the effective actions that could be undertaken to reduce the vulnerability.

## Conceptual Framework

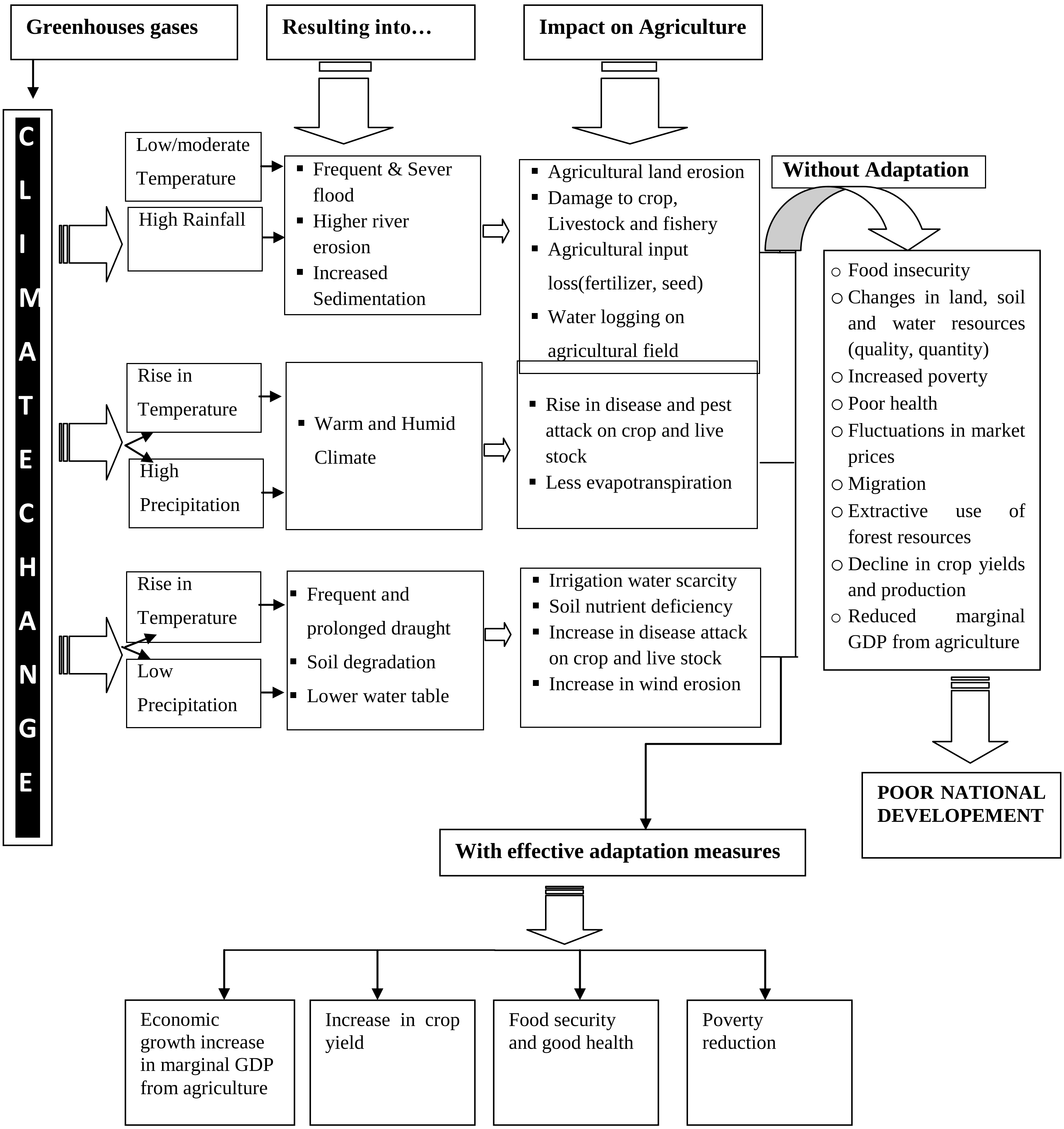



**Figure 1:** Climate change impacts on agriculture sector and adaptation measures
Source: Adapted from (Byishimo, 2017) with amendment.

# CHAPTER THREE:

## 3. RESEARCH METHODOLOGY

### 3.1 Research Design

To analyze the impact of climate change on agriculture, production approaches used in the study. The production function approaches similar to that of (Lee, *et al* 2012). The approach has an advantage as it controls for other inputs explicitly and takes into account year-to-year randomly weather fluctuations (Deschenes & Greenstone, 2007). Since the data used has spatial and temporal scale variation, the model fit for the data because it has an advantage to illuminate unobserved time variant effects and to control for time differences in the dependent variables.

The study used panel data research design and fully depends on secondary data of Sub-Saharan Africa countries. It covers all Sub-Saharan African countries. Due to missing data for few countries, the data used in the analysis are unbalanced panel data. The secondary data used includes climate variables, economic variables and food security indicators data of 30 years' time period from 1989 to 2018.

### 3.2 Data Sources and Nature

For the statistical data analysis, panel data used in the paper. The empirical analysis based on the panel data of SSA countries.  Regarding data source; temperature and precipitation data collected from World Bank climate change Portal website. Two years moving average is used for 2017 and 2018 years using stata for climate Variables due to unavailability of the data for the two years.

Economic variables such as agricultural production index, livestock production index, total number of employment in agriculture sector, agricultural land, fertilizers consumption, pesticides used in agriculture and food security indicators variables like people access to clean water, food supply variability, GDP per capita, food production index and percentage of irrigated land data are collected from Food and Agriculture Organization of United Nation Statistics Division (FAOSTAT),World Development Indicator of the World Bank and Our world in data database.

### 3.3 Description and Measurement of the Variables

#### 3.3.1 Dependent Variables

***Agricultural production index***

Measure aggregate level of agricultural production which covers all crops and livestock products calculated by adding price-weighted quantities of each agricultural commodity. It is calculated after quantities used as seed and animal feed used in production deducted from it for each year relative to base year period. According to FAO, to calculate regional and global aggregate "international dollar" is used as international commodity price measurement. It is preferred to avoid the exchange rates problem, as well as to facilitate internal comparative productivity analysis at national level.

***Prevalence of Undernourishment***

It is the probability that individual who selected from the population consumes blow required amount of calories that cover his/her dietary need for vigorous and health life. In the analysis Percentage is used as a measurement.

### 3.3.2 Independent Variables

***Livestock production index***

It includes milk and all dairy products, meat, egg, honey, wool, raw silk, hides and skins. According to FAO it computed by aggregating livestock products after feed used in the production removed from. All intermediate products are not included in the computation to avoid double counting problem.

***Food production index***

It covers aggregate level of edible commodities production that contains nutrients excluding coffee and tea since they do not contain nutrients. Its computation methodology and measurement is similar with agricultural production index except only edible commodities are considered in case of food production index.

***Agricultural land***

It is defined as any form of land that used for growing crops and rearing livestock. This is the part of the land that used as arable land, land with permanent crops and permanent pastures (Maletta, 2014).In this research analysis data area of land in hectare(ha) is used as a measurement.

***Employment in agriculture***

Employment in agriculture consists of the total number peoples of working age that engaged in agricultural production as a means of income generating or as a means of survival. Though rural agriculture work force shifts from rural to urban manufacturing employment, in 2017 agriculture sector stay a main employment sector that absorb 68% of total employment in developing countries (Christiaensen *et al.*, 2011). In this research analysis, total number of employment data of the sector obtained from WDI.

***Fertilizer used in agriculture***

Fertilizer is any substance that is applied to the soil or on plant part to provide essential elements that contribute plant nutrition and growth (Reetz, 2016). As described by FAO statistics division it is measured by quantity of nutrients used in kilo gram per hectare of arable land. These include nitrogen, Phosphorus and Potash fertilizers and exclude organic nutrients that obtained from plant and animal compost.

***Pesticides used in agriculture***

Are ingredients help to kill or prevent pathogens that cause cop destruction and health of animals including human beings. These include all types of chemicals that used to control disease and pests that harm agricultural production (Aktar *et al.*, 2009). Since pesticides are toxic to living organisms a great concern should be given while they are used to avoid attack on human being and other non-target organisms. The data used in this in this research analysis measured in tones of pesticides that used in agricultural production.

***Precipitation***

It is a water that comes to the earth surface in a form of ice, rain, hail and sleet (Selase *et al.*, 2016). In this research, average annual precipitation in millimeter (mm/year) is used as a unit of measurement. In the analysis its standard deviation from its long term average is used together with square deviation.

$\sigma = P - \bar{P}$ is deviation of a precipitation from its long term average and

$\sigma^2 = [P - \bar{P}]^2$ is square deviation of precipitation from its long term average

In food security model its coefficient of variation is used in regression analysis. Coefficient of variation is computed to measure its variability. The larger the coefficient of variation represents the high variability in precipitation.

$$CV = \frac{\sigma}{\mu} * 100$$

Where;

- **CV** is coefficient of variation in percent
- **σ** is standard deviation of precipitation from its long term mean
- **μ** is long term mean of annual precipitation in millimeter(mm)

***Temperature***

Similar to precipitation the standard deviation from long term average and coefficient of variation are used for the temperature in agricultural production and food security model. Average annual temperature that calculated from monthly average in $^{O}$C is used to compute the deviations and coefficient of variation. Standard deviation from its long term average together with square deviation as well as coefficient of variation is used in the analysis.

$\sigma = T - \bar{T}$ Where **σ** is deviation of a temperature from its long term average and

$\sigma^2 = [T - \bar{T}]^2$ is square deviation of temperature from its long term average

The coefficient of variation is used in food security model also computed as follows;

$$CV = \frac{\sigma}{\mu} * 100$$

Where;

- **CV** is coefficient of variation in percent
- **σ** is standard deviation of temperature from its long term mean
- **μ** is long term mean of annual temperature in degree Celsius($^{O}$C)

The coefficient of variation(CV) is defined as the ratio of standard deviation from long term average to long term mean. It is used as variability measurement in relative long term mean.

Both temperature and precipitation coefficient of variation is computed for each country for every year separately in the region.

***Gross Domestic Product (GDP) per capita***

GDP per capita measures the purchasing power of the population that gives the information on economic access to food in the region. This research uses GDP per capita that bases the purchasing power parity(PPP) converted to international dollars using PPP rates. The data used are in constant 2017 international Dollars($).

***Access to Clean Water source***

It measures the percentage of populations that have facility to access sufficient amount of water from clean water source. It measures food utilization dimensions of food security. The measurement used is percent.

***Per capita food supply variability***

It is estimated by the standard deviation from the trend of the food supply for each country in the region. According to FAO Statistics division its unit of measurement is the supply of food in kilo calories per person per day (Kcal/person/day).

*Irrigated Land*

It refers to agricultural land that intentionally flooded with water, including controlled flooding of the agricultural field. It refers parts of agricultural land in hectares that used for production during off season using water application.

## 3.4 Data analysis and presentation

In this research data analysis and interpretation performed using statistical software tools. Regarding software package, Stata and eviews are used, to analyze quantitative data. Secondary data collected, summarized and checked for its completeness before analyzed and interpreted. Descriptive data analysis methods mean and standard deviations are used to compare the effect of variables. In addition regression analyses including hypothesis testing are used to evaluate the relationships between dependent and independent variables. The outputs are presented by using text, table and graphs. To identify the effect of climate change, the analysis controls for agricultural inputs such as agricultural land, livestock, labour, irrigated land, pesticide and fertilizers.

## 3.5 Model Specification

### 3.5.1 Conceptual model

To investigate the effects of climate change on agricultural production, the study used a panel data production function approach (advanced Ricardian model). The approach is preferred because data are only available on an aggregate basis for the inputs in SSA countries. Also, consistent time series data of temperature and precipitation are not available for the specific commodity produced in the regions. As a result the model preferred for the data than other models.

In order to explore climatic changes impact on agricultural production in SSA countries, production function is specified in the study; where agricultural production index is a function of a number of economic inputs and climate factors: Y=f (V, A,L, M, F, I, Pe, P, T). In this analysis agricultural production model has the following specification form:

$$Y_{it}=\beta_o*V_{it}^{\beta 1}*A_{it}^{\beta 2}*L_{it}^{\beta 3}*F_{it}^{\beta 4}*I_{it}^{\beta 5}*Pe_{it}^{\beta 6}*e^{\beta_7 P_{it}+\beta_8 P^2{it}+\beta_9 T_{it}+\beta_{10} T^2{}_{it}}*e^{\varepsilon_{it}} \qquad (1)$$

Where, **Y** represents net agricultural production. According to the FAO, for every commodity production quantities are weighted by 2014-2016 average international commodity prices and added for each year. Instead of using production quantity or local currency "international dollars" is used as unit of production. FAO explains that; to avoid exchange rates problems, to obtain continental and world aggregates as well as to simplify international comparative analysis of productivity the international commodity prices are preferred to use.

**V** stands for the livestock production index (2014-2016 = 100). **A** is the agricultural land (in hectares) that refers to the part of land area that is arable, covered with permanent crops, and used permanent grass land or grazing land. **L** represents the total number of employment in agriculture sector as their livelihood. **F** represents the total NPK fertilizers used in agricultural production in Kilogram per hectare of agricultural land. **I** represent area of land equipped for irrigation and **Pe** represent pesticide used in production in metric tons. Climate variables are precipitation and temperature. **P** represents precipitation deviation(mm), and **T** represents temperature deviation (°C) from their long term mean.

### 3.5.2 Econometric Model

In many literatures the cross-section model, the experimental model and the simulation model are the three most widely used methods for the climate impact study. However, due to the characteristics of country-level panel analysis, that considers different countries during many years, temporal and regional scale variation considered in the analysis. Thus, the panel data model (within effects model) is used in this research analysis.

The panel data econometric model given by equation (2) blow is obtained after taking log on both sides of the model specified above by equation (1) for any country "i" at time "t".

$$lnY_{it}= \beta_o+\beta_1 lnV_{it}+ \beta_2 lnA_{it}+ \beta_3 lnL_{it}+\beta_4 lnF_{it}+\beta_5 lnI_{it}+ \beta_6 lnPe_{it} +\beta_7 P_{it}+\beta_8 P_{it}^2+ \beta_9 T_{it} + \beta_{10} T_{it}^2+\mu_t+\alpha_i+\varepsilon_{it} \qquad (2)$$

Where; lnY, lnV, lnA, lnL, lnF, lnI and lnPe represent the logarithms of agricultural production index, livestock production index, agricultural land, labor, fertilizers consumption, area of irrigated land and pesticides used in agriculture respectively. **P** and **T** represent climate variables; precipitation and temperature respectively. For climate variables, both the linear and square deviations are estimated in the model. The square deviations are included in order to give larger weight for larger deviations.

Fixed effects included in the model to capture time invariant and unobserved country specific effects, **α**, that may be correlated with the other regressors as well as to control for time differences in the dependent variable. Additionally the time varying effects **μ**, which are common to all countries, are proxied by a set of time dummies that are anticipated to capture factors like technological advancement. Finally, the error term is given by $\boldsymbol{\varepsilon}_{it}$. The βs, for s = 1, 2, …,10, are the coefficients to be estimated. For input variables that are expressed in natural logarithms form, their coefficients are interpreted as elasticity's of agricultural output with respect to each input.

Next to this, the analysis of climate variables effect on food security is followed. It analyzed using food security indicators variables and the prevalence of undernourishment as food insecurity indicator. Ordinary Least Square (OLS) regression analyses, is used in the study in order to analyze the impact of climate change on food security. OLS model adopted to estimate food security impact because there is no evidence from previous researches for non-linearity relationship between climate variables and food security.

$$UN_{it} = \delta_0 + \delta_1 P_{it} + \delta_2 T_{it} + \delta_3 F_{it} + \delta_4 GDPP_{it} + \delta_5 W_{it} + \delta_6 FS_{it} + \delta_7 I_{it} + \varepsilon_{it} \qquad (3)$$

Where, $\mathbf{UN}_{it}$ represent prevalence of undernourishment as food insecurity indicator; $\mathbf{P}_{it}$ represents the coefficient of variation of annual precipitation from its long term average; $\mathbf{T}_{it}$ represents coefficient of variation of annual temperature from its long term average. The long term average is calculated over the period 1901-1950 which considered as pre-climate change era; $\mathbf{F}_{it}$ represents food production index that capture availability of food; $\mathbf{GDPP}_{it}$ is GDP per capita represents economic access to food equivalent to purchasing power; $\mathbf{W}_{it}$ represent percentage of population access improved drinking water to appraise food utilization; $\mathbf{FS}_{it}$

represents food supply variability measuring that stability to food and $\mathbf{I}_{it}$ represents percentage of agricultural land equipped for irrigation measuring stability dimension food and "$\varepsilon$" stands for the error term.

# CHAPTER FOUR

## 4. RESULTS AND DISCUSSIONS

In this chapter results are presented in different sub sections. In the first sub section descriptive statistics are summarized to analyze and present data in a more meaning full way. In the second sub section statistical data tests are conducted to identify and select appropriate data analysis method as well as regression analysis model. Finally, in the last sub section data analysis and interpretation were done and major research findings were discussed in meaning full way.

### 4.1 Descriptive Statistics

Under this section summary of descriptive statistics of agricultural production input variables, food security indicator variables and climate change variables; temperature and rainfall are presented.

**Table 1: Summaryof agricultural production inputs, economic and climate variables**

| Variable | Observation | Mean | Std.Dev | Min | Max |
|---|---|---|---|---|---|
| ***AGP(Y)*** | 1,416 | 79.19104 | 24.70844 | 20.89 | 191.35 |
| ***LIV*** | 1,416 | 80.51907 | 26.09445 | 17 | 226.97 |
| ***AGL*** | 1,418 | 1.89e+07 | 2.12e+07 | 1500 | 9.81e+07 |
| ***EMP*** | 1,392 | 3520165 | 5201443 | 11163.54 | 3.43e+07 |
| ***FERT*** | 999 | 19.61572 | 49.15661 | .01 | 398.93 |
| ***IRGL_Ha*** | 1,180 | 1168864 | 2909585 | 228 | 1.51e+07 |
| ***PESTC*** | 1,007 | 1195.417 | 4127.772 | 1 | 26857 |
| ***TEMP D*** | 1,470 | .7095551 | .5633051 | -.722140 | 2.855729 |
| ***PREC D*** | 1,470 | -23.0275 | 182.8304 | -1269.33 | 1230.357 |

***Source: Own computation using stata software***

Table 2: Summaryoffood security indicators and climate variables

| Variable | Observation | Mean | Std.Dev | Min | Max |
|---|---|---|---|---|---|
| ***PUN*** | 1,141 | 26.14365 | 14.58057 | 0.5 | 76.8 |
| ***FP*** | 1,141 | 97.14958 | 27.72531 | 37.03 | 206.96 |
| ***GDPpct*** | 1,290 | 4389.41 | 5476.556 | 436.7203 | 41249.44 |
| ***ACWS*** | 1,220 | 64.88574 | 18.51493 | 13.2 | 99.9 |
| ***PFSV*** | 875 | 41.67886 | 26.76632 | 3 | 184 |
| ***IRGL*** | 737 | 9.339891 | 20.32669 | 0.1 | 100 |
| ***TCV*** | 1,470 | 3.135065 | 2.78805 | -3.17978 | 17.15362 |
| ***PCV*** | 1,470 | -1.93470 | 16.55088 | -72.1652 | 110.4732 |

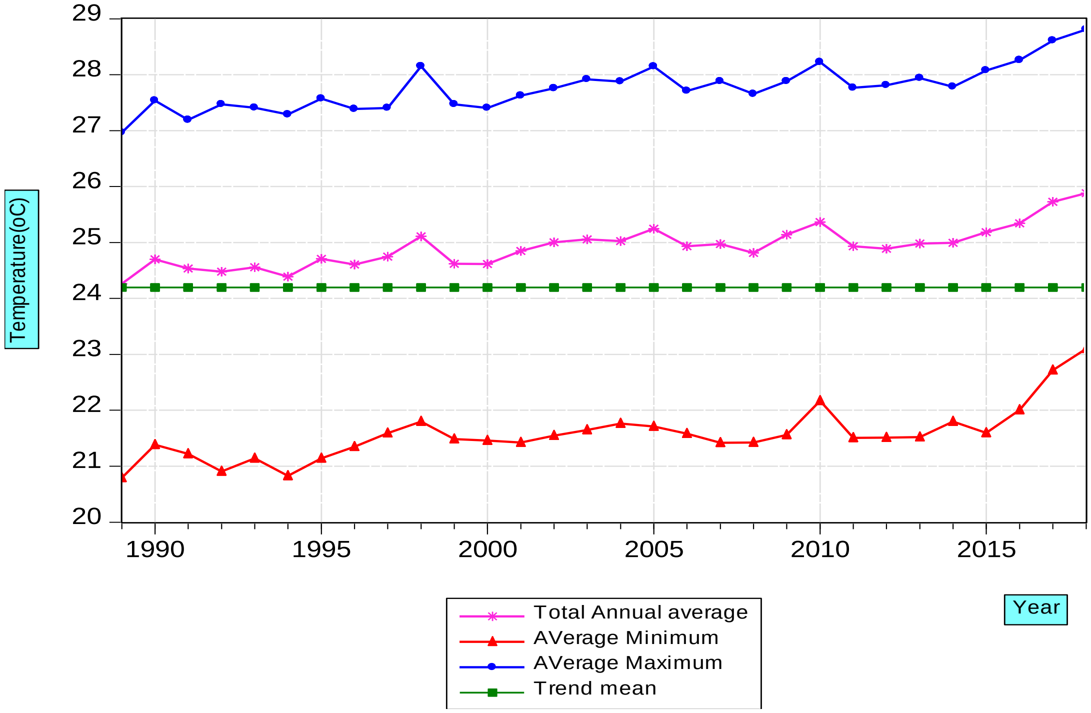
***Source: Own computation using stata software***

**4.1.1 Climate change, Agricultural Production, and Food security trend in Sub-Saharan Africa**

During the study period from 1989 to 2018 the average annual temperature shows high increment. Both annual maximum and minimum average temperature shows an increasing trend compared to trend mean that was considered as value before climate change era(1950). The average maximum temperature which was 27$^{o}$C in 1989 increased to 27.8$^{o}$C in 2014 and to 28.8$^{o}$C in 2018 with sharp increment. Similarly the average minimum temperature with the value of 20.8$^{o}$C in 1989 increased to 21.6$^{o}$C in 2014 and surprisingly with sharp increase it increased to 23.1$^{o}$Cin 2018 with an increment of 1.5$^{o}$C within 4 years periods.

The total annual average temperature of the region was 24.3$^{o}$C in 1989 which was closer to the trend mean 24.2$^{o}$C during the period. The value shows increasing trend with slight up and down variations and reached 24.9$^{o}$C in 2012. With sharp increase, the value reached 25.9$^{o}$C in 2018 with 0.9$^{o}$C increment with 6 years period. During the study period the total average temperature shows an increasing trend with 1.6$^{o}$C deviation from its trend mean that may be considered as large increase.

**Figure 2: Maximum and minimum temperature deviation from long term mean in SSA**

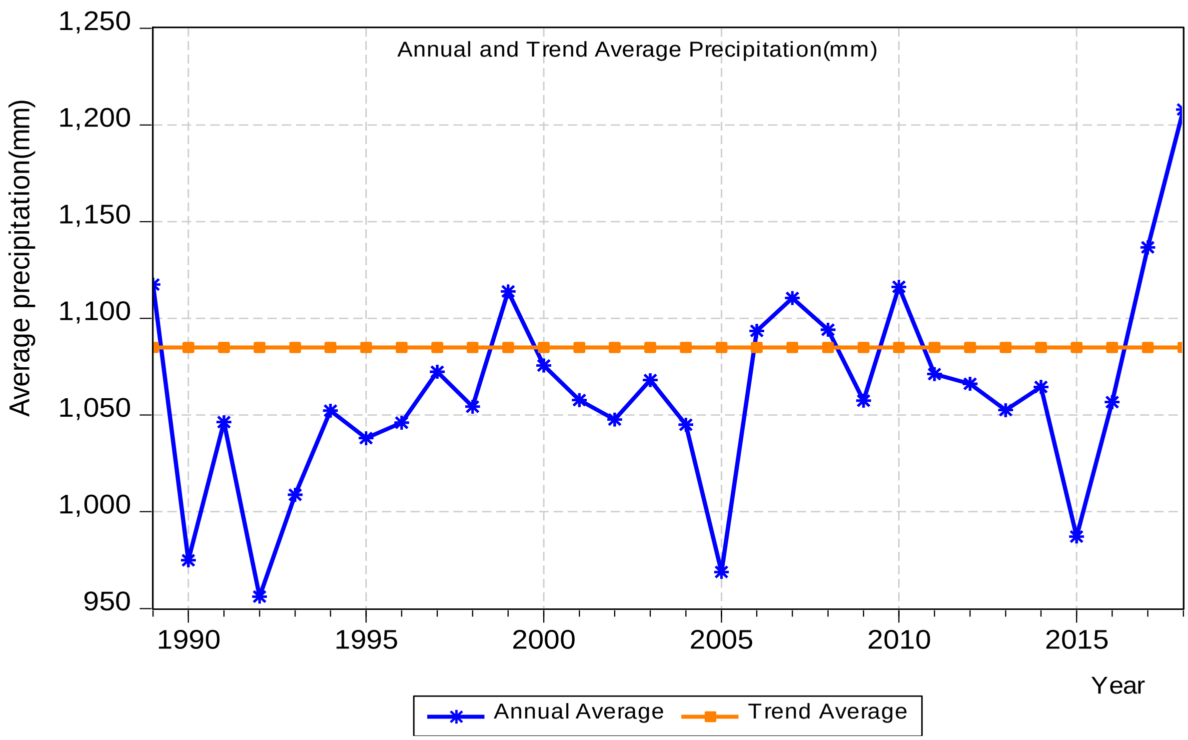



***Source: Author's Construction using Eviews software***

In the Sub-Saharan Africa average precipitation trend during the study period shows fall in amount compared to trend mean with high variability. In 1989 the average precipitation was 1117mm which was higher than the trend mean 1085mm. However, continuously declined and fall blow trend mean for 10 years up to 1998. During 1992 when the lowest value recorded the value declined far blow trend mean and reached 956 mm.

For 27 years period from 1989 to 2015 except for 6 years (1998-1999, 2006-2008 and 2010-2011) the average yearly rain fall is blow the trend mean with high variability trend. However, starting from 2015-2018 the value increased sharply from 987mm to 1208mm without declining trend. Generally the average precipitation of the region shows declining trend with high variation and it has been increasing sharply since 2015.

**Figure 3: Average Annual precipitation deviation from long term mean in SSA**




***Source: Author's Construction using Eviews software***

### 4.2 pre-estimation test

#### 4.2.1 Unit Root test

In this study different tests are conducted, to check robustness of the model and to identify the characteristics of error terms. In addition they are conducted to identify the long-run relationship of the variables and to select appropriate model that fit for data. Since other panel data unit root tests need strongly balanced data, the study used Fisher-type unit root test(Augmented Dicky-

Fuller test) to perform panel data unit root test. The test is preferred as it is appropriate for unbalanced and heterogeneous data sets(Im, Pesaran and shin, 2005). It also enable to use different lag lengths in individual ADF regression and for any derived unit root tests as well as in performing better statistic results than IPS statistics(Maddala and Wu, 1999).

Table 3 and table 4 summarize the test results that computed using stata for Augmented Dicky Fuller unit root test for all variables with level and at first difference. The test provides four different test statistics with separate p-value for a single variable. To reject or accept the null hypothesis that says all panels contain unit root when mixed test statistic results are obtained, more emphasis is given on the z test. Choi(2001) recommends the Z-test for empirical analysis over the other tests as it outperform than other tests and used both for finite and infinite N size.

As can be seen from the table 3 blow, except for **lnApinx**, **lnlvinx** and **lnAgL** variables, the test reject the null hypothesis that says all panels contain unit root for the remaining variables. From these we can confirm that the tests for **lnApinx**, **lnlvinx** and **lnirigL** are stationery at first difference or integrated of order I(1). All the remaining variables that do not contain unit root at level are considered stationery at level having integrated of order I(0). The test result confirm that, none of the variables are integrated of order I(2). All the variables that are stationary at level are used directly in the regression analysis while non-stationary variables or I(1) to be checked for co-integration test to evaluate their stationarity at first difference before used in the regression analysis.

### Table 3: Summery of Augmented Dicky-Fuller test Results for Agricultural production Model

| Variables | Level | | | First Difference | | | I(d) |
|---|---|---|---|---|---|---|---|
| | Test Statistics | | P-Value | Test Statistics | | P-Value | |
| lnApinx | P | 131.1700 | 0.0142 | P | 1813.5795 | 0.0000 | I(1) |
| | Z | 0.4194 | 0.6625 | Z | -37.2905 | 0.0000 | |
| | L* | -0.2806 | 0.3896 | L* | -71.4892 | 0.0000 | |
| | Pm | 2.3693 | 0.0089 | Pm | 122.5414 | 0.0000 | |
| lnLvinx | P | 136.36 | 0.0063 | P | 1276.94 | 0.0000 | I(1) |
| | Z | 0.32 | 0.6248 | Z | -30.86 | 0.0000 | |
| | L* | 0.16 | 0.5642 | L* | -50.36 | 0.0000 | |
| | Pm | 2.74 | 0.0031 | Pm | 84.21 | 0.0000 | |
| lnAgL | P | 260.26 | 0.0000 | P | 1017.88 | 0.0000 | I(0) |
| | Z | -3.16 | 0.0008 | Z | -25.18 | 0.0000 | |
| | L* | -6.35 | 0.0000 | L* | -40.38 | 0.0000 | |
| | Pm | 11.59 | 0.0000 | Pm | 65.71 | 0.0000 | |
| lnAg_Emp | P | 494.32 | 0.0000 | P | 358.57 | 0.0000 | I(0) |
| | Z | -6.34 | 0.0000 | Z | -9.35 | 0.0000 | |
| | L* | -13.91 | 0.0000 | L* | -12.95 | 0.0000 | |
| | Pm | 28.75 | 0.0000 | Pm | 18.95 | 0.0000 | |
| lnFertzr | P | 133.26 | 0.0000 | P | 1404.86 | 0.0000 | I(0) |
| | Z | -3.83 | 0.0001 | Z | -33.55 | 0.0000 | |
| | L* | -4.08 | 0.0000 | L* | -65.64 | 0.0000 | |
| | Pm | 5.35 | 0.0000 | Pm | 112.82 | 0.0000 | |
| lnirgL | P | 209.9948 | 0.0000 | P | 661.0984 | 0.0000 | I(1) |
| | Z | -1.0204 | 0.1538 | Z | -18.6076 | 0.0000 | |
| | L* | -3.2970 | 0.0000 | L* | -26.3795 | 0.0000 | |
| | Pm | 8.4598 | 0.0000 | Pm | 41.3599 | 0.0000 | |
| lnPest_c | P | 214.3630 | 0.0000 | P | 1065.4651 | 0.0000 | I(0) |
| | Z | -5.9739 | 0.0000 | Z | -28.1068 | 0.0000 | |
| | L* | -8.3467 | 0.0000 | L* | -50.4352 | 0.0000 | |
| | Pm | 11.8636 | 0.0000 | Pm | 82.7888 | 0.0000 | |
| ltd | P | 321.3170 | 0.0000 | P | 2167.5150 | 0.0000 | I(0) |
| | Z | -10.8721 | 0.0000 | Z | -43.2515 | 0.0000 | |
| | L* | -12.0243 | 0.0000 | L* | -85.5307 | 0.0000 | |
| | Pm | 15.9512 | 0.0000 | Pm | 147.8225 | 0.0000 | |
| ltd2 | P | 317.8731 | 0.0000 | P | 1777.284 | 0.0000 | I(0) |
| | Z | -7.2729 | 0.0000 | Z | -37.8522 | 0.0000 | |
| | L* | -9.9592 | 0.0000 | L* | -70.1269 | 0.0000 | |
| | Pm | 15.7052 | 0.0000 | Pm | 119.9489 | 0.0000 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| lPd | P | 954.5613 | 0.0000 | P | 2771.1017 | 0.0000 | I(0) |
| | Z | -25.7876 | 0.0000 | Z | -49.0115 | 0.0000 | |
| | L* | -37.4295 | 0.0000 | L* | -109.3405 | 0.0000 | |
| | Pm | 61.1829 | 0.0000 | Pm | 190.9358 | 0.0000 | |
| lpd2 | P | 993.7389 | 0.0000 | P | 2848.0404 | 0.0000 | I(0) |
| | Z | -25.7079 | 0.0000 | Z | -49.0667 | 0.0000 | |
| | L* | -38.8650 | 0.0000 | L* | -112.0888 | 0.0000 | |
| | Pm | 63.9813 | 0.0000 | Pm | 196.4315 | 0.0000 | |

P= Inverse chi-squared(98)

Z= Inverse normal

L*= Inverse logitt(249)

Pm= Modified inv. chi-squared

**Source own computation using stata16 software**

Where: **lnApinx** is log of agricultural production index; **lnlvinx** is log of livestock production index; **lnAgL** is log of agricultural land in ha; **lnAgemp** is log of total labour force employed in agricultural sector; **lnfertzr** is log of fertilizer used in agricultural sector, **lnirgL** is log of agricultural irrigated land in ha; **lnPest_c** is log of pesticide used in agricultural sector; **ltd** is lag of average temperature in deviation; **ltd2** is lag of average temperature deviations square; **lpd** is lag of average precipitation in deviation and **lPd2** is lag of average precipitation deviation square.

Table 4 summarizes the stata unit root test results for food security model. Based on the results; access to clean water source (ACWS); Prevalence of food supply variability (Pfsvar); percentage of irrigated land (IrigL) and climate variables(TVC and PCV) reject the null hypothesis that states all the panels contain unit roots. However, the remaining variables are failed to reject the null hypothesis. The variables that reject null hypothesis are stationary at level I(0) while the remaining are stationary at first difference I(1). From the result we can confirm that none of the variables are integrated of order I(2). Here also, for variables those are non-stationary at level for co-integration test to be checked before used in the regression analysis.

**Table 4: Summery of Augmented Dicky-Fuller test Results for food Security Model**

| Variables | Level | | | First Difference | | | I(d) |
|---|---|---|---|---|---|---|---|
| | Test Statistics | | P-Value | Test Statistics | | P-Value | |
| Punoursh | P | 105.35 | 0.0423 | P | 357.37 | 0.0000 | I(1) |
| | Z | 3.06 | 0.9989 | Z | -12.73 | 0.0000 | |
| | L* | 1.45 | 0.9263 | L* | -14.98 | 0.0000 | |
| | Pm | 1.82 | 0.0341 | Pm | 21.50 | 0.0000 | |
| Fprdx | P | 92.49 | 0.5825 | P | 1671.51 | 0.0000 | I(1) |
| | Z | 3.72 | 0.9999 | Z | -35.78 | 0.0000 | |
| | L* | 3.47 | 0.9997 | L* | -66.63 | 0.0000 | |
| | Pm | -0.25 | 0.6000 | Pm | 113.70 | 0.0000 | |
| gdppct | P | 88.92 | 0.5716 | P | 708.88 | 0.0000 | I(1) |
| | Z | 5.92 | 1.0000 | Z | -20.42 | 0.0000 | |
| | L* | 5.49 | 1.0000 | L* | -28.76 | 0.0000 | |
| | Pm | 0.23 | 0.5899 | Pm | 45.48 | 0.0000 | |
| ACWS | P | 216.51 | 0.0000 | P | 398.31 | 0.0000 | I(0) |
| | Z | 2.04 | 0.9791 | Z | -8.02 | 0.0000 | |
| | L* | 0.08 | 0.5322 | L* | -13.52 | 0.0000 | |
| | Pm | 8.46 | 0.0000 | Pm | 21.45 | 0.0000 | |
| Pcfsvar | P | 110.52 | 0.0135 | P | 664.12 | 0.0000 | I(0) |
| | Z | -3.17 | 0.0008 | Z | -20.82 | 0.0000 | |
| | L* | -3.03 | 0.0014 | L* | -28.97 | 0.0000 | |
| | Pm | 2.41 | 0.0079 | Pm | 46.18 | 0.0000 | |
| irgL | P | 221.4140 | 0.0000 | P | 260.0861 | 0.0000 | I(0) |
| | Z | -2.0766 | 0.0189 | Z | -9.7332 | 0.0000 | |
| | L* | -5.4139 | 0.0027 | L* | -10.9130 | 0.0000 | |
| | Pm | 9.2926 | 0.0000 | Pm | 12.1131 | 0.0000 | |
| TCV | P | 242.2132 | 0.0000 | P | 2121.8289 | 0.0000 | I(0) |
| | Z | -6.8858 | 0.0000 | Z | -42.6599 | 0.0000 | |
| | L* | -7.8452 | 0.0000 | L* | -83.7279 | 0.0000 | |
| | Pm | 10.3009 | 0.0000 | Pm | 144.5592 | 0.0000 | |
| PCV | P | 769.85 | 0.0000 | P | 2729.04 | 0.0000 | I(0) |
| | Z | -20.88 | 0.0000 | Z | -48.51 | 0.0000 | |
| | L* | -29.41 | 0.0000 | L* | -107.69 | 0.0000 | |
| | Pm | 47.99 | 0.0000 | Pm | 187.93 | 0.0000 | |

P= Inverse chi-squared(98)
Z= Inverse normal
L*= Inverse logitt(249)
Pm= Modified inv. chi-squared
***Source: own computation using stata 16 software***

Where: **Punoursh** represent prevalence of undernourishment; **Fprdx** is food production index; **gdppct** is GDP per-capita equivalent to purchasing power; **ACWS** is access to clean water source; **Pcfsvar** is food supply variability; **irgL** is percentage of agricultural land equipped for irrigation; **TCV** is coefficient of variation of average annual temperature and **PCV** is coefficient of variation of average annual precipitation.

The variables those are non-stationary at level changed to stationary by taking the first difference. As can be seen from the above tests the non-stationary variables changed to stationary after transformed to first difference and confirm that none of the variables are integrate of order I(2).

### 4.2.2 Cointegration Test

Cointegration test help to find common trends among variables while panel unit root tests are applied to get individual specific characteristics. Pedroni(1999) and Kao(1999) proposed cointegration test for I(1) variables to explore long-run relationship among the variables.

For I(1) variables, the cointegration tests were conducted to investigate the long run relationship between the variables. The test result for Pedroni tests were summarized in the table 5 blow with their test statistics and corresponding p-values. For agricultural production input data, the outcome for Pedroni test statistically significant for all test statistics at 1% level of significance and rejects the null hypothesis that says there is no cointegration. Hence, the test result confirms the long-run co-integration existence among the log of Agricultural production index, log of livestock production and log of agricultural irrigated land.

**Table 5: Panel cointegration test for agricultural production data set**

| Pedroni test for cointegration | | |
|---|---|---|
| | **Statistic** | **p-value** |
| Modified Phillips-Perron t | -3.5809 | 0.0002 |
| Dickey-Fuller t | -9.3974 | 0.0000 |
| Augmented Dickey-Fuller t | -10.4453 | 0.0000 |

***Source: Author's computation using stata 16 software***

Similarly the outcome of co-integration test for I(1) variables of food security indicators data set are summarized in the table 6 blow. The pedroni test result shows all the test results are statistically significant at 1% significance level and reject the null hypothesis that states no co-integration. The result confirmed the presence of cointegration among I(1) variables; prevalence of undernourishment, food production index and GDP per capita.

**Table 6: Panel cointegration test for food security indicators data set**

| Pedroni test for cointegration | | |
|---|---|---|
| | **Statistic** | **p-value** |
| Modified Phillips-Perron t | 4.4140 | 0.0000 |
| Phillips-Perron t | 3.5864 | 0.0002 |
| Augmented Dickey-Fuller t | -5.038e+15 | 0.0000 |

***Source: Author's computation using stata 16 software***

### 4.3 Diagnostic Tests

Different diagnostic tests are conducted to ensure the appropriateness of data for the model and help to use for further analysis. The tests are also used as a diagnostics to do some adjustments to our data and to take corrective measures during estimation as well as help to select appropriate regression model to be used.

#### 4.3.1 Autocorrelation Test Result

Table 7: Wooldridge serial correlation test results

| Model | F-statistic | Prob> F |
|---|---|---|
| Agricultural output | F(1, 28) 26.954 | 0.0000 |
| Food Security | F(1, 37) 689.524 | 0.0000 |

**Source: Author's computation using stata 16 software**

To check the presence of serial correlation among the variables Wooldridge test were performed for agricultural output model and food security model in table 7. The probability of F-statistics results is less than 5% and it is strongly significant. Thus, the results obtained reject the null hypothesis that says no first order serial correlation. So, we can conclude the presence of autocorrelation in the models.

#### 4.3.2 Hetroskedasticity Test Result

Table 8: White's hetreskedasticity test results

| Model | White test | |
|---|---|---|
| | $Chi^2$ | Prob> chi2 |
| Agricultural GDP | 430.31 | 0.0000 |
| Food security | 101.11 | 0.0000 |

**Source: Author's computation using stata 16 software**

To investigate the presence of hetroskedasticity in the model general white's test is performed to identify whether the error term in the model are constant or varying. The P-value obtained from general white's test for both models rejects the null hypothesis that says constant variance (homoscedasticity). Thus, the result obtained witness the presence of heteroskesdasticity in the models.

### 4.3.3 Cross-Sectional Dependency Test Result

To check the presence of correlation of the error terms across cross sections Breush-Pagan LM test, Pesaran scaled LM test and Pesaran CD tests are performed for both Agricultural output and food security data sets and the results are presented in the tables blow.

Table 9: Cross sectional dependence test results

| Test | Statistic | Prob. |
|---|---|---|
| Breusch-Pagan LM | 2296.930 | 0.0000 |
| Pesaran scaled LM | 66.3586 | 0.0000 |
| Pesaran CD | 11.81374 | 0.0000 |

***Test results for Agricultural Production**

| Test | Statistic | Prob. |
|---|---|---|
| Breusch-Pagan LM | 2028.096 | 0.0000 |
| Pesaran scaled LM | 35.33904 | 0.0000 |
| Pesaran CD | 6.08945 | 0.0000 |

***Test results for Food Security**

**Source: Author's computation using eviews 10 software**

Table 9 summarizes test results for cross sectional dependency tests for agricultural production and food security models. The results reject the null hypothesis of no cross-section dependence (correlation) in residuals at 1% level of significance. Thus, the results obtained confirm the presence of cross sectional dependency. As a result, the estimation method that can account the problem employed in regression analysis.

As observed from the tests, the results for both models show the presence of autocorrelation, heteroskedasticity and cross-sectional dependence that violate the regression model assumptions. Though many estimators were developed to generate consistent and robust standard errors in the regression analysis with heteroscedasticity and/or autocorrelation, most of them do not considered cross-sectional dependence.

To overcome the problem of heteroscedasticity, autocorrelation and cross-sectional dependency; Driscoll-Kraay estimator is used in the regression for the time and cross sectional dimension of this research. Diriscoll and Kraay estimator with xtscc stata command, generate consistent standard errors and conducive for both balanced and unbalanced panel data as well as has the ability to handle missing values (Diriscoll and Kraay, 1998; Hoechle, 2007).

### 4.3.4 Multicollinearity Test Result

The relationship between independent variables estimated by multicollinearity test, using value inflation factor(VIF). The structural multicollinearity that arises due to square transformation of climate variables was resolved by centering the variables. Centering is the method of standardizing the variables by subtracting its mean from all observed values of the variable used in the model (Frost, 2017). In both table 11 and table 12 the values of test results for all variables not exceed 5 witnessing the absence of perfect multicollinearity in the model.

Table 10: Multi collinearity test result for Agricultural production model

| Variable | VIF | 1/VIF |
|---|---|---|
| LnirgLand | 5.07 | 0.197297 |
| lnAgri Land | 4.69 | 0.213131 |
| lnFertilizer | 1.91 | 0.523236 |
| Pricip Dev. Sq | 1.85 | 0.540104 |
| Tmp Dev. | 1.84 | 0.544388 |
| Agri.Employ. | 1.71 | 0.583503 |
| Temp. Dev Sq. | 1.48 | 0.674350 |
| Pestcide used | 1.42 | 0.703096 |
| Pricip. Dev.Sq | 1.33 | 0.750543 |
| Livestock indx | 1.17 | 0.856844 |
| Mean VIF | 2.25 | |

**Source: author's computation using stata software**

Table 11: Multi collinearity test result for Food Security model

| Variable | VIF | 1/VIF |
|---|---|---|
| ACWS | 1.71 | 0.584274 |
| gdppct | 1.67 | 0.599837 |
| Irggated Land | 1.11 | 0.904592 |
| Fprdx | 1.09 | 0.914800 |
| Temp CV | 1.08 | 0.924656 |
| Prici.CV | 1.07 | 0.936457 |
| Pcfsvar | 1.06 | 0.947135 |
| Mean VIF | 1.25 | |

**Source: author's computation using stata software**

### 4.4 Regression Model Selection Methods

Regression model selection test is very important to identify appropriate model that to be used for regression analysis. In panel data analysis, model selection is very important to evaluate and select the model that best suitable for specific data set. In order to select the best model F-test, Brausch-Pagan LM test and Hausman test were conducted and summarized in table 12 and table 13 as follows.

**Table 12: Model Selection Tests for Agricultural Production Data Set**

| **Tests type** | **Test statistics** | **P-Value** | **Null hypothesis** | **Decision** |
|---|---|---|---|---|
| F-test | F-statistic | 0.000 | Individual specific effect=0 | $H_o$: Rejected |
| Brausch-Pagan LM test | Chi2 | 0.000 | REM is not appropriate | $H_o$: Rejected |
| Hausman test | Chi2 | 0.000 | Difference in Coefficients not systematic/ REM is appropriate | Ho: Rejected and FEM selected to analyze the regression model |

**Source: Own computation using stata software**

To select the regression model that best fit to the data F-test, Breusch-Pagan LM test and Hausman test conducted. F-test is conducted to test whether joint significance of the dependent variables or individual panel fixed effects is present in the model. Accordingly the result for agricultural production data set rejects the null hypothesis that says individual effects are equal to zero in favor of fixed effect model.

To test the appropriateness of the Random Effect model the Breusch Pagan LM test conducted and its result rejects the null hypothesis that says there is no random effect and the RE model is also identified as an appropriate. To select the best model among the FE and RE model, Hausman test is conducted and its result rejects the null hypothesis in favor of fixed effect model for agricultural production model.

Table 13: Model Selection Tests for Food Security Data Set

| Tests | Test statistics | P-Value | Null hypothesis | Decision |
|---|---|---|---|---|
| F-test | F-statistic | 0.000 | Individual specific effect=0 | $H_o$: Rejected |
| Brausch-Pagan LM test | Chi2 | 0.000 | There is no RE | $H_o$: rejected |
| Hausman test | Chi2 | 1.000 | Difference in Coefficients not systematic/ REM is appropriate | Ho: not Rejected and REM selected to analyze the regression model |

**Source: Own computation using stata software**

Similarly to select the model for food security data set in table 14the F-test rejects the null hypothesis that says all individual specific effects are equal to zero. It is against pooled OLS in favor of fixed effect model. While Brausch-Pagan LM test rejects the null hypothesis that says there is no random effect in favor of random effect model. Further to check between FEM and REM, Hausman test conducted and the result fail to reject the null hypothesis in favor of random effect model.

Thus, based on the above model selection tests for econometric regression analysis; fixed effect model is selected for the agricultural production model and random effect model is selected for the food security model.

## 4.5 Regression Results

### 4.5.1 Regression result for Agricultural Production

Table 14 summarizes the fixed effect panel data analysis for climate change impact on agricultural production in SSA. The model analyzes the data for 5 versions of the model given in equation (2). The first version of the model incorporate linear term of temperature and precipitation deviations from their long term average and other agricultural production input variables. The second version of the model, incorporate precipitation deviation with its square deviation and temperature deviation. The third version of the model, introduce temperature deviation with its square deviation and precipitation deviation. The fourth model, incorporate the deviation for of precipitation and temperature with their square deviations. The fifth model incorporates pesticides that used as an adaptation mechanism to protect yield loss due to pest infestation.

Though Hausman test, Woodridge test, White's test and Pesarian CD test that performed as diagnostic tests and model selection test based on equation (2) which is similar to the fifth version of the model, for other versions models the tests are also performed and the results are presented in table 14 blow. The test result of all models shows the existence of autocorrelation, heteroskedasticity and cross sectional dependence. Thus, in all regression analysis Driscoll and Kraay standard error is employed. In all versions of the models Hausman test rejects the null hypothesis that states the REM is appropriate. As a result, FEM is used as a regression model in all versions of the models.

Linear terms of temperature deviation from its long term mean which represent the slight deviation impact agricultural productions positively and significantly. However, its square deviations that represent the larger the deviation from its long term average impact the production negatively and statistically significant at 5% level of significance. In model 4 a $1^{o}C$ increase in temperature deviation from its linear term results 7.7% increase in agricultural production keeping other factors constant. In contrast a $1^{o}C$ increase in temperature square deviation results 3.6% decrease in agricultural production keeping other factors constant.

In all versions of the models precipitation deviations and its square deviation, negatively and significantly impact agricultural production. Keeping other factors constant a 1mm in increase in precipitation deviation results 0.01% decreases in agricultural production. Further to compute the interaction impact of both temperature and precipitation deviation with their square deviation on agricultural production, the marginal impacts at means are computed later in table 15.

As expected in all versions of the model most of agricultural production input variables show significant and positive impact on agricultural production. Since all input variables are in logarithmic form, their interpretation computed in elasticity form. Livestock production index has positive relationship with agricultural production and statistically significant at 1% level of significant. This means an increase in livestock production index by 1% results increase in agricultural production by about 0.5% keeping other factors constant.

The impact of agricultural land on agricultural production is positive and significant at 1% level of significance. Keeping other variables constant 1% increase in agricultural land results an increase agricultural production by about 1%. This shows agricultural production in the region is based on extensive farming that depend on natural resource.

Employment in agriculture impact agricultural production positively as well as significantly. It is found to be significant at probability which is less than 1%. The result obtained clarifies that, agricultural production in the region is labour intensive which employs large number of labour forces and not mechanized. From the result, a 1% employment increase in agriculture results increase in agricultural production by 0.23% keeping other factors constant.

Fertilizer is an important agricultural production inputs which impact the production positively and statistically significant at less than 1% level of significance. An increase in fertilizer use by 10% results increase agricultural yield by 0.27% keeping other variables constant.

Similarly the use of pesticide as an adaptation mechanism to prevent yield loss due to pest and disease infestation, impact agricultural production positively with a significance level of less than 5%. As seen in model 5 keeping other variable constant; an increase in pesticide use in agricultural farm by 10% results increase in agricultural production by 0.14%. The impact of irrigation on agricultural production is become significant when pesticide is considered as an adaptation option.

**Table 14: Empirical results impact of climate change on agricultural production**

| Dependent Variable Agricultural production index(Apinx) | | | | | |
|---|---|---|---|---|---|
| **Models / Variables** | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
| **Livestock pro. Index** | 0.573*** (0.0188) | 0.571*** (0.0191) | 0.562*** (0.0177) | 0.561*** (0.0180) | 0.510*** (0.0176) |
| **Agri. Land** | 0.985*** (0.298) | 0.991*** (0.30) | 0.990*** (0.297) | 0.994*** (0.300) | 1.405*** (0.183) |
| **Agri. Emp** | 0.229*** (0.0655) | 0.233*** (0.0653) | 0.235*** (0.0680) | 0.238*** (0.0675) | 0.221*** (0.0658) |
| **Irrigated Land** | 0.112 (0.0174) | 0.0103 (0.0175) | 0.0137 (0.0190) | 0.0128 (0.0191) | 0.0376** (0.0173) |
| **Fertilizer Used** | 0.0257*** (0.00644) | 0.0268*** (0.00618) | 0.0268*** (0.00615) | 0.0273*** (0.00631) | 0.0219*** (0.00641) |
| **Pesticide used** | | | | | 0.0145** (0.00641) |
| **Temperature Deviation** | 0.0222 (0.0209) | 0.0206 (0.0213) | 0.0810** (0.0304) | 0.0774** (0.0305) | 0.0859** (0.0401) |
| **Temperature Sq. Deviation** | | | -0.0381* (0.0214) | -0.0367* (0.0209) | -0.0400 (0.0240) |
| **Precipitation Deviation** | -0.000086** (0.000035) | -0.000104* * (0.0000377) | -0.000093** (0.0000364) | -0.000108** (0.0000396) | -0.000117** (0.0000512) |
| **Precipitation Sq. Deviation** | | -0.000000158** (7.42e-08) | | -0.000000139 (8.19e-08) | -0.00000016* (8.13e-08) |
| **Constant** | -17.73*** (3.963) | -17.87*** (4.006) | -17.93*** (3.935) | -18.04*** (3.982) | -24.70*** (2.370) |
| **Observation** | 829 | 829 | 829 | 829 | |
| **Within R-Sq** | .751 | 0.751 | 0.753 | 0.753 | 0.763 |
| **F-test** | 40.67*** | 38.19*** | 40.98*** | 38.09*** | 38.05*** |
| **Brausch Pagan LM test** | 1734.41*** | 1422.93*** | 1766.93*** | 1457.42*** | 921.74*** |
| **Ch2 of Hausman test** | 297.59*** | 302.70*** | 301.37*** | 303.37*** | 300.30*** |
| **Wooldridge test for Autocorrelation** | 32.514*** | 32.452*** | 33.440*** | 33.381*** | 26.954*** |
| **White's test for heteroskedasticity** | 213.93*** | 224.00*** | 218.12*** | 228.00*** | 244.05*** |

Note: Standard errors in parentheses * p<0.1, ** p<0.05, *** p<0.01

***Source: Author's computation using stata software***

### 4.5.3 Marginal Impact Analysis

By derivation equation of equation (1) with respect to precipitation and temperature the marginal impact of both variables calculated at mean as in equation(4) and (5)

$$E[\frac{dY}{dP}]=[B_7 + 2B_8 \times E(P)] * E(Y) \qquad (4)$$

$$E[\frac{dY}{dT}]=[B_9 + 2B_{10} \times E(T)] * E(Y) \qquad (5)$$

Where, $B_7$ and $B_9$ are coefficients for the deviation of precipitation and temperature respectively, while $B_8$ and $B_{10}$ are coefficients for square deviation of precipitation and temperature respectively. E(P), E(T) and E(Y) are the mean value of precipitation deviation, temperature deviation and agricultural production respectively.

Table 15 summarizes the marginal effect of climate variables; precipitation and temperatures on agricultural production. Based on the results, deviation of temperature from its long term average has overall positive marginal gain from agricultural production in the region. However, deviations of precipitation from its long term mean negatively impacts over all marginal gain from agricultural production.

**Table 15: Marginal impact Analysis**

| | Marginal Impacts | | | | |
|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
| Temperature | 1.76 | 1.62 | 2.13 | 2.0 | 2.30 |
| Precipitation | -0.00687 | -0.007675 | -0.0074 | -0.0080 | -0.0086 |

***Source: Own Computation***

#### 4.5.2 Regression result for climate impact on prevalence of Undernourishment

Table 16 summarizes the panel data random effect model analysis for climate variables impact on food security in SSA. The model analyzes the data for the model given in equation(3). Climate variables temperature coefficient of variation and precipitation coefficient of variation are positively affect food insecurity. Temperature coefficient of variation is statistically significant at 1% level of significance. A 1% increase in temperature coefficient of variation results increases in food insecurity by 0.27% keeping other variables constant. Similarly variability in precipitation positively affects food insecurity and statistically significant at 10% level of significance. A 10% increase in precipitation variability results increase in food insecurity by 0.34% keeping other variables constant.

Food production index has significant and negative impact on prevalence of undernourishment, implying that food insecurity decreases with an increase in food production. A 1 unit increase in food production leads 0.12 percentage point decrease in level of food insecurity keeping other variables constant. GDP per capita which is equivalent to the purchasing power of the people and measures the economic access to food, negatively impact prevalence of undernourishment and its impact statistically significant at 10% level of significance. This implies that, an increase in income by 1 dollar leads to decrease in food insecurity by 0.06 percentage point keeping other variables constant.

Access to clean water source negatively impacted food insecurity and statistically significant at 1% level of significance. A 1% increase in access to clean water source decreases food insecurity by about 0.2% keeping other factors constant. Surprisingly percentage of land equipped for irrigation and prevalence of food supply variability are insignificant. This is may be due irrigation usage and data obtained in the region not remarkable.

**Table 16: Empirical results impact of climate change on food security**

| **Dependent Variable: Prevalence of undernourishment** | | | | |
|---|---|---|---|---|
| **Regressors** | **Coefficient** | **Standard error** | **T-Ratio** | **Prob.** |
| **Food Production index** | -.1287948 | .0134169 | -9.60 | 0.000 |
| **GDP per-capita** | -.0006263 | .0003095 | -2.02 | 0.071 |
| **Access to Clean Water** | -.1889945 | .0334522 | -5.65 | 0.000 |
| **Per capita food SS Var** | -.0014452 | .0072669 | -0.20 | 0.846 |
| **Irrigated Land** | -.1192689 | .1176792 | -1.01 | 0.335 |
| **Temp. CV** | .2734217 | .0674253 | 4.06 | 0.002 |
| **Prip. CV** | .0346592 | .0156746 | 2.21 | 0.051 |
| **constant** | 52.86369 | 1.581244 | 33.43 | 0.000 |
| **Overall $R^2$** | 0.30 | | | |
| **N** | 418 | | | |

***Source: Own Computation using stata software***

**CHAPTER FIVE**

# 5. CONCLUSION AND POLICY IMPLICATIONS

## 5.1 Conclusions

This paper analyzes the impact of climate change on agricultural production and food security using panel data of SSA countries from 1989 to 2018. The research examines the impact of climate variables and agricultural input variables on agricultural production. Moreover, it investigates the impact of climate variables and food security indicators on the prevalence undernourishment in the region.

The results show that a slight deviation in temperature from its long term mean affects agricultural production positively and significantly. However, a square deviation in temperature from its long term means impact the agricultural production negatively and significantly, if pesticide is not used as adaptation mechanism. When pesticide included as production input the effect of square deviation on agricultural production no longer remain significant. This is due to the fact that pesticide helps to prevent yield loss due to disease and pests damage that infested as a result of climate factors.

The analysis show the slight deviation in temperature favors the production while the larger the deviation from its long term means impact agricultural production negatively. This shows slight warming stimulates higher agricultural production but as warming proceeds beyond certain threshold level it is damaging to the production. Hence, the average temperature in the region not reaches the damaging level for agricultural production. Moreover since the trend for average temperature shows increasing trend, the future damage is inevitable if the trend will continue in similar manner and appropriate adaptation measure will not be taken.

The finding shows linear and square deviations of precipitation from long term average negatively affect agricultural production. Agricultural production in SSA countries is sensitive to precipitation, indicating that the production in the region is rain fed agriculture. Furthermore, the agricultural production in the region positively affected by livestock, labor and land inputs which show the dependence of the regions agriculture to natural resource and labor intensive which is not supported by technology and not mechanized.

Both temperature and precipitation variability affect food security negatively and significantly. These climate variables negatively impact food security directly through their impact on food production which is directly linked to agricultural production, and indirectly through their impact on food security indicators.

### 5.2 Recommendations and Policy Implications

The following recommendations and policy options forwarded from this study to decrease or avoid climate change impact on agricultural production and food security in the region.

(i) Increasing the availability of agricultural water by harvesting rain water to use during off season and efficient use of irrigation to tackle water shortage and remove excess water from field by using good drainage system where water lodging is prevalent.

(ii) Planting multipurpose agro-forest trees that sequester carbon, control soil degradation, increase soil nutrition through nitrogen fixation, and used as fodder and wind breaks.

(iii) Investment on agricultural research to develop drought tolerant, disease resistant, high yielding and early maturing varieties that need low water for maturing.

(iv) Formulating viable land use policy with committed enforcement so that; agricultural and other land used practiced in environmentally save ways.

(v) Controlling population growth at optimum level to avoid excessive use of natural resources that harms the ecosystem. This is because of the fact that agriculture is unable to absorb labor forces that want to engage in the sector due to increase in number of population since land resource is limited. As a result the government should be concerned to control population growth through expanding family planning method and imposing policies that limit the number of child every individual bears.

(vi) This study recommends further research on future climate change impact prediction. It is recommended to include future climate change impact on agricultural production and food security prediction in order to aware stakeholders to prepare in advance for adaptation and mitigation action.

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# APPENDICES

## Regression output

```
. xtscc lnAgPinx lnLvinx lnAGL_ha lnAg_Emp lnirgL_ha lnFertzr ltd lpd, fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       829
Method: Fixed-effects regression                 Number of groups  =        34
Group variable (i): C_id                         F(  7,    25)     =    855.24
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.7511
```

| lnAgPinx | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnLvinx | .5725163 | .018814 | 30.43 | 0.000 | .5337681 | .6112645 |
| lnAGL_ha | .9853109 | .2976345 | 3.31 | 0.003 | .3723213 | 1.598301 |
| lnAg_Emp | .2288972 | .0655116 | 3.49 | 0.002 | .0939734 | .363821 |
| lnirgL_ha | .0111967 | .0173986 | 0.64 | 0.526 | -.0246363 | .0470297 |
| lnFertzr | .0257325 | .0061514 | 4.18 | 0.000 | .0130635 | .0384015 |
| ltd | .022239 | .020893 | 1.06 | 0.297 | -.020791 | .065269 |
| lpd | -.0000867 | .000035 | -2.48 | 0.020 | -.0001587 | -.0000147 |
| _cons | -17.73156 | 3.963129 | -4.47 | 0.000 | -25.89378 | -9.569348 |

```
. xtscc lnAgPinx lnLvinx lnAGL_ha lnAg_Emp lnirgL_ha lnFertzr ltd lpd lpd2 , fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       829
Method: Fixed-effects regression                 Number of groups  =        34
Group variable (i): C_id                         F(  8,    25)     =   1600.83
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.7517
```

| lnAgPinx | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnLvinx | .5711275 | .0191386 | 29.84 | 0.000 | .5317108 | .6105441 |
| lnAGL_ha | .9907603 | .2998641 | 3.30 | 0.003 | .3731786 | 1.608342 |
| lnAg_Emp | .2328983 | .0652752 | 3.57 | 0.001 | .0984615 | .3673351 |
| lnirgL_ha | .010318 | .017515 | 0.59 | 0.561 | -.0257548 | .0463909 |
| lnFertzr | .0262768 | .0063491 | 4.14 | 0.000 | .0132005 | .0393531 |
| ltd | .020564 | .0213219 | 0.96 | 0.344 | -.0233492 | .0644773 |
| lpd | -.0001042 | .0000377 | -2.76 | 0.011 | -.0001818 | -.0000266 |
| lpd2 | -1.58e-07 | 7.42e-08 | -2.12 | 0.044 | -3.10e-07 | -4.72e-09 |
| _cons | -17.87024 | 4.006409 | -4.46 | 0.000 | -26.12159 | -9.618887 |

```
. xtscc lnAgPinx lnLvinx lnAGL_ha lnAg_Emp lnirgL_ha lnFertzr ltd lpd ltd2 , fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       829
Method: Fixed-effects regression                 Number of groups  =        34
Group variable (i): C_id                         F(  8,    25)     =    911.87
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.7530
```

| lnAgPinx | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnLvinx | .5621662 | .0177216 | 31.72 | 0.000 | .5256679 | .5986645 |
| lnAGL_ha | .9897655 | .2972012 | 3.33 | 0.003 | .3776682 | 1.601863 |
| lnAg_Emp | .2349352 | .0680379 | 3.45 | 0.002 | .0948085 | .3750618 |
| lnirgL_ha | .0137123 | .0189637 | 0.72 | 0.476 | -.0253442 | .0527688 |
| lnFertzr | .0268404 | .0061538 | 4.36 | 0.000 | .0141664 | .0395144 |
| ltd | .0810019 | .0303835 | 2.67 | 0.013 | .0184259 | .143578 |
| lpd | -.000093 | .0000364 | -2.56 | 0.017 | -.0001679 | -.000018 |
| ltd2 | -.0381202 | .0213777 | -1.78 | 0.087 | -.0821484 | .0059079 |
| _cons | -17.92516 | 3.934758 | -4.56 | 0.000 | -26.02895 | -9.821378 |

```
. xtscc lnAgPinx lnLvinx lnAGL_ha lnAg_Emp lnirgL_ha lnFertzr ltd lpd lpd2 ltd2 , fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       829
Method: Fixed-effects regression                 Number of groups  =        34
Group variable (i): C_id                         F(  9,    25)     =   1617.50
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.7535
```

| lnAgPinx | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnLvinx | .5613146 | .0179543 | 31.26 | 0.000 | .5243371 | .5982922 |
| lnAGL_ha | .9944148 | .299607 | 3.32 | 0.003 | .3773627 | 1.611467 |
| lnAg_Emp | .2382487 | .0674723 | 3.53 | 0.002 | .0992869 | .3772105 |
| lnirgL_ha | .0128456 | .0190985 | 0.67 | 0.507 | -.0264884 | .0521796 |
| lnFertzr | .0272808 | .0063061 | 4.33 | 0.000 | .0142931 | .0402685 |
| ltd | .077397 | .0304892 | 2.54 | 0.018 | .0146032 | .1401907 |
| lpd | -.0001082 | .0000396 | -2.73 | 0.011 | -.0001898 | -.0000266 |
| lpd2 | -1.39e-07 | 8.19e-08 | -1.70 | 0.102 | -3.08e-07 | 2.95e-08 |
| ltd2 | -.0367408 | .0209102 | -1.76 | 0.091 | -.0798061 | .0063244 |
| _cons | -18.04058 | 3.982415 | -4.53 | 0.000 | -26.24252 | -9.83864 |

```
. xtscc lnAgPinx lnLvinx lnAGL_ha lnAg_Emp lnirgL_ha lnFertzr lnPest_c ltd lpd lpd2 ltd2 , fe

Regression with Driscoll-Kraay standard errors   Number of obs     =       704
Method: Fixed-effects regression                 Number of groups  =        29
Group variable (i): C_id                         F( 10,    25)     =   2220.87
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.7631
```

| lnAgPinx | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnLvinx | .5104643 | .01756 | 29.07 | 0.000 | .4742988 | .5466298 |
| lnAGL_ha | 1.404913 | .182885 | 7.68 | 0.000 | 1.028254 | 1.781572 |
| lnAg_Emp | .2213021 | .0658166 | 3.36 | 0.002 | .0857504 | .3568538 |
| lnirgL_ha | .0375806 | .0173238 | 2.17 | 0.040 | .0019015 | .0732597 |
| lnFertzr | .0219249 | .0064087 | 3.42 | 0.002 | .0087259 | .0351239 |
| lnPest_c | .0145202 | .0067016 | 2.17 | 0.040 | .0007179 | .0283224 |
| ltd | .085869 | .0401411 | 2.14 | 0.042 | .0031969 | .1685411 |
| lpd | -.000117 | .0000512 | -2.28 | 0.031 | -.0002225 | -.0000115 |
| lpd2 | -1.63e-07 | 8.13e-08 | -2.00 | 0.056 | -3.31e-07 | 4.45e-09 |
| ltd2 | -.0400145 | .0239733 | -1.67 | 0.108 | -.0893884 | .0093594 |
| _cons | -24.70382 | 2.370067 | -10.42 | 0.000 | -29.58507 | -19.82258 |

```
. xtscc Punoursh Fprdx gdppct ACWS Pcfsvar irg_L PCV TCV , re
(1,052 missing values generated)

Regression with Driscoll-Kraay standard errors   Number of obs     =       418
Method: Random-effects GLS regression            Number of groups  =        38
Group variable (i): C_id                         Wald chi2(7)      =   5600.03
maximum lag: 2                                   Prob > chi2       =    0.0000
corr(u_i, Xb) = 0 (assumed)                      overall R-squared =    0.3010
```

| Punoursh | Coef. | Drisc/Kraay Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Fprdx | -.1287948 | .0134169 | -9.60 | 0.000 | -.1586894 | -.0989001 |
| gdppct | -.0006263 | .0003095 | -2.02 | 0.071 | -.0013159 | .0000633 |
| ACWS | -.1889945 | .0334522 | -5.65 | 0.000 | -.2635307 | -.1144582 |
| Pcfsvar | -.0014452 | .0072669 | -0.20 | 0.846 | -.0176368 | .0147464 |
| irg_L | -.1192689 | .1176792 | -1.01 | 0.335 | -.3814746 | .1429368 |
| PCV | .0346592 | .0156746 | 2.21 | 0.051 | -.0002661 | .0695844 |
| TCV | .2734217 | .0674253 | 4.06 | 0.002 | .1231887 | .4236547 |
| _cons | 52.86369 | 1.581244 | 33.43 | 0.000 | 49.34046 | 56.38692 |
| sigma_u | 10.813624 | | | | | |
| sigma_e | 2.2963111 | | | | | |
| rho | .95685171 | (fraction of variance due to u_i) | | | | |