EFFECT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY IN KENYA

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DECLARATION

This research project is my original work and has not been presented for award of degree in any university or for any other award.

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I confirm that this research project has been developed by the student under my supervision

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DEDICATION

To my mother Florence Akumu Otieno and to my brothers Kennedy and Moses

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ABBREVIATIONS AND ACROYNMS

ADF: Augmented Dickey Fuller

AGW: Anthropogenic or Man-made Global Warming

ARCH: Auto-regression Conditional Heteroskedasticity

ASALs: Arid and Semi-Arid Lands

CDM: Clean Development Mechanism

CGE: Computable General Equilibrium

GCF: Green Climate Fund

GDP: Gross Domestic Product

GHGs: Greenhouse Gases

IET: International Emissions Trading

IPCC: Intergovernmental Panel on Climate Change

JI: Joint Implementation

KNBS: Kenya National Bureau and Statistics

KPSS: Kwiatkowski-Phillips-Schmidt-Shin

MDGs: Millennium Development Goals

NCCRS: National Climate Change Response Strategy

NCCAP: National Climate Change Action Plan

ODI: Overseas Development Institute

OLS: Ordinary Least Square

PACJA: Pan African Climate Justice Alliance

RESET: Regression Equation Specification Error Test

SDGs: Sustainable Development Goals

UNFCCC: United Nations Framework Convention on Climate Change

OPERATIONAL DEFINATION OF TERMS

Climate Change:	Long-term continuous change (increase or decrease) to average weather conditions or the range of weather over a period of 30 years.
Climate:	The average weather condition of a place or a region over a long period usually a decade or a century
Climate variability:	The way climate fluctuates yearly above or below a long-term average value.
Economic growth:	The qualitative and quantitative changes of the economy over the years
Relative Humidity:	Is the amount of water vapour in the atmosphere.
Rainfall:	Is the amount of rain that falls on a given area over a given period of time
Sink:	Is the absorption of greenhouse gases from the atmosphere by either plants or ocean.
Temperature:	The hotness or coldness of a region over a given period of time
Agriculture:	Is the act of tilling the land and rearing livestock with the main aim of realizing future return on current investment made.
Production:	This is the combination of various units of inputs to give output

ABSTRACT

Climate change is a global phenomenon that has greater impacts on productivity through agricultural crop production, livestock production, energy and tourism. Countries all over the World have put adequate measures in place to combat or reduce its effects. This paper analyzed the effects of climate change on agricultural productivity in Kenya. The paper did answer two specific objectives; to determine the effect of climate change on crop production and to evaluate the effect of climate change on livestock production in Kenya. The study adopted time-series data on all the variables under study. Even though some studies considered the impacts of climate on crop production and on livestock production none actually considered the simultaneous effect on agricultural crop and livestock production. The study employed Ricardian Regression Model to analyze time-series data. A diagnostic research design was employed to carry out the study as it explored secondary sources of data which was analyzed using multivariate regression model and Augmented Dickey Fuller (ADF) was carried out to check the stationary of the data. The variables considered for the study were crop production and livestock production as dependent variables while temperature, rainfall, and relative humidity as independent variables. The data for crop production and livestock production were obtained from economic surveys (KNBS) ministry of agriculture and International Livestock Research Institute (ILRI) while temperature, rainfall and relative humidity from Kenya Metrological Department and World Bank. The study found out that temperature and relative humidity significantly affect agricultural productivity. Relative humidity was found to be positively related to agricultural productivity, temperature has negative relationship. The study recommended that government should sensitize the farmers on the need to carry out smart agriculture to reduce losses as a result of climatic change. The study also found out that rainfall positively related to agricultural productivity. Therefore, the study concluded that indeed climate change affect agricultural productivity in Kenya.

CHAPTER ONE

INTRODUCTION

1.1 Background

Climate change is significantly acknowledged as shortcomings in global prosperity in human development. Intergovernmental Panel on Climate Change (IPCC) (2007), note that the rise in climate changes indeed affect the growth of humanity in terms of social, economic and human welfare of various countries since the world's economies are connected via trade and capital flows. The notion that atmosphere knows no boundaries makes international cooperation to curb greenhouse gases essential to ensure prosperity for human and economic development.

Combating climate changes has become one of the key global development priorities. The institutional framework for such cooperation is provided by the 1992 United Nations Framework Convention on Climate Change (UNFCCC) which became operational ten years ago and was known as Kyoto Protocol in1997. The Protocol is one of the most complex treaties ever negotiated (UNFCCC, 2015). During the conference, some legally binding targets for the world's wealthier countries to reduce greenhouse gas emissions were agreed upon. These targets could be achieved through domestic efforts of each individual country. The greenhouse gases (GHG) could also be reduced through some flexible mechanisms which were set out such as joint implementation (JI), the Clean Development Mechanism (CDM), and international emissions trading (IET), IPCC (2015). Geographically, emissions of GHG is environmentally irrelevant, combating climatic change need to take into account cross countries by taking credit for overseas actions that curb GHG emissions at source or enhance the removal of GHGs by sinks (Rechard, 2009).

Although there are other political, economic, social and ethical reasons at the global level for preferring domestic action, the most remarkable aspects of the Protocol is how implementation of its mechanisms is proceeding rapidly around the world, prior to its formal entry into force. The scheme have been implemented in over 50 developing nations of the World and in 25 countries in Europe and most developing nations in South East Asia and Africa in general. Asia countries were at higher risk that may slow down implementation of sustainable development policies, which is a tool for prosperity in the regions. If climate change would be worse, then it is good for all to reduce greenhouse gas emissions as noted by IPCC (2015). Agreement or rules on emissions need to be put in place, so that actions by individual firms, cities or nations are adequate.

Population in developing countries' is expected to increase by around 2.4 billion by 2050. In these developing countries agriculture is the main source of employment and income to the majority. 20 per cent of the populations are food insecure and 75 per cent of the World populations live in rural areas where agriculture is the main source of their livelihood Lipper, Campell and Thorntonn (2014). Global projections puts it that agricultural production need to be increased by 60 per cent in 2050 to meet high demand of food and this need to come from agricultural production increment. Climate change already interferes with agricultural productivity IPCC (2015), crop production is affect the most in most developing nations with negative effects greater than positive effects. Climate change has already reduced crop production by 4.7 per cent and it is expected to experience a steep decrease if temperatures exceed the critical physiological thresholds

Climatic change is a public good, therefore, requiring comprehensive action to deal with. Causes of climate change are found to be the natural greenhouse effect due to high carbon dioxide concentration in the atmosphere, Wheel and Braun (2013). Accumulation of too much carbon dioxide in atmosphere reduces ozone layer allowing infrared rays of the sun to infiltrate resulting to global warming which subsequently leads to climate change.

Climate change is an externality that agricultural production of the world faces such that current decisions made by agents influence future welfare of individuals in the future periods, Sanders and Islam (2007). Externality is a global environmental issue that has a cost to be incurred by everyone and all nations including those that do not contribute to its effect through the decisions made currently which results to changes in state variables such as the atmospheric concentration of greenhouse gases, water availability and specimen richness. Stern (2009), says that efficient allocation of resources with global externalities require cooperation by independent countries over a long period of time involving various cohorts of decision-making. Failure to address these issues results to devastating effect on the economy of any particular nation. In case of climate change, IPCC said that continues emissions of greenhouse gases (GHGs) would possibly results to global warming over the subsequent years with possibility of large degradation on the world economy (IPCC, 2007).

There is consensus that climate change is a serious issue in Sub-Sahara Africa and in fact the greatest problem during the 21st century, together with poverty, Wario (2012). Development projections in Africa proportionately affected by climate change as most countries in Africa are composed of undiversified economic structures, poor infrastructural facilities, weak governance institutions and structures, low human development and more so the countries heavily rely on agriculture to feed most of their population (Akram, 2012).

Consequences of climate change are threat to productivity which is a key ingredient of development and poverty reduction, Nkonde (2014). Africa's growth aspirations and reduction in poverty are directly affected by changes in the climatic conditions which are evident through changes in water availability, biodiversity loss, agricultural yields loss or decline, floods and droughts which are humanitarian disasters, weakened infrastructural facilities, inadequate political goodwill due to scramble over the scarce resources, increased incidence and prevalence of vector-borne diseases (Mburu, Kungu and muriuki, 2015).

Productivity in Africa is affected by climatic conditions, Bozzola (2014), agriculture being the back born of livelihood to many poor Africans. It also has diverse effects on tourism which is the main source of foreign exchange earner and factors of productive such as land, labour and capital. Adverse effect of climate change poses a major threat to human security and political stability since there is frequent movement experienced which could results to civil conflicts if not checked (McGeehin and Maria, 2001).

Changes in climatic conditions will reduce growth by drawing resources away from development through taxing individuals, firms and government institutions. Further existence of climate shocks of larger magnitude will enormously affect economic growth of Africa and lock many Africa countries in poverty traps, Frankhause (2010). In order to achieve sustainable growth, poverty reduction, and attainment of other development goals, then African countries need to expand their energy, agriculture and industrial production. The question is how can these development goals be achieved without exacerbating the problem of climate change? For growth and prosperity to be achieved then climate change must be affected, Stern (2007). Africa will soon realize emissions of carbon dioxide grow daily, however, high carbon growth path is unsustainable, therefore, a robust decision-making and a long-term planning that take into account a wide range of climate and socio-economic scenarios and adoption climate-smart policies that enhance development in Africa, this would help reduce vulnerability and finance the transition to low carbon growth path (Lindzen and Choi, 2010).

1.1.1 Climate change in Kenya

Kenya's climatic condition varies from one region to another with high temperatures at sea level and low temperatures at mountain level. The average annual rainfall ranges from less than 250 mm in the arid and semi-arid areas to greater than 2,000 mm in high potential areas. Government of Kenya (2016), states that 580,367 square kilometers which is approximated total area, only 12 per cent of Kenyan land is perceived to be high potential for farming and also for animal rearing. Further 6 per cent is medium or moderately suitable for animal husbandry.

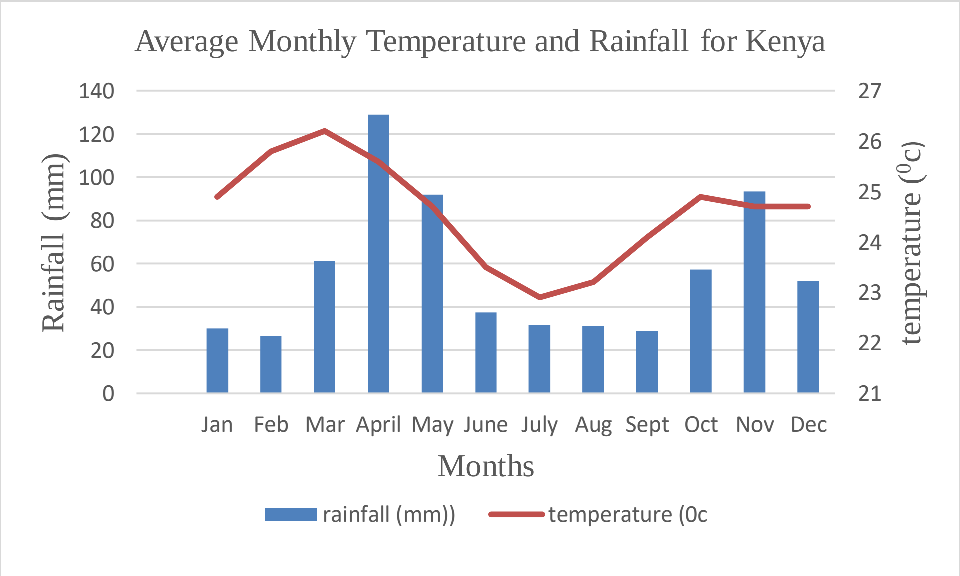
In Kenya, climate is a very important natural resource that if well utilized plays a critical role in the development of agricultural sector, Bryan and Okoba (2011). Climate change is unequivocal, as evidently shown by increases in atmospheric global air and the oceanic temperatures which results to glacier melting, rising global sea level and snow and ice melting, IPCC (2007). Climate varies due to variations in topography both in time and space which depends on water bodies, great valleys and high mountain. Agriculture is the main driver of the economy of Kenya and mainly depends on rainfall. Frequent increase in drought will greatly results to crop failures which adversely affect food security. Farnsfield, (2012), puts it that livestock keeping which is mainly practiced in arid and semi-arid areas which are prone to severe droughts resulting to loss of animals, out-break of diseases like Rift Valley Fever due to high temperatures and heavy rainfall also lead to losses which impact the livelihood of pastoralists.

The vulnerability of agriculture in general and crop production in particular to climate change is an important issue Kenya as the country is highly dependent on the agricultural sector for the livelihood of the majority of her population, Lam (2007). Agriculture contributes a significant proportion or share to national income, export earnings, rural employment and non-farm enterprises; both rural and urban populations depend on agriculture for food security. However, over the last three decades, the relative contribution of the agricultural sector to the livelihoods has continued to decline, Kabubo (2015). Multiple factors are responsible for this decline, including climate change, poor initial resource endowments, endogenous factors such as population growth and disease infestation which is associated with changes in climate among others.

The effects of climate change and disasters associated with it have the potential to adversely affect the productivity of majority of Kenyans given that about 75 per cent of the population depends directly on land and natural resources for their livelihoods, Johnson (2007). Recently, attention to climate change has increased due to its impacts on the lives of Kenyans. From 1990-2000, the average climate change was 0.15^0c, this has increased over a decade to 4.1^0c for a period 2001-2012, Republic of Kenya (2010). This is due to an increase in intensity and frequency of extreme climate events such as occasional floods and severe droughts. Climate change has been a disaster to economic plans such as Millennium Development Goals and Sustainable Development Goals that are geared towards achieving economic growth and human development objectives (Kabubo, 2015).

Agricultural sector contributes about 26 per cent to the Gross Domestic Product and 60 per cent to foreign exchange earnings Mburu, (2015). Over the past decade, it was noted that incidence and intensity of hunger and malnutrition has increased significantly, food availability has not also kept pace with the geometrically growing population in Kenya (Mburu, 2015).

Figure 1.1 shows the average monthly temperature and rainfall for Kenya in the year 2016. The table depicts a fluctuating trend in rainfall amount and an increasing trend for temperature during the year. This trend has affected various sectors of the economy such as agricultural crop production, livestock production, tourism, energy production and oceanic level.



Source: World Bank Database

Figure 1.1**:** Average Monthly Temperature and Rainfall for Kenya - 2016

Reduction in food production and increase in famine rate are regularly being experienced in most parts of the country despite the involvement of the largest proportion of population in agricultural output. Increase in temperatures and frequent droughts have to a larger extend affected the flood and drought prone peasant farmers who heavily rely on rain-fed agriculture for survival. The effect of climate change is more severe for the vulnerable and disempowered groups in the society including women and children have the capacity and capability of being strong contributors of productivity and development. Hostile climatic conditions experienced in arid and semi-arid areas have made the achievement of Vision 2030 and Millennium Development Goals (MDGs).

1.1.2 UN Conference Agreement on Climate Change 2015 in Paris

In December, 2015, countries met in Paris France to sign agreement on climate change. In this conference, countries were tasked to come up with ambitious and robust plans to reduce carbon within their jurisdictions, this was different from the previous agreements where countries were focusing on setting top-down targets which were national oriented, IPCC (2015). This global agreement was important as their contribution will add to adequate global action in terms of financial support for adaptation and low carbon transition while ensuring national transparency to ensure global co-operation. In the conference countries agreed to start acting from then in order to be able to reduce temperatures rise by at least 2^{0}C or much less than 1.5^{0}C above the pre-industrial levels.

According to Paris Conference on climate change 2015, the Kenyan government committed to reduce pollution caused by climate change by 30 per cent and also to give average temperature under a 2-degrees Celsius. At the conference, Kenya agreed to contribute to the Multilateral Green Climate Fund (GCF) which was established to help mobilize funding in developing countries to reduce carbon emissions and adapt to the effect of climate change within their areas of jurisdiction, IPCC (2015). This commitment was highly welcome by the crusaders of climate change and it was evidenced that Kenya can prosper without necessary using fossil fuels. This target was to be met by expanding the use of solar, wind and geothermal energy as witnessed in the North Eastern where these activities are ongoing, as a result of this, the area under forest cover would increase by about 10 per cent and reduce the reliance on the use of wood fuel. A Kenyan climate expert and adviser puts it that, “Kenya has submitted its commitment much sooner than many richer countries, demonstrating the kind of ambition other such countries should be aiming for.” End of quote (IPCC, 2015).

A framework from which rolling commitment was made to reduce emissions and support adaptation was established. The Kenyan government committed to the framework which was to be rolled on a five-year basis due to two main reasons. Firstly, carbon targets need to be revised in the light of emerging science and secondly, countries to the framework were to implement low carbon strategies.

At the conference, a clear link between Sustainable Development Goals (SDGs) and Millennium Development Goals (MDGs) was set up, this was to ensure a distinct path for international development for the next generation by taking action on climate change to achieve development aims such as poverty eradication, education for all, food and energy security. The agreement on climate change and SDGs was seen as a complementary with mutual benefits in areas such as low carbon development, climate adaptation and resilience and this will encourage financial flows for which Kenya will benefit to a larger extend (IPCC, 2015).

The Overseas Development Institute (ODI) was tasked with carrying out a thorough review of the effects of climate change on different development goals and they found out that climate change had an impact on all of the goals, directly or indirectly. Direct impacts include food security, availability of water, and health outcomes. These outcomes in turn affect other development goals such as gender equality, education human rights and productivity (Smith and Pete, 2013).

1.2 Problem Statement

Climate change is globally acknowledged as a serious development challenges facing agricultural sector and production in general. It is evident that by 2050 agricultural production needs to be increased by 60 per cent in order to meet high food demand post by the ever increasing population. Production of wheat and maize has declined by 5.5 per cent and 3.8 per cent IPCC, (2015). In Kenya, impacts of climate change on crop and livestock production has been great, Kasimba (2012). The frequent climatic changing patterns have resulted to severe droughts and flooding which have resulted to decline in agricultural production level. The National Climate Change Response Strategy (NCCRS) in 2010, National Climate Change Action Plan 2013-2017 (NCCAP), (Government of Kenya, 2010), and Climate Change Act 2016, Government of Kenya (2016) were documented to respond to the impacts in order to achieve economic plans such as Medium-Term Plans, Vision 2030, Millennium Development Goals and Sustainable Development Goals,

A number of international treaties had also been put in place for climate change mitigations, studies that take into account the effect of climate change have only started to emerge. Although studies have been done on sociological effects and despite the difficulties in getting common ground to tackle climate change issues, the study investigated the effect of climate change on agricultural productivity which the study is anchored on. Most of the studies adopted cross-sectional data which were analyzed using Ricardian model, however, none of them employed time series data which this study employed with the same model. The study added to the body of knowledge the economic effects of climate change on agricultural productivity on local and international farmers.

1.3 Research Questions

The study will seek to respond to the following questions;

i) What is the effect of climate change on Agricultural crop production?

ii) What is the effect of climate change on livestock production?

1.4 Objectives of the Study

The general objective of the study is to determine the effect of climate change on agricultural productivity. The specific objectives of the study are;

i) To determine the effect of climate change on agricultural crop production

ii) To investigate the effect of climate change on livestock production

1.5 Signification

Changes in climatic conditions have been proved problematic when it comes to development planning. The study seeks to form both mitigation and adaptation policies which are cost effective and easy to implement into Kenyan development plans. The study findings would be more important to farmers who are suffering loses as a result of climate change by planting drought resistant crops, keeping livestock that adapt to climatic changes to avoid such loses in future.

1.6 Scope of the Study

The study was carried out in Kenyan agricultural economic sector from 1984-2017. This was because changes in climatic conditions in terms of temperature, rainfall and relative humidity often affect the agricultural production in the country as a whole and also has greater impact on crop production specifically. The arrival of climate change on the policy agenda in Kenya is fairly recent. The main Government document on climate change is the National Climate Change Response Strategy (NCCRS) in the year 2010 and Mitigation and Adaptation

Strategies to Climate Change in 2015, the development of these documents shows that the government is concerned on the impacts of climate change on the economic activities. The timeframe from 1983-2017 is chosen to give appropriate sample size that will be used for data analysis during project work

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section is divided into three parts; theories of climate change, theoretical literature, empirical literature and overview of literature.

2.2. Theoretical Literature Review

2.2.1. Theories on Climate Change.

Theories of climate change that are quite familiar are the anthropogenic or man-made global warming, or Anthropogenic or Man-Made Global Warming (AGW). The theory holds that the main cause of global warming is man-made greenhouse gases such as carbon dioxide which occurred 50 years ago (Bast, 2013). These gases cause a catastrophic rise in temperature which is commonly referred to as enhanced greenhouse effect or the theory of anthropogenic global warming. Energy from the sun travels and reaches the Earth's surface through its transparent atmosphere to the surface of the earth where some of it is absorbed and some is reflected back as heat into the atmosphere. The reflected heat is absorbed by the GHGs resulting in the Earth's atmosphere becoming warmer than it otherwise could have been. The proponents of this theory hold that over 0.7^0C global warming for the past century and over 0.5^0C for the last 30 years had been attributed to GHGs which are man-made and rejected the claim that it could be as a result of recovery from Ice Age. The computer models used in the theory to postulate future GHGs level predicted that doubling the level of carbon dioxide in the atmosphere would make the Earth's temperature to rise further. The model also predicts that more warming would be experienced at the tropics due to warming of the troposphere than the level that has been observed by the satellites and radiosonde measurements. It is argued in the theory that man-made carbon dioxide is the main contributor of severe weather, oceanic coral bleaching, crop failures, species extinctions, floods, droughts, famines and spread of diseases while the study determine the effect of climate change on agricultural production.

The Bio-thermostat theory of climate change as put forward by Bast (2013), holds that negative feedbacks from biological and chemical processes wholesomely counteract positive feedbacks caused by rising CO_2. The rise of CO_2 in the atmosphere is due to increased carbon sequestration by plants and higher temperatures are also responsible for this increase. Plants wholesomely depends on carbon dioxide as a raw material for photosynthesis to take place, therefore, the more in the atmosphere the better, the power of offset of higher carbon dioxide in the atmosphere depends on the size, growth rate and duration of the sinks in which carbon is stored. These sinks keep on growing in tandem with man-made emissions. The increase in CO_2 in the atmosphere causes global warming which results to changes in climatic conditions which the study seek to analyze.

Theory of solar variability of climate change states that global warming in late twentieth century is due to solar variability which will also account for most of the global warming in the twenty-first century irrespective of man-made GHGs emissions. Solar flares from the surface of the sun occasionally burst in cycles which cause an outflow of charged particles known as solar winds. These solar winds reach the surface of the earth and the atmospheres affecting the galactic cosmic rays which subsequently affect cloud formation. Changes in cloud formation are mostly associated with variations in the sea surface temperatures and wind patterns according to a seminal paper by Soon (2009). These changes in sea surface temperatures results to changes in global climate change which the study seeks to analyze its effect on agricultural productivity in Kenya.

2.2.2 Theories on Impacts of Climate Change

The study of climate change and its effects on productivity or output encompasses a number of theories such as market theories and development theories that act as a framework for the understanding of the subject of study. The growth and development theories from the era of Washington Consensus of early 1990s that emphasized that market should be left alone to the forces of demand and supply to operate. Theories put forward by growth experts' emphasize on the need to incorporate climate change into growth models to ensure macroeconomic stability, stimulate innovation and inventiveness, and open up the world economy and political stability as demonstrated by Brown, Cochrane and Frankhauser (2012). The theory does not only focus on institutions but also put a lot of emphasize on both human and physical geography that plays a great role in development. Element of growth and development that are often associated with sustainable and private sector-led growth are interlink so as to realize a fast-growing economy.

The endogenous growth theories of standard neoclassical economic growth models used to study effects of climate change on productivity are Ramsey, Cass and Koopmans model in which growth is a function of savings, investment and capital accumulation, (Akram, 2012). These models clearly do not explain how climate affects productivity which is the main objective of this study. Factors such as patterns of migration, growth of population, depreciation of capital and levels of production are considered as exogenous variables in the model. Studies done in this area focus on the level of growth rather than the rate of growth, in the model, it was demonstrated that the effect of climate change on economic growth through reduced growth was larger than that of direct level effect.

The approaches used to analyze the impacts of climate change on productivity are the enumerative and the dynamic approach, (Akram, 2012). Enumerative approach, analyzes the impacts on sector basis, such as the effect on agriculture, ecosystem, energy, infrastructure and tourism. The effects are analyzed in order to come up with an estimated total change in socio-economic welfare stemming from changes in climatic conditions. In this approach, the analysis is based on one period only while inter-temporal effects are basically ignored. However, the information on the long-run effect of climate changes on welfare has not been provided by the study. The approach also ignores the fundamentals of horizontal inter-linkages such impacts sectorial interactions. Computable General Equilibrium (CGE) Models and Simulation Techniques are commonly used to study the impacts of climate change.

Dynamic approach incorporates the damage function in the growth models. Solow-Swan and Ramsey-Cass-Koopmans models are the common growth models used to study the impacts of climate change on production. The Mankiw, Romer and Weil model is also used but to a lesser degree, this is according to Fankhauser and Tol, (2005). The three models above assume a constant rate of saving as it is a major component of a production function that stimulates production, the study found out that climatic changes greatly impact output negatively and thus reduces the level of investment in the economy which subsequently affect productivity in the short-run. Capital stock and consumption per capita will most likely decline in the long-run, resulting to the shrinkage of aggregate demand and adversely affect output. In case endogenous growth model is used, the level of investment becomes much lower due to capital accumulation effect which slows the rate of technical progress and productivity of labour or human capital accumulation (Akram, 2012).

The two approaches were used to carry out the present day study to analyze the impacts of climate change on output sectorial contributions such as agriculture, energy, tourism, manufacture and in service delivery.

The theory that is used mostly to study the effect of climate on agricultural crop and livestock production is the Recardian theory which utilizes cross-sectional data to determine farm performance across various climatic zones of the world Mano and Nhemachena (2007), Mendelsohn (2008), Passel (2012), Thapa and Ganesh (2010). The methodology was named after David Ricardo (1772-1823) due to its originality that the value of the land is reflected in the net production of the farmland output, (Mano and Nhemachena 2007). The model has been applied across both developed and developing countries of the world. The model was mainly developed to explain variations in the value of the land per hectare of agricultural land over different climatic zones. Various studies found that a land value per hectare of agricultural land is sensitive to seasonal changes in temperature, rainfall and precipitation (Nkonde 2014, Bozzola 2014, Passal 2012 and Mano 2007). The Recardian model assumes that the value of the arable land per hectare (V) of each farm in a given location is equivalent to the present value of future net revenues earnings from farm output. The model is as follows;

$$V = \int P_{IE} e^{\delta}\, dt = \int [\sum P_i Q_i\, (X, F, Z, G) - \sum RX]\, e^{\delta}\, dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

Where P_{IE} is the net revenue per hectare, P_i is the market price of crop i, Q_i is output of crop i, F is a vector of climate variables, Z is a set of soil variables, G is a set of economic variables such as market access, X is a vector of purchased input prices, t is time, and δ is the discount rate. The value of the land is a function of climatic variables (F), soil variable (Z) and economic variables (G), thus the model is expressed as a function of exogenous climatic variables only as;

$V = f(F, Z, G)$……………………………………………………………2.3

But F which is a vector of climatic variables as represented by equation 2.4 below

$F = f(T, R, P, E)$…………………………………………………………….2.4

Equation 2.4 contain exogenous climatic variables which include temperature (T), rainfall (R) and precipitation (P) and control variables (E)

2.3 Empirical Literature Review

Fankhauser and Tol (2005), carried out a study on the effect of climate change on agricultural productivity especially on livestock production. The study found that the impact of climate change can only be measured to the extent of a given period and the social welfare of that period. The study considered the dynamic effect of climate change on livestock production and the wellbeing of the society as a whole. The variables considered in the study were precipitation and temperature as independent variables while livestock production as the dependent variable. The study adopted diagnostic research design with panel data across some countries in Africa.

The study assumed constant savings rate, so that a reduction in output as a results of climate change will proportionately lead to reduction in level of investment which in turn depress future livestock production level, this is due to capital accumulation effect, in return affecting future level of consumption per capita. If the rate of savings is taken as an endogenous variable, then forward looking agents would most likely alter their rate of savings to match with the effect of future changes in climatic conditions.

Luedeling (2011), carried out a study on impacts of climate change on crop production in Homabay and Busia Counties around Lake Victoria Basin and its environment found out that climatic changes had an inverse relationship with crop production. The variables of the study were crop productivity as the dependent variable and rainfall, temperature and soil type were independent variables. The main climatic factor that affects crop productivity was found to be temperature but not rainfall as it was easily predicted than rainfall which usually changes from time to time. A cross-sectional study design was used in order to obtain the data across various crops for the study. The study recommended introduction of drought resistant crop to cub crop vulnerability to climate change.

Tol (2011), while carrying out a study on effect of climate change on crop production, found out that, moderate climate change brought net benefits. Some of the benefits included carbon dioxide, fertilization of crops and reduced energy demand. Climate change has had a negative effect on water sources and (by and large) human health. Most rich and poor countries benefitted from effects of climate changes until early 1980s, after which the trend become negative for most poor countries and positive for financially stable nations. Thereafter, the trend became negative for both poor and rich nations. Future changes in world's climatic condition are a concern for most developing countries as the impact will be greater on productivity. The effect of climate change on human health was found to be more negative than positive; the study also found out that there is a negative relationship between climate change and human health; and that the growth rate of most poor countries would be reduced by 0.6 per cent points. Climate change affects accumulation of capital and people's propensity to save, which, subsequently, reduces production level of the world developing nations. The study adopted descriptive research design with cross-sectional data across various crops. The data was analyzed using multivariate regression model to analyze the effect of climate change on crop production.

Variables used in the study are carbon dioxide, rainfall amount and net crop production, however, the study failed to consider the effect of other climatic variable such as precipitation and temperature which the study seek to undertake

Baumgard, Rhoads, Gabler, Lenka and Sejian (2012), while carrying out a study on the impact of climate change on livestock production found out that climate change adversely affects livestock industry and ultimately impacts the production of animal protein which is a crucial ingredient dietary required by human for healthy production. The study used a cross-sectional data across countries from published sources for analysis using descriptive research design, the study also considered mean temperature as the independent variable. The study found that climate change directly and indirectly affects the livestock welfare and productivity. The direct effects of climate change on livestock production are post-absorptive metabolism, nutrient portioning, and eventually production while the indirect effects are reduced feed intake, alteration of immune systems, reduction in feeding habits, water body availability and quality, and increased environmental interaction with disease causing parasites and vectors. The negative effects of climate change on livestock production will be on the rise as long as global warming is on the upper hand. The greatest impediment to livestock production that the study found out is the heat stress (high temperature) in regions which is agriculturally rich in animal production and particularly in tropics and sub-tropic regions of developing countries. Even though the study analyzed the effect of temperature on livestock production, the study failed to consider the effect of humidity and rainfall variability on livestock production which the study seek to incorporate in the model and analyze their effect on livestock production.

Bowen, Cochrane and Fankhauser (2012), while carrying out study on the impacts of climate change on economic growth and its adaptation across countries found out that changes in climate has both positive and negative impacts on economic growth and development but in the long-run, negative effects out-do positive effects. The study also found out that growth and development reduce vulnerability to changes in climate but only right growth policies will have such reduction. Climate change can alter the growth path of a country especially the agricultural sector and also interfere with investment plans since the priorities will be directed to adaption. High temperatures and extremes of climate change tend to lower growth rates in less-developing countries by affecting growth factors such as human capital accumulation and fiscal and monetary stability of a country. The ability of a country to handle climate change highly depends on quality of the institutions handling climate change, education level of the citizens and per capita income that is brought about by improvement in economic growth. The study found that a 1 per cent increase in temperature reduced economic growth by about 1.1 per cent point per year using panel data across countries. The variables used in the study were temperature, economic growth and income from various countries, the study adopted descriptive research design with cross-sectional data across countries. However, the study failed to consider time-series data and the effect of humidity on production which the study analyzed.

Smith, Pete and Peter, (2013), carried out a study on the impacts of climate change on sustainable food production found out that changes in climatic conditions greatly affect food production negatively. The study adopted descriptive research design with panel data, the variables used in the study were rainfall, temperature and carbon dioxide. The study found out that problems of food security, reduction of climatic impacts and provision of resilience to future changes in climatic conditions, means choosing between capital and consumption-based food production systems is a problem in the world that intensively depends on agriculture as the main source of livelihood; indeed, we clearly need both. The more the management of the demand for land-intensive food production, the less production is intensified. Reducing GHG emissions in agricultural sector, the more reduction potentials are realized through a combination of technological and food consumption-based measures. The study suggested that measures that deliver on sustainable food production will also deliver on reducing GHGs emission in agriculture together. According to the United Nations' definition; 'food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. As the focus on delivering of food security on top gear, we must also endeavor to reduce the environmental impacts of food production that are associated with GHGs emissions as future climate change will make a great impact on food production since agricultural production nearly contributes about 30 per cent of anthropogenic GHGs emissions that contributes to climate change. The variables of the study were temperature, rainfall and carbon dioxide as food production highly dependent on them, therefore, very vulnerable. The study failed to incorporate relative humidity which the current study incorporated and analyzed its effect on agricultural productivity in Kenya.

Kasimba (2014), carried out a study on the impacts of climate change on crop production, found out that climate change affects crop productivity as a result of insufficient rains, high temperatures and sometimes too much rain resulting to the outbreak of various crop diseases. The study was carried out in Guruve district in Zimbabwe and used qualitative and quantitative research design methodologies to analyze the impacts of climate change on crop production practices and tried to come up with best approaches to improve crop production. The data used in the study was collected across farmers in the region using structured questionnaires and one on one interview. The variables considered under the study were rainfall, temperature and disease. The study found out that rainfall variability causes decline in crop production as a result of drought, occasional occurrence of extreme low temperature also found to have the same effects as rainfall while frequent change in climate also led to widespread of pest and diseases as a result of high temperature which adversely lowers crop production. The study failed to consider the effect of climate change on large scale farmers which the current study considered as climate change affect all farmers irrespective of the type of farming being carried out.

Kabubo, Mariara and Kabara (2015), while carrying out a study on impacts of climate change on food security in Kenya found out that climate variability and change reduces food security through food availability, food accessibility, food utilization and food stability. During the study, the country was divided into three major regions that is high potential region, medium potential region and arid and semi-arid region. The study found that high rainfall is necessary for increased crop yield hence food security while excess leads to flooding and water logging which is harmful to crops at initial stages and during harvest it leads to rotting of mature crops. The study adopted descriptive research design with a panel data collected from published sources from county to county basis was used on major crops such as beans, sorghum and maize, the climatic variables used in the study were precipitation, temperature, and run-off and cloud cover over the years. The study adopted Ricardian regression model to estimates the impacts of climate change on food security. The variables considered during the study were crop agricultural land as dependent variable while crop productivity and the factors affecting climate were used as independent variables. Regression analysis was used to show the effects of climate change on food security. The study did not consider the effect of relative humidity as a climatic variable on food security; the current study took to incorporate relative humidity and analyzed its effect on crop production.

Study carried out by Nkonde (2014) on the impacts of climate change on livestock production in Mpolonjeni Area in Swaziland found out that climate change does affect livestock production and livestock system particularly in less developed countries. The study found that high temperatures and unpredictable rainfall patterns translates to an increased spread of vector-borne diseases and parasites as well as emergence and spread of new diseases, it also has effects on natural pastures which livestock owners majorly depend on for feeding their livestock. Variables of the study were livestock production as an independent variable, rainfall, temperature and land use as independent variables. The study utilizes both qualitative and quantitative research design. Primary data was used where a stratified sampling design was used to obtain required sample after which the data for livestock was collected using personal interviews while temperature and rainfall data was collected from published documents from Swaziland Meteorology Department. Ricardian regression model and descriptive statistics was used to show the impacts of climate change on livestock production.

Adams, Hurd, Lenhart and Leary (2015), carried out a study on the effects of climate change on agriculture, considered effects on crop productivity and livestock production across countries in Africa. The study found out that climatic factors such as temperature, precipitation change and high amount of carbon dioxide concentration in the atmosphere have greater effect on crop productivity, temperature was found to both positive and negative impacts on yield, but generally, increases in temperature was found to reduce crop yields and quality of grains. Increase in precipitation was found to be useful in drier areas buy increasing soil-moisture, therefore increasing crop yield while high levels of carbon dioxide concentration were found to results to higher net photosynthesis rates. Generally, these climatic factors were found to have effects of crop productivity. The study also considered the effects of climate change on livestock productivity, climatic changes affects livestock productivity in two ways, that is, through the quality and amount of forage from grasslands and higher temperatures. Livestock production were affected in terms of milk production, heifer and meat production. The study adopted descriptive research design with stratified sampling design. The variables of the study were temperature, precipitation, rainfall and carbon dioxide as independent variables while net livestock and crop productivity as dependent variables. The study utilizes time series data for analysis using structural approach where crop simulation models were used to factor in effects of carbon dioxide. The study found out that holding all the other factors constant, temperature changes results to a decrease in crop yield while precipitation increases results to increases crop yield.

2.4 Overview of Literature

Theories of climate change show that the effect of climatic changes are not limited to agricultural crop production, livestock production and productivity in general but also results to flooding, drought, oceanic coral bleaching extinctions of species, spread of diseases and severe weather changes.

The studies reviewed clearly show that climatic changes greatly impact productivity. Most studies investigated the effect of climate change on food security, livestock production, health, poverty, manufacturing, service sectors, the results from these studies confirmed the findings of the theoretical literature that changes in climate adversely affect agricultural productivity. Even though studies have been done to investigate the effect of climate change on aquatic life, little has been done on the effect on crop and livestock production of which the study will majorly investigate, analyze and tabulate the findings using time series data with diagnostic research design.

The Ricardian regression model was conveniently used in the study as it best showed how change in climatic variables affects net farm output. The approach explains how the model variables affect the output. The main variables considered were temperature, rainfall and relative humidity.

The study carried out by Nkonde (2014) used panel data, this study borrowed from Ricardian regression approach used in the study to analyze the relationship between climate change and agricultural productivity in Kenya. The findings by Nkonde show that climatic change adversely affects livestock production. The studies failed to consider the effect of climatic variables on agricultural productivity that the current study considered and gave a comprehensive analytical finding. The reviewed empirical literature had so far not been able to a systematic causal relationship between climate change and agricultural productivity that the current study seek to undertake.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The general objective of the study was to determine the impacts of climate change on agricultural productivity in Kenya. Therefore, this chapter sets out the methodology used to achieve the study objectives. The chapter also focused on research design used in the study, the theoretical framework adopted. The section also presented model specification. Lastly the section highlighted the data type, source and data analysis.

3.2 Research Design

Research design encompasses the methodology and procedures that was employed to conduct the study. The study adopted diagnostic research design to determine the effect of climate change on productivity because the study seek to analyze the frequency with which climatic variables occur and there effect on agricultural productivity. Quantitative time series data pertinent to each variable was used to answer the research questions and objectives as stated in chapter one. The study used annual data for the period 1984-2017 for all the variables. Multivariate regression analysis was used to measure the relationship between the variables, the direction and the magnitude of change.

3.3 Theoretical Framework

The study relied on the Ricardian Model as explained in Chapter 2 using time-series data across the country (Mano and Nhemachena, 2007, Bozzola 2014 and Nkonde 2014). Theoretically, the model prescribes equation 3.1 below in explaining the effect of climate change on agricultural production:

$V = f(F, Z, G)$………………………………………………………….……. (3.1)

Where;

V- Net farm output, F- vector of climatic variables, Z-a set of soil variables and G-economic variables such as market access by the farmers.

The model states that net farm output in an economy depends on climatic variables, soil variables and economics variables. In the model Ricardo believed that the variable that affects farm output level was climatic variable which was determined by the temperature level, rainfall amount and relative humidity in the atmosphere. Therefore, any change in the climatic variables affects farm output which subsequently affects the level of economic growth of a country.

Equation 3.1 above, according to Nkonde (2014) can be reduced to capture only the effects climatic variables on the farm output as follows;

$$Y = B_0 + \sum \beta_1 (X_1 - \overline{X_1}) + \sum \beta_2 (X_2 - \overline{X_2}) + \sum \beta_3 (X_3 - \overline{X_3}) + \mu \text{........................ } 3.2$$

Where;

Y-net farm output, $X_1 - \overline{X_1}$- rainfall variability, $X_2 - \overline{X_2}$- temperature variability, $X_3 - \overline{X_3}$- relative humidity, β_j – the value of the j^{th} coefficient and μ- error term

3.4 Model Specification

The Ricardo model equation 3.2 above was modified to suit the study by replacing the variables in the model as follows, in the model net crop production and net livestock production was used as dependent variables to measure the effect of climate change on productivity and are represented by Y_1 and Y_2 respectively in the equation 3.3 and 3.4 below

$$LnY_1 = f(\beta_0 + \beta_1 rnf + \beta_2 temp + \beta_3 rel.hum + \beta_4 carb + \beta_5 \, irrig + \beta_6 inp.prc + \beta_7 pop + \varepsilon) \quad (3.3)$$

$$LnY_2 = f(\beta_0 + \beta_1 rnf + \beta_2 temp + \beta_3 rel.hum + \beta_4 carb + \beta_5 \, irrig + \beta_6 inp.prc + \beta_7 pop + \varepsilon) \quad (3.4)$$

Where;

LnY_1- Log of Net Crop Production, LnY_2- Log of Net livestock production, rnf- rainfall, $temp$- Temperature, $rel.hum$- Relative Humidity, $inp.prc$ - input prices, $carb$ - carbon dioxide, pop - population growth, $irrig$- irrigation and $\varepsilon -$ error term

Net production means total production less damages and losses

Equation (3.3), states that any change in climatic variables had effect on the level of crop production which would subsequently have effect on the level of productivity either positively or negatively depending on the direction of the change. Equation (3.4), also states that the same changes in the climatic variable would also have effect on livestock production hence affecting productivity positively or negatively.

Temperature, relative humidity and rainfall are chosen as indicators of climate change

Equations (3.3) and (3.4), will be used to estimate the model by obtaining the co-efficient of the following Parameters;$\beta_{1,}$ $\beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ and the intercept β_0 and ε is the error term, that will take care of any other variable that the model might not have captured but affect economic growth.

The focal variables in the study are the agricultural crop production and livestock production which was used as a measure of productivity that are directly affected by the changes in the climatic conditions while rainfall, temperature and relative humidity were used as indicators of climate change.

The study used Multivariate Regression Model with Ordinary Least Square (OLS) model to examine the relationship between the variables and Augmented Dickey Fuller (ADF) unit was used to test for the stationary of the variables. The OLS test the casual relationship among the variables.

3.5 Definitions and Measurement of Variables

Table 3.1: Definitions and Measurement of Variables

Variable	**Definition**	**Measurement**
Crop production	Farm production aggregate of cereals and legumes	Annual percentage crop production in tonnes per unit area
Livestock production	Animal output in terms of hides, meat and milk	Annual percentage animal output per unit sales
Rainfall	Amount of rain realized over a given period of time	Average annual rainfall received in millilitres
Temperature	Hotness or coldness of a given region	Average annual temperature in degrees celcius
Relative Humidity	Amount of water vapour in the atmosphere	Average annual humidity in mililitres.

Source: Developed by the author

3.5.1 Definition of variables used in the Study

Agricultural Crop Production; this is the production of all agricultural crop production aggregated together in Kenya. It is expected to have a positive correlation with rainfall and precipitation but a negative correlation with temperature as high temperatures results to stunted growth which lowers crop yield.

Livestock Production; this is the sum total of all livestock products aggregated together in Kenya. It is also expected to have a positive correlation with rainfall and precipitation but a negative correlation with temperature as moderate amount of rainfall and precipitation results to nutritious pasture which is a good feed for livestock hence increasing the output in terms of meat, milk and even hide.

Rainfall; is the amount of rain that fall within a given region for a period of time. The rainfall variability will be used in the study are deviations from the expected annual rainfall since it is this difference that causes a change in climate. The variable is expected to have a positive relationship to crop production and greener pasture for livestock consumption hence high milk production and better quality of meat. Rainfall was found to have a positive relationship with agricultural productivity.

Temperature; temperature is defined as the hotness or coldness of a given region over a given period of time. Temperature changes have greater effect on both crop and livestock production which consequently affects the level of productivity. The temperature variability was used in the analysis. It was used as a proxy for the measure of climate change. It was found to be negatively related to agricultural productivity.

Relative humidity; relative humidity is defined as the amount of water vapour in the atmosphere. When it is high, there is good crop and livestock production. Relative humidity was used as a measure of climate change. Changes in relative humidity were found to be positively related to agricultural productivity over time.

3.6 Data Type and Source

The study used secondary Time Series annual data from 1984- 2017. The data was sourced from published time series data from Kenya National Bureau of Statistics (KNBS), in economic surveys and statistical abstracts for agricultural crop production and livestock production was used as a dependent variable; Kenya Metrological Department for temperature, humidity and precipitation from weather station across different stations in Kenya.

3.7 Time Series Property Tests

3.7.1 Unit root test

Unit root test was used to test for the stationary or non-stationary of the series used in the study. Stationary variable is one with a mean and variance over time is constant, this was necessary to ensure that spurious results are not obtained which is a common case with non-stationary variables. The study used Augmented Dickey Fuller (ADF) to carry out stationary test.

3.7.2 Co-integration test

Co-integration test was carried out to show the relationship among the variables used in the study. The study adopted Johansen Co-integration test to show long-run relationship among variables. It was preferred over other methods since it can be used on variable irrespective of the order of integration.

3.8 Data Analysis

In order to achieve the two objectives of the study as outlined in chapter one, the first step was to test for the stationary among the variables using ADF test was preferred over other because it gives both intercept and trends stationary of time-series data, stationary test was to ensure that lags in the data were removed and that means and variance over time were constant and spurious results were not obtained. The second step was to test for the relationship among the variables using Johansen Co-integration Test (JCT) model and time irreversibility of the data using diagnostic test. Ones these were done, ordinary least square (OLS) model was used to regress the data for the analysis of the study. To achieve objective one, regression analysis was carried out where the co-efficient of temperature, relative humidity, rainfall, carbon dioxide, input prices, irrigation and population values were interpreted to determine the relationship between crop production and changes in the climatic indicators. Objective two was achieved by running multi-regression to determine interrelationship between climatic variables and livestock production where the co-efficient index was interpreted depending on the direction and the magnitude of the results.

CHAPTER FOUR

EMPERICAL FINDINGS

4.1 Introduction

The chapter begins by presenting the findings of the study explaining step by step time series test results, stability test, and diagnostic test and regression results of the effect of climate change on agricultural productivity in Kenya.

4.2 Descriptive Statistics

Descriptive statistics for all the explanatory variables in table 4.1. Descriptive statistics was used to capture the basic element of the data used in study. This summary was used as a fundamental basis for all the quantitative data analysis. The table comprises of mean, median, minimum, maximum values, standard deviation, skewness and kurtosis values of the variables. Discussion to the meaning of these values is as below.

Table 4.1: Descriptive Statistics

	AV__HUM	AV__RNF	AV__TEMP	CARB	INP__PRC	IRRIG	POP
Mean	37.71355	78.33339	21.68544	8.997504	7.813405	5.207009	31.78824
Median	43.31389	75.72479	22.16317	8.983225	6.553122	5.413034	30.50000
Maximum	53.19444	103.7531	23.13773	9.567079	11.09893	9.439044	46.60000
Minimum	7.351852	57.66354	19.21529	8.180579	4.600000	1.303999	19.80000
Std. Dev.	13.25944	10.95690	1.140734	0.327012	2.427142	2.443591	7.786732
Skewness	-0.877907	0.471457	-0.799639	-0.197588	0.060190	-0.019830	0.225947
Kurtosis	2.582571	2.931564	2.287540	2.628202	1.240788	2.148843	1.980048
Observation	34	34	34	34	34	34	34

Source: Computation by the Author

Mean annual average rainfall has the highest mean of 78.33 mm with maximum and minimum values of 103.75 mm and 57.66 mm as compared to other variables respectively over the period of study. Average annual relative humidity followed closely with a mean value of 37.71 mm with maximum and minimum of 53.19 mm and 7.351 mm and temperature with the least mean value of 21.69 mm with maximum value of 23.14 and minimum value of 19.22 mm. On standard deviation which measures dispersion from the mean value. Average relative humidity has the largest dispersion from the mean value of 13.26 followed closely by average annual rainfall with 10.96 and temperature is the least with 1.141. On skewness of the variables, average relative humidity and average annual temperature are skewed to the left while average annual rainfall is skewed to right meaning the data is evenly distributed. On kurtosis which measures the peakedness of the data, average annual rainfall has the highest kurtosis of 2.9. The study can generally conclude that the variables are normally distributed since the values are near the allowed kurtosis value of 3.0.

4.3 Time Series Analysis Results

The following time series tests were carried out to ensure that spurious results are not obtained. The time series properties are discussed as follows.

4.3.1 Unit Root Test

The unit root test was carried out to ensure that all variables used in the study are stationary prior to any subsequent analysis, this was necessary to avoid any spurious results that are associated with non-stationary data. Augmented Dickey Fuller (ADF) was used to carry out the test on both dependent and independent variables as shown in the table 4.2.

Table 4.2: Unit Root Test

Variables	Type of test	Form of test	Test Statistic	Critical values at 5per cent	Remarks
Crop Productivity (1st difference)	ADF	C-Level	-9.2732	-2.9571	Stationary
		C&T-Level	-9.1165	-3.5578	
Livestock productivity (1st difference)	ADF	C-Level	-5.8708	-2.9571	Stationary
		C&T-Level	-5.7768	-3.5578	
Average Temperature (1st difference)	ADF	C-Level	-4.7810	-2.9571	Stationary
		C&T-Level	-5.2396	-3.5578	
Average Rainfall (Level)	ADF	C-Level	-5.2651	-2.9604	Stationary
		C&T-Level	-5.1180	-3.5629	
Average Rel. Humidity (1st Difference)	ADF	C-Level	-4.9935	-2.9571	Stationary
		C&T-Level	-6.1173	-3.5629	
Average Temp (1st Difference)	ADF	C-Level	-4.7810	-3.9571	Stationary
		C&T-Level	-5.2396	-3.5578	
Carbon dioxide (1st Difference)	ADF	C-Level	-7.3001	-2.9571	Stationary
		C&T-Level	-7.2755	-3.5578	
Input Prices (1st Difference)	ADF	C-Level	-5.6497	-2.9571	Stationary
		C&T-Level	-5.5550	-3.5578	
Irrigation (1st Difference)	ADF	C-Level	-7.8988	-2.9571	Stationary
		C&T-Level	-7.7704	-3.5578	
Population (1st Difference)	ADF	C-Level	-5.4755	-2.9571	Stationary
		C&T-Level	-6.0437	-3.5578	

Source: computation from Author

Table 4.2 above shows the results of unit root test carried out using ADF. The tests were carried out at both intercept and at intercept with trend. The results of the unit root test at level were found to be greater than the critical value at 5per cent level of significance, Mackinnon (1999) for the rejection of the null hypothesis that the variables do not have unit root except average rainfall which was stationary at level with the decision rule we do not reject the null hypothesis (Baharumshah, Laws and Azman-saini, 2010).

The ADF test was employed again at both intercept and intercept with trend at first difference. The computed test statistics values were compared with critical value at 5per cent level of significance and were found to be greater hence the decision is that we do not reject the null hypothesis at this level of significance. Since temperature and relative humidity have a unit root test at level and at first difference, then, the null hypothesis was reject and the conclusion was that they were stationary at first difference (Baharumshah, Laws and Azman-saini, 2010).

The results derived from table 4.2 shows that both temperature and relative humidity except rainfall were stationary at first difference implying that there could be a stochastic trend in the series therefore; there was a need to carry out a diagnostic test to evaluate the long-run relationship among the variables.

4.3.2 Correlation Test

Correlation analysis test was carried out. Table 4.3 shows the results of the test. The test was necessary to show the presence of correlation between the explanatory variables (Farrar and Glauber,1967).

Table 4.3: Correlation Analysis Results

	AV__TEMP1	AV__HUM1	AV__RNF1	CO21	INP__PRC1	IRRIG1	POP1
AV__TEMP1	1.0000						
AV__HUM1	0.811185	1.0000					
AV__RNF1	0.287673	0.212126	1.0000				
CO21	0.383462	0.540513	-0.127163	1.0000			
INP__PRC1	0.053483	-0.068789	0.008254	0.249981	1.0000		
IRRIG1	0.138451	-0.069703	0.027865	0.115560	0.825358	1.0000	
POP1	-0.006507	-0.172068	-0.023677	0.159122	0.754944	0.816779	1.0000

Source: Author's computation

The findings are shown in table 4.3. From the analysis it could be seen that average rainfall, average temperature, relative humidity, Carbone dioxide, input prices, irrigation activities and population were found to be not highly correlated to any other independent variable in the study since the coefficient of the correlation was less than or equals 0.8.

In this scenario all the predictor variables which were highly correlated were used in the two regressions and therefore did not show any form of singular matrix problem, Kasimba (2014) and Kabubo. *et, al.,* (2015).

4.3.3 Co-integration Tests Results

Co-integration test was carried out to ensure that no long-run relationship among the independent variables of the study. Johansen Co-integration states if there are n variable, then, co-integrating variables should be n-1 as shown in table 4.4.

Table 4.4: Co-integration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesid No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.956039	398.4671	228.2979	0.0001
At most 1 *	0.951665	298.4849	187.4701	0.0000
At most 2 *	0.818203	201.5377	150.5585	0.0000
At most 3 *	0.752326	146.9819	117.7082	0.0002
At most 4 *	0.674814	102.3214	88.80380	0.0038
At most 5 *	0.538473	66.37388	63.87610	0.0304
At most 6	0.492699	41.63104	42.91525	0.0669
At most 7	0.375845	19.91424	25.87211	0.2303
At most 8	0.140120	4.830810	12.51798	0.6208

Trace test indicates 6 cointegrating eqn(s) at the 0.05 level

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Source: Computation from the Author

From the test in table 4.4 there were six co-integrating equations obtained from seven explanatory variables at 5 per cent level of significant. The decision rule state that the co-integrating equations should be less than the number of variable used in the study by one (1) otherwise no co-integration. The study has seven (7) variables with six (6) co-integrating equations, therefore, the study concluded that there was co-integration among the variables

4.4: Diagnostic Test Results

Diagnostic tests were carried out to ensure that the model used for the study was statistically fit for the analysis. The diagnostic tests carried out were autocorrelation, histogram-normality test, Ramsey Reset test and heteroskedasticity test.

4.4.1: Serial Correlation LM Test

Serial correlation LM test was shown in table 4.5

Table 4.5: Serial Correlation LM Test (Equation 3.3)

F-statistic	2.185224	Prob. F(2,24)	0.1343
Obs*R-squared	5.237677	Prob. Chi-Square(2)	0.0729

Source: Author's Computations

Serial correlation was tested so that the error terms are independent from each other in the series. This was necessary to ensure that the estimator biasness is not achieved as it would affect the model reliability. From the results and according to Breusch-Godfrey LM Test, the computed F-statistics of 2.19 with a probability of 0.13 which is greater than 5 per cent significant level states that do not reject the null hypothesis that there is no serial correlation among the variables. Considering the Obs* R-squared of 5.238 with a p-value of 0.0729 hence do not reject the null hypothesis that there is no serial correlation among the variables at 5 per cent statistically significance level.

Table 4.6: Serial Correlation Test (Equation 3.4)

F-statistic	0.593253	Prob. F(2,24)	0.5604
Obs*R-squared	1.601699	Prob. Chi-Square(2)	0.4489

Source: computation from the Author

The F-statistics of 0.5932 with a probability of 0.5604 and Obs* R-squared of 1.602 with probability of 0.4489 are both greater than 5 percent level of significance. The conclusion is that do not reject the null hypothesis. The study made an overall conclusion that the errors in the two equations were serially independent.

4.4.2: Heteroskedasticity Test-ARCH

The study carried out heteroskedasticity test to test whether the error term had a constant variance in the model. Table 4.7and table 4.8 shows the results of the test

Table 4.7: Heteroskedasticity Test (Equation 3.3)

F-statistic	0.359233	Prob. F(1,31)	0.5533
Obs*R-squared	0.378029	Prob. Chi-Square(1)	0.5387

Source: Computation from the Author

Table 4.8: Heteroskedasticity Test (Equation 3.4)

F-statistic	0.077812	Prob. F(1,31)	0.7821
Obs*R-squared	0.082625	Prob. Chi-Square(1)	0.7738

Source: Computation from the Author

The results in both table 4.7 and 4.8 had F-statistics of 0.36 with probability of 0.55 and 0.078 with probability of 0.78. The probabilities computed were greater than the critical value of 0.05 indicating that the null hypothesis that there was constant variance in the residual at 5 per cent could not be rejected. Computed Chi-Squares for the two equations were 0.54 and 0.77 which were greater than the tabulated of 0.05 hence accepting the null hypothesis. Implying that the residual values were homoscedasticity across the period. The study therefore, concluded that the errors terms in the model were homoscedastic.

4.4.3 Ramsey RESET Test

Ramsey RESET test was carried out to ensure no variable was omitted during analysis. It shows whether non-linear values explain any response in the dependent variable and if they have any power in explaining the change in the dependent variable, if so then the model is mis-specified. The results are shown in table 4.9 and 4.10

Table 4.9: Ramsey RESET Test (Equation 3.3)

F-statistic	26.29635	(1, 25)	0.0657
Likelihood ratio	24.43729	1	0.0573

Source: Computation from the Author

Table 4.10: Ramsey RESET Test (Equation 3.4)

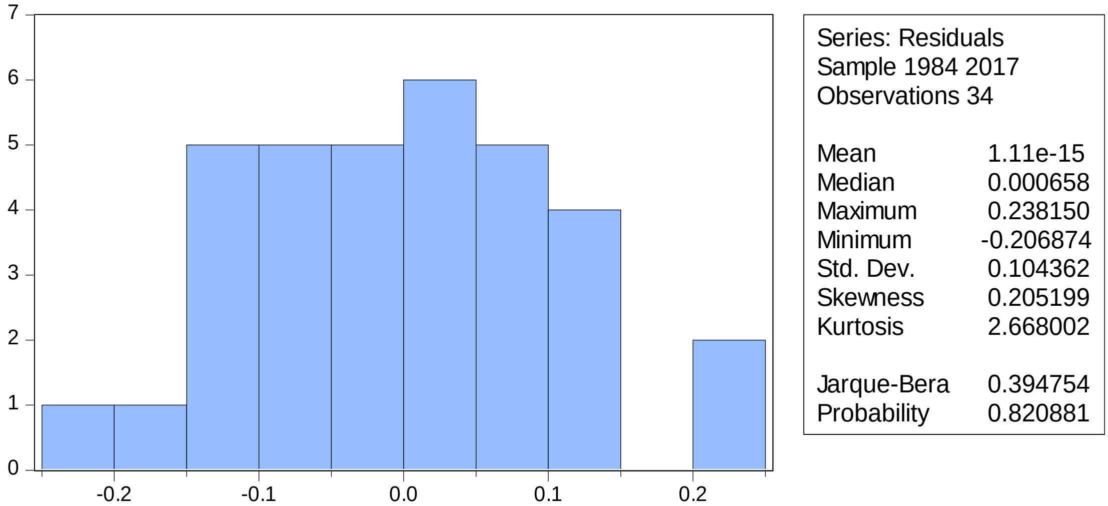
F-statistic	3.453134	(1, 25)	0.0749
Likelihood ratio	4.399004	1	0.0560

Source: Computation from the Author

From the table 4.9 and 4.10 above, the F-statistics were 0.067 and 0.074 which were greater than 0.05 hence the decision was that do not reject the null hypothesis that the values fitted were all zero. From the results, the study made a conclusion that the model was correctly specified and was stable.

4.4.4: Histogram-Normality Test

Histogram-normality test was carried out to ensure that the residual values were normally distributed in the model. Figure 4.1 below shows the result for the test.



Source: Computation from the Author

Figure 4.1: Histogram-Normality Test

From figure 4.1 above, Jarque-Bera statistics of 0.39 with a probability of 0.82 is greater than 0.05 level of significant. This means that the residual values were normally distributed and that the hypothesis that the residual were normally distributed was accepted at 5 per cent statistically significance level. The study therefore, made a conclusion that the model assures unbiased results since the residuals were normally distributed.

4.5. Regression Analysis Findings

The main objective of the study was to determine the effect of climate change on agricultural productivity in Kenya. The objective was achieved by first determining the effect of climate change on crop productivity and then evaluated the effect of climate change on livestock productivity for a period 1984-2017. The study adopted time series data with Ordinary Least Square (OLS) Model since the time series data had exhibited stationary at level and at first difference. Lagged variables were included to capture variability in productivity caused by extreme climatic change. Objective one and two of the study were achieved as discussed below.

4.5.1 Effect of Climate Change on Crop production

To achieve objective one equation 3.3 was regressed. The results are shown in Table 4.11

Table 4.11: Regression Analysis Results (Equation 3.3)

Depend Variable: Average Annual Crop Production (Tonnes)				
Independent variable	**Coefficient**	**Std. Error**	**t-Statistics**	**Prob.**
Constant	16.76279	3.506793	4.780091	0.0001
Average Temp.	-0.334511	0.115072	-2.906957	0.0074
Average Rainfall	-0.011023	0.00694	-1.588268	0.1243
Rel. Humidity	0.042064	0.011033	3.812453	0.0008
Carbon dioxide	-0.343812	0.289243	-1.188662	0.2453
Input Prices	0.15588	0.121867	1.279105	0.2122
Irrigation Population	0.233798 0.045464	0.091648 0.056141	2.551027 0.809817	0.017 0.4254
Adjusted R-Squared	0.896936			
R-Squared	0.918798	**F-Statistics**		42.02711
Durbin-Watson Statistics	2.080741	**Probability (F-statistics)**		0.000000

Source: Computation from the Author

The F value of 42.02711 with a p-value of 0.0000 indicate that the sampled data statistically important for the study. Results from the regression analysis shows significance effect of independent variable on dependent variable (crop production) and therefore, the null hypothesis is rejected. The value of Durbin-Watson of 2.080741 showed non-serial autocorrelation. Analysis the equation 3.3 shows that the value of R^2 statistics was 91.88 per cent. This implies that both dependent and explanatory variables of the model are good as shown by adjusted R^2 statistics of 89.69 per cent. About 89.69 per cent of the changes in dependent variable (average annual crop production) is explained by changes in climatic variables while the remaining 10.31 per cent are explained by the error term(ε)

The table 4.11 shows that in the absence of climatic changes, crop production would still be realized. At 5 per cent level of significance; relative humidity, average temperature and irrigation variables explained changes in average annual crop production. Relative humidity (0.042064) and irrigation (0.233798) all with positive signs shows that high humidity and increased area under irrigation results to increased crop yield Kang *et al*,.(2009). This is because changes in climate have effect on availability of atmospheric water and soil water due to high rate of evaporation being experienced having effect on soil water hence decreased crop yield. Temperature coefficient (-0.334511) had negative sign indicates changes in temperature level have a negative effect on crop production, this is because global warming will increase temperature level and reduce amount of rainfall hence affecting soil moisture level influencing crop water which negatively affect crop production Kang *et al*,.(2009) and Adams *et al*,. (1998); implying that there is a positive relationship between relative humidity and crop yield.

The results also show that relative humidity with a positive coefficient sign of 0.042064 with corresponding probability of 0.0008 means that 1 per cent change in humidity results to about 4.2 per cent increase in crop yield; this implies that relative humidity has significant effect on crop production. The findings are in line with those found (Kasimba, 2012) and (Luedeling, 2011).

In future, continued increase in temperature and fluctuating relative humidity, water availability would decrease hence crop production would also be expected to decrease. This calls for increase in irrigation acreage to ensure crop production is maintained to feed the ever increasing population (Kang *et al*,.2009).

4.5.2 Effect of Climate Change on Livestock Production

The effect of climate change on livestock production was determined by carrying out multi-regression of equation 3.4 as show in table 4.12

Table 4.12: Regression Analysis results-2

Depend Variable: Livestock Production				
Idependent variable	**Coefficient**	**Std. Error**	**t-Statistics**	**Prob.**
Constant	6.76279	1.506793	4.780091	0.0001
Average Temp.	-0.334511	0.115072	-2.906957	0.0374
Average Rainfall	-0.011023	0.00694	-1.588268	0.1243
Rel. Humidity	0.002064	0.011033	3.812453	0.0408
Carbon dioxide	-0.343812	0.289243	-1.188662	0.2453
Input Prices	0.15588	0.121867	1.279105	0.2122
Irrigation	0.233798	0.091648	2.551027	0.017
Population	0.045464	0.056141	0.809817	0.4254
Adjusted R-Squared	0.766936			
R-Squared	0.778798	**F-Statistics**		472.2536
Durbin-Watson Statistics	2.210761	**Probability (F-statistics)**		0.000000

Source: Computation from the Author

Climate change has been a degenerating effect to livestock production in terms of milk, meat, and other milk products. The government of has since formulated policies to combat the effect of climate change on livestock production. The second objective was therefore, to investigate the effect of climate change on livestock production in Kenya.

The results indicate that the coefficient of the constant term (6.76279) is positive showing that livestock production would be realized whether there is a change in climatic conditions or not. The coefficient of relative humidity of 0.002064 is positive with a probability of 0.0408 is 5 per cent statistically significant. On the other hand coefficient of average temperature is -0.334511 is also statistically significant at 5 per cent but negatively related to livestock production (Kabubo *et al.*, 2015).

The goodness fit of the model was measured using the adjusted R square. The value of adjusted R squared was found to be 0.766936 this shows that the model was good and fit to be used in the analysis of the effect of climate change on agricultural productivity. This can be explained that the productivity of agriculture is 76.69 per cent determined by the changes in climatic conditions. The p value of the F statistics in table 4.4 is 0.00000 and is significant and Durbin Watson is 2.210761 showing non-serial correlation among the variables (Baumgard *et al.*, 2012).

The p value of the average temperature was 0.0374 is significant at 5 per cent level, this means that livestock products like milk is sensitive to thermal stress when temperature exceeds the internationally recognized temperature humidity index (THI) of 72, therefore leading to reduction in milk production Baumgard *et al.*, (2012). The constant coefficient term of temperature (-0.334511) is negative indicating temperature is negatively related to livestock production, this means that as temperature increases , livestock production is expected to decrease and vice versa (Bozzola e*t al.*, 2014).

4.5.3 Effect of other variable on agricultural productivity in Kenya

The study also analyzed the effect of other variable on agricultural productivity in Kenya. According to the regression results in both cases, irrigation with a constant term of 0.233798 is positive and significance at 5 per with cent p value of 0.0170, this shows that irrigation has a positive effect on agricultural productivity. This means that 1 per cent change in irrigation cause 23.38 per cent increase in agricultural productivity. The finding is in agreement with the findings by Lee, De Goyze and Six (2009). This is because per acreage land irrigated, soil water would increase likewise to crop water and also livestock would have fresh and nutritious grass and nippier grass to feed on thereby increase production in overall agriculture.

The study also evaluated the effect of carbon dioxide on agricultural productivity. Carbon dioxide was found to have a negative but insignificant effect on agricultural productivity with a coefficient of -0.343812 and probability of 0.2453. Input price was found to be insignificance but had a positive relationship with agricultural productivity with a coefficient of 0.155880 and a probability of 0.2122. The result was expected to have a negative relationship and significance at 5 per cent level (Nkonde, 2014).

CHAPTER FIVE

SUMMARY, CONCLUSION AND POLICY RECOMMENDATION

5.1 Introduction

The chapter comprise of the summary, conclusion, policy recommendation and areas for further studies.

5.2 Summary of the study

The study evaluated the effect of climate change on agricultural productivity in Kenya for a period 1984-2017. Kenya continues to strive to achieve food security as enshrined in sustainable development goals of 2015. The study presented an empirical result which provided the effect of climate change on agricultural productivity yielding a negative result for both crop and livestock production. The first objective of the study was to determine the effect of climate change on agricultural crop production and the second objective was to investigate the effect of climate change on livestock production in Kenya. The results of the first objective show that crop production is negatively affected by changes in climatic conditions, the same results were obtained by the second objective. Diagnostic tests were carried out at 5 per cent where rainfall was found to be stationary at level while temperature, relative humidity, log crop production and log of livestock production were stationary at first difference. Intuitively, the findings reviled that moderate level of temperature and rainfall would results to increase in crop and livestock production.

The objectives of the paper were met by carrying out regression analysis. The regression results for both the objectives yielded a negative relationship between the dependent and independent variables, leading to the conclusion that adverse climatic changes affect crop and livestock negatively in Kenya.

5.3 Conclusion of the study

The first objective of the study was to determine the effect of climate change on agricultural crop productivity. To achieve this objective a unit root and diagnostic tests of all the variables on time series data for the period running from 1984-2017 was conducted. Multiple regression analysis was carried out using Ordinary Least Square (OLS) Model on the four key variables; crop production and/or livestock production, relative humidity, average temperature, average rainfall. The results from the analysis showed that coefficient of relative humidity and average temperature were of the expected sign and their p values showed that they were of significant for the study. Relative humidity have positive coefficient to agricultural productivity while average temperature have a negative coefficient. Rainfall had a negative coefficient showing that adverse changes in rainfall amount a decrease in crop and livestock production. This means therefore, that changes in temperature, rainfall and humidity greatly affect crop productivity in Kenya.

The second objective of the study is to evaluate the effect of climate change on livestock productivity. Table 4.12 in chapter 4 shows results of the regression analysis to achieve this objective. Even though relative humidity and average temperature are still significant, average temperature has more effect on livestock production than relative humidity because temperature causes decrease in livestock production in terms of reproduction, lactation and meat quality. At a given point in time the country has experienced drought and this point to a changing climate pattern. Livestock production is normally under threat to this ever changing climate pattern in Kenya. This is because the natural grass that the livestock heavily rely for feed drying up and quality and quantity fluctuates every year.

In addition to this available water sources are drying up and therefore not available due to high temperature and unreliable rainfall experienced in Kenya over the years. In North and North-Eastern parts of Kenya, a number of livestock have been lost as a result of excessive thermal stress, inadequate rainfall, insufficient natural and artificial feeds and a number of diseases due to high temperatures. From this it is now clear that livestock production is very sensitive to climatic changes in Kenya and therefore the study concludes that climate change has effect on livestock production. The study has satisfactorily achieved the two specific objectives; therefore, the study concludes that indeed climate change has effect on agricultural productivity in Kenya.

5.4 Policy Recommendation.

The main objective of this study was to determine the effect of climate change on agricultural productivity in Kenya. The study found out that climate change affect agricultural productivity.

From the findings the following recommendations are made; the government needs to carry out sensitization program awareness on cause, impact, mitigation and adaptation to climate change. Given that the findings shows that temperature is significant in the study, therefore, drought tolerant livestock and crop varieties need to be given to farmers at a subsidized price to resist effect of climate change and also encourage scientific research on crop and livestock varieties that adapt to climate change to boost yield in agriculture to achieve objective one and two of the study.

The government should also encourage smart agriculture where farmers do not rely on rain feed agriculture but on scientific agriculture in order to achieve objective two of the study. For this to succeed, the government should supply farmers with drought resistant seeds and livestock variety to increase production and maintain food security in Kenya as this is one the key pillars of four agenda of Jubilee government since the results show that climate change affect agricultural productivity hence mitigation, adaptation and resilience agriculture would increase crop and livestock production in Kenya hence ensuring food security.

5.5 Areas for further studies

The study suggests some of the most promising areas for future studies. First it would be of great important to carry out innovation research on those crops which are drought resistant to mitigate the effect of climate change on yield and also areas in which the crops thrive well to ensure farmers of good future harvest. The same should be carried out on livestock by carrying cross breeding to ensure that the species that farmers rare are drought tolerant.

The study also gives room for regional future research so that the government can implement the project in that specific region for the benefit of the citizen. The study also recommends future studies be done on the effect of irrigation on agricultural productivity.

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Appendix A

Appendix A1: Data used for the study

YEARS	Log of Crop Production	Log of Livestock Production	Average Temp	Average rainfall	Rel. Humidity	Input price	CO2	POP	IRRIG
1984	9.5	7.8	19.9	74.2	22.6	4.6	8.6	19.8	1.5
1985	9.3	7.7	20.2	74.7	23.9	4.8	8.7	20.1	1.5
1986	9.7	8.1	20.0	74.5	23.4	4.8	8.5	20.9	1.4
1987	9.4	8.2	20.1	74.9	21.7	4.9	8.6	21.6	1.3
1988	9.6	8.5	20.4	64.6	33.5	5.0	8.8	22.4	1.3
1989	7.3	8.5	22.4	95.3	29.2	5.0	8.8	23.4	1.7
1990	9.7	8.7	21.8	88.5	30.9	5.2	8.9	24.0	3.6
1991	9.8	8.8	22.2	81.8	41.7	5.4	9.1	24.8	3.0
1992	9.9	8.8	22.5	74.6	42.1	5.5	9.0	25.7	3.7
1993	10.5	9.0	22.3	73.8	40.3	5.8	9.2	26.0	4.0
1994	10.7	9.2	22.2	65.9	45.3	6.1	9.2	26.8	4.7
1995	10.8	9.4	22.0	87.0	49.6	6.0	9.3	27.5	4.7
1996	10.8	9.5	22.5	78.3	51.1	6.1	9.1	28.3	4.7
1997	10.9	9.5	22.1	74.4	46.5	6.3	9.0	29.5	6.3
1998	11.2	9.6	22.6	103.6	50.8	6.4	9.0	28.8	6.2
1999	11.0	9.6	22.2	86.8	53.2	6.4	8.8	29.5	5.3
2000	11.1	9.5	22.0	73.8	43.9	6.5	8.9	30.2	5.5
2001	11.1	9.7	22.7	57.7	46.3	6.7	9.1	30.8	5.6
2002	11.0	9.8	22.6	82.5	51.6	9.6	9.2	32.2	6.7
2003	11.4	9.9	22.5	90.0	46.6	9.6	9.2	33.2	4.1
2004	11.5	9.9	22.1	76.5	47.1	9.7	9.2	34.2	4.1
2005	11.6	10.1	21.0	71.0	46.2	9.8	9.4	35.1	4.6
2006	11.7	10.2	21.1	66.0	48.2	9.7	9.4	36.1	5.5
2007	11.9	10.3	22.3	103.8	52.9	9.8	9.4	35.8	6.1
2008	11.9	10.6	22.6	80.9	46.9	10.2	9.5	36.7	6.0
2009	11.9	10.7	22.6	67.9	43.6	10.4	9.5	37.7	6.0
2010	12.2	10.9	23.1	65.6	43.1	10.4	9.6	38.5	7.9
2011	12.4	11.3	23.0	90.1	43.6	10.4	8.2	39.5	7.8
2012	12.5	11.4	23.0	80.4	37.7	10.5	8.7	40.7	9.0
2013	12.4	11.5	21.8	86.6	32.5	10.6	8.7	41.8	7.1
2014	12.4	11.4	21.0	79.8	17.2	10.8	8.8	43.0	9.3
2015	12.5	11.5	19.8	69.8	11.8	10.9	8.8	44.2	9.4
2016	12.6	11.7	19.2	85.4	10.0	11.0	8.9	45.4	8.7
2017	12.6	11.8	19.4	62.5	7.4	11.1	8.9	46.6	8.7