IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

By

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DECLARATION

This is my original work and has not been presented for a degree or award in at any other University

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Declaration by

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This project report has been submitted for examination with my approval as the University supervisor

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DEDICATION

Dedicated to my parents, Mr. John Mati and Mrs. Linah Mati for their encouragement and moral support.

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ABSTRACT

Climate variability threatens agriculture at local and global scales. Resilience to climate variability impacts calls for adequate preparedness among affected populations. Farmers who rely primarily on rain-fed agriculture appear to be more relatively prone to the accumulated effects of climate variability. The effects are relatively more pronounced in developing world. Rice is a crop of major concern since it is generally one of the most cultivated and consumed cereal crops in Africa and specifically in Kenya. Its productivity is on the decline for factors largely attributable to climate variability. Rice is primarily an irrigated crop. In Kenya, river volumes supplying irrigation water are rapidly dwindling and are no longer able to sustain rice farming as in the past. This study was set to investigate impacts of climate variability on rice farming in Mwea area of Kirinyaga County. The study looked into the area in particular 1990 and 2019 and evaluated effects of the variability on rice production in the same period. It also set out to assess climate variability adaptation strategies employed by rice farmers. To obtain primary data, 144 households were randomly selected from all the rice farmers in the area and the sample was assigned questionnaires. The households were given questionnaires with closed and open-ended items on the specified variables. Further, field observations were made and data recorded in observation sheets and photographs. Other forms of data were obtained from secondary sources including Kenya Meteorological Department, electronic repositories and farmer association offices. Data for each variable and combination of variables were statically analyzed $p \leq 0.05$) using "R" software and the results displayed in graphs, tables and pie charts. April recorded the highest mean rainfall of 242.8 mm. Conversely, the mean temperature of the research area over the period was found to be 28.36^0C. The highest maximal mean temperature of 29.94ºC was recorded in 2019 while highest minimal mean temperature of 19.30ºC was recorded in 2011. The results showed that there was a positive ($r = .3152$) significant ($p < 0.01$) between rainfall and the rice production (in tonnes) per hectare/year. The p-value at 0.39 shows a correlation coefficient of +0.16 between rice production and temperature. After a 30 years' time series weather trend analysis, there was a high variation trend in annual rainfall and temperatures averages. The year 1992 was the wettest year while 1999 was found to be the driest year. From the findings, correlation between quantities of rice produced and weather variables showed that rice is adversely affected by increased temperatures and so reduced rice yields. Climate variability adaptation strategies employed by rice farmers in Mwea, indicated that majority (64%) apply chemical fertilizer to fasten the growth rate in the face of limited rain water, 22% of them do early planting while minority (12%) of the respondents prefer use of weeds and pest control. This research concluded that temperature increases with less rainfall reduced rice yields. The study recommended that there is need for the government, through the National Irrigation Authority (NIA), to construct a high-capacity central water storage reservoir upstream, more canals around all rice fields and establish dams for harvesting and storage of rainwater. Also, farmers need to get introduced to drip irrigation techniques and establish Kenyan rice- based farming systems and System of Rice Intensification (SRI) for responding to climate variability effects.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASALs	Arid and Semi-Arid Lands
ARDA	Africa Rice Development Association
CDM	Clean Development Mechanism
CGIAR	Consortium of International Agricultural Research Centers
ENSO	El Nino – Southern Oscillation
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GRiSP	Global Rice Science Partnership
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
KARI	Kenya Agricultural Research Institute
KARLO	Kenya Agricultural & Livestock Research Organization
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
MIAD	Mwea Irrigation and Agricultural Development
MIS	Mwea Irrigation scheme
MRGM	Mwea Rice Growers Multipurpose C-operative Society
MOALFI	Ministry of Agriculture, Livestock, Fisheries and Irrigation
NACOSTI	National Commission for Science, Technology and Innovation
NCPB	National Cereals and Produce Board
NDMA	National Drought Management Authority
NERICA	New Rice for Africa
NGOs	Non-governmental organizations
NIA	National Irrigation Authority
NRDS	National Rice Development Strategy

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Climate variability universally acceptable description is a contentious subject among the climate experts and environmentalists globally. Nevertheless, Inter-governmental Panel for Climate Change (IPCC) as well as majority of the most renowned academicians define it as the mean variations and other statistical deviations due to climate extremes in spatial temporal scale that is beyond specific weather event (Mendelsohn, 2012). Chao, (2014) observes that climate variability effects could hasten over time, whereas growth in harvests of main grains such as rice is seemingly slowing. The implication of this is that annual total yield growths that appears to be greater than damages attributed to climate change are a past phenomenon. At the same time, it is anticipated that there would be an upsurge in losses due to climate variability. For instance, China's potential to grow rice in her drier regions of the nation would be hindered, thus destructively affecting global rice production.

Excessive use of nitrogenous fertilizers increases Greenhouse Gases (GHGs) in the atmosphere. Water shortage, constantly increasing temperatures, and over accumulation of Carbon (IV) oxide in the atmosphere makes rice farming less climate-friendly as a result of changing atmospheric situation (Pittock, 2017). Climate variability has been realized to be a major perplexing international occurrence of major concern currently through scientific findings such as people are exceedingly most probable cause of the prevailing climate change. Charles Keeling of the Mauna Loa observatory in Waimea, Hawaii, revealed a substantial indication of swiftly rising CO_2 intensities thorough quantification of atmospheric CO_2, thus generating the Keeling curve (Howe, 2015). This accumulation of CO_2 in the atmosphere has been linked to global warming, thus raising the observed annual average temperature. This effect has directly affected rice farming. Today's climate change scientists are aware of politically motivated plans such as that of the *Global Environmental Change;* Human dimensions on the Sahel of West Africa (Alemaw, 2015).

Recently, very crucial research by Lobell *et al.* (2011) highlighted that the level of production in the last thirty years point out that rice yield levels have improved near the poles whereas some noticeable reduction in production levels have been realized in hotter zones such as Mwea, near the equator. This phenomenon has been attributed with temperature changes more than rainfall. They also noted that more indirect climate variability effects such as above average precipitation occasions and extremely hot days, are habitually ignored in most scientific analyses, thus bringing about an underestimation of climate variability effects.

While focusing on climate change and rice production, Wassmann *et al* (2021), explains how rise in temperatures would affect rice farming due to slow changes, such as alterations in water accessibility, and can possibly lead to crop sterility if temperatures surpass a certain threshold. Rice production in Africa during dry-season would particularly be endangered by the increasing temperatures. One of the leading effects of climate variability is its impacts on human health, food security and global impairment of development through calamities. It is paramount to achieve global food security sustainably putting in to consideration mitigation of environmental impacts (FAO, 2015). In the third world countries, food security is a leading challenge. Kenya is one of these countries hit hard by climate variability especially in its agricultural sector. It's crucial to harness this evolving global occurrence by practicing sustainable rice farming methods as well as employing acceptable adaptation strategies (Ngare, 2017).

Consequently, an urgent reaction is necessary to mitigate the waning rice production and curb the tenacious problems farmers' experience in rice farming especially in Mwea Irrigation Scheme (MIS). Research on the repercussions of climate variability to plant health and production is necessary to address this developing matter among the rice farmers. Climate change adaptation and mitigation concept has been disseminated to the masses of late. This follows climate scientists as well as the IPCC's prediction that the average global temperature may rise by 4°C by the year 2100, and under such a condition, agricultural mitigation measures will not work among farmers, except if the said measures happen to be broadly recognized by all the people from all nations (Dupar, 2020).

Under the said apprehensions, climate experts will be compelled to figure out most likely scenarios on which policy making will be based in globally (Feliciano, 2019). Still, farmers and decision makers in developing nations are also being exhilarated to embrace climate change adaptation with time, because they find it difficult to fully mitigate climate change effects due to a number of socio-economic and other established inadequacies (Devkota 2018). According to the (Dupar, 2020) "The effects of these changing conditions on agriculture are obvious, but considerable gaps exist in our knowledge of how agricultural systems can be affected by both short- and long-term changes in climate and what implications these changes will have for rural livelihoods, particularly among the most vulnerable. For some regions and crops, opportunities for increased production exist, but, for most, there is simply not enough information available regarding impacts at scales that are relevant to decision making and research prioritization, and this has an adverse effect on the global net agricultural production."

Adapting to the changing climate in agriculture, alongside rice farming, has been flawed by primeval age approaches. Therefore, lack of suitable modern adaptation practices founded on the principles of a changing climate and weather variability remains to be a great challenge in most of the developing countries such as Kenya (Mathew, 2019). Agricultural scientists have been developing genetically modified crop varieties that can withstand erratic climates, such as tolerance to drought and coldness. However, the undertaking has proved to require enormous financial resources and very engaging extensive research thus being likely beyond their adaptive potential (Mustafa, 2019). For instance, adaptation to rice farming in Kenya can go through numerous developmental changes that can either reduce damage or increase benefits that can be obtained from climate variability (Kariuki, 2016). These effective adaptive measures are very helpful in maximizing the resultant gains.

1.2 Problem Statement

Rice farming has been a renowned source of living among the people of Mwea in Kirinyaga County. Most residents in Mwea (approximately 7,022 households) practice rice farming for income generation and subsistence (MRGM, 2020). On the other hand, rice production has been declining as a result of unfavorable effects of climate variability (Stuecker, 2018). Rice farming in Mwea is vulnerable to the said effects of climate variability. The rice response to temperature highly relies on its growth stage (Lizumi, 2010). However, sometimes in the course of the year, temperatures surpass 31^0 C leading to a significant reduction in productivity by approximately up to 10% since the rice growth temperature threshold is exceeded (Lizumi, 2010).

Projected rice production is hampered by such collective climate variations impacts on temperature and rainfall. Climate variability is projected to seasonally hinder rice production by altering rainfall and temperature pattern and intensity (Kantar, 2018). This means that there is need for conducting an instantaneous study to investigate how climate variability is impacting rice farming.

There is no much literature done regarding how climate variability is affecting rice farming as well as analyses of the available various climate variability coping options in Africa, including Kenya. To achieve this, the researcher picked a case study for Mwea west sub - county in Kirinyaga County, central Kenya since this has left a knowledge gap in the assessment of the effects of climate variability to rice farming in the region as well as climate variability coping strategies available and being adopted by the rice farmers in the process of rice production in Mwea.

Therefore, the main aim of this study was to address this research gap by carrying out research on the effects that the changing climate has had to rice farming in the region as well as investigating the coping strategies for the rice farmers; contributing factors and farmers' perceptions and hurdles to these climate variability coping strategy options. The next area discusses the objective of the study, research question, hypotheses and significance of the study as well as the conceptual framework.

1.3 General Objective

The general objective for the study was to investigate the impacts of climate variability on rice production in Mwea, Kirinyaga County.

1.4 Specific Objectives

1. To examine rainfall and temperature variation trend in Mwea, Kirinyaga County from 1990 to 2019.
2. To evaluate the effect of climate variability on rice production in Mwea, Kirinyaga County.
3. To determine the climate variability coping strategies employed by rice farmers in Mwea, Kirinyaga County.

1.5 Research Questions

1. How did rainfall and temperature vary in Mwea, Kirinyaga County from 1990 to 2019?
2. How does climate variability affect rice production in Mwea, Kirinyaga County?
3. What are climate variability coping strategies used by rice farmers in Mwea, Kirinyaga County?

1.6 Hypotheses of the Study

1. H_a Mwea has experienced variation in Temperature and Rainfall between 1990 and 2019.
2. H_a Climate variability negatively affects famers' rice production levels in Mwea.
3. H_a Rice farmers in Mwea, Kirinyaga County, are coping to climate variability.

1.7 Significance of the Study

Global climate variability impacts in agriculture cannot be assumed because they have augmented choking of crop yields in Kenya. This research will be important to the future climate change researchers in regard to enlightening science and decision making in rice farming. Therefore, it will add knowledge to this area of study. It will enable rice farmers understand the effects of climate variability on their productivity. It will also greatly influence the policy makers when making decision in regard to addressing effect of climate variability to rice farming.

1.8 Definition of Terms

Climate Change- refers to a change in the state of the climate that can be identified by changes in the mean and in the variability of precipitation and temperature that persists for an extended period—typically decades or longer (IPCC, 2007).

Climate variability- aberrations in magnitude and distribution from the normal climate data especially for temperature and precipitation of a given place for a prolonged period (IPCC, 2007).

Climate variability awareness- publicizing climate related information by educating the general populace in a community that is susceptible to climate - related disasters (Elia, 2017).

Climate variability perception- this refers to the way rice farmers' view climate variability effects in regards to rice farming as their means of survival (Nyang'au, 2014).

Impacts- these are the effects of climate change and variability on rice farming and rice farmers' wellbeing (Matata, 2018)

Adaptation- Farmers' modification to their rice farming practice in the face of a changing climate so as to minimize its devastating effects to rice production (Brooks, 2005).

Food Security- refers to a situation where all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Huho, 2010).

Vulnerability- this is the extent to which a given process is susceptible to adversarial impacts of climate variability (Brooks, 2005).

Weather- refers to the prevailing daily atmospheric condition and its short-term variations such as temperature, rainfall, cloud cover, humidity or wind direction and intensity (Hanemann, 2012).

1.9 Conceptual Framework

Figure 1.1 is an illustration of interaction of the variables in the study area. The independent variables that were used to control the research outcome were climate variability's main indicator elements which are rainfall and temperature. Adaptation and mitigation strategies employed by the farmers, their financial capital and land size were the intervening variables since they determine the productivity of the rice paddies, thus affecting the yield obtained from a given land size. Rice quantity as a dependent variable reflected the finishing point for the conceptual framework of the research survey. The Intervening variables acted as the facilitators to dependent variables which relied on independent variables. The leading climate indicators, temperature and rainfall variations as independent variables had a direct impact on the quantity of rice harvested which depended on it. The result of altering the intervening variables is change in rice yields.

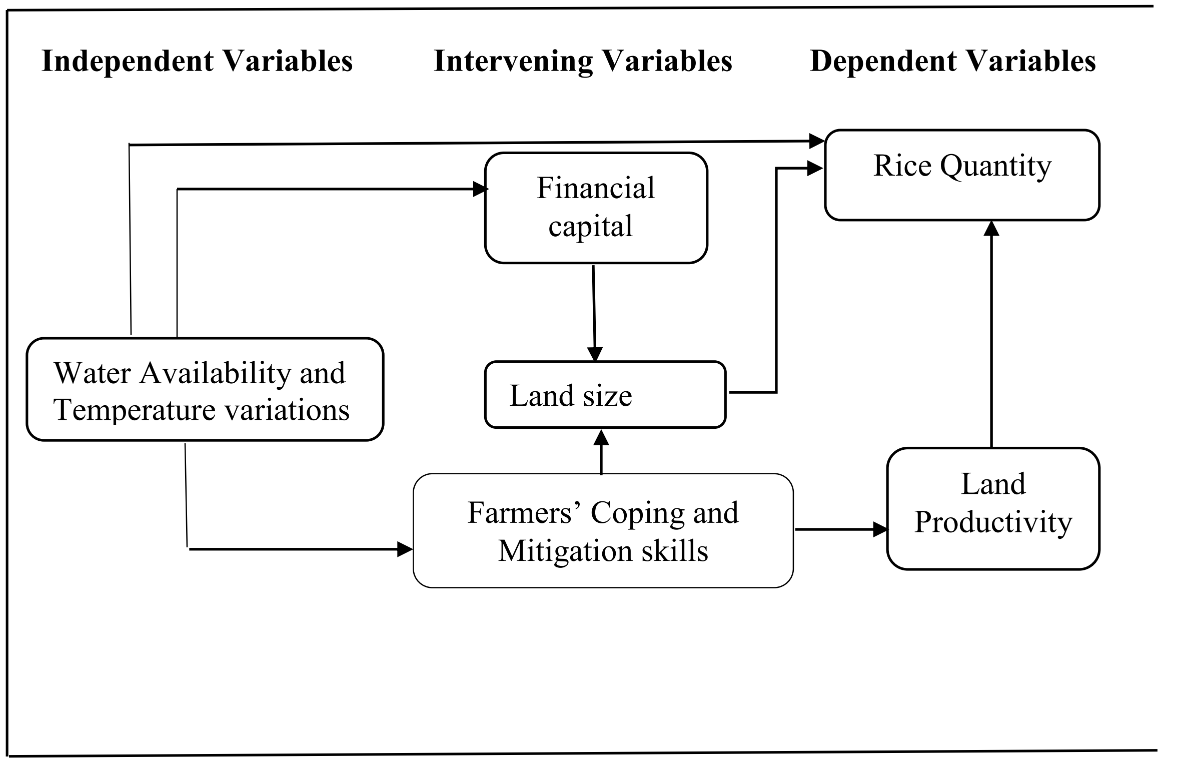

Figure 1.1: Conceptual Framework. Adapted from Ngare (2017)

CHAPTER TWO: LITERATURE REVIEW

2.0 Preview

Impacts of climate variability are causing massive destruction to the ecosystems that support fauna and flora globally (Ngare, 2017). Intergovernmental Panel for Climate Change (2012) predicted that acute variation in meteorological conditions will persist worldwide as we will experience more climate extremes. Higher temperatures, particularly frequency in extremely hot days along with unpredictable rainfall pattern are considered to be the leading climate variables distressing agriculture in Africa (Pereira, 2017).

According to the IPCC (2012), the weather patterns are most likely to change in the foreseeable future. Many areas in the globe will experience intense heat or extreme cold because of intensified climate variability. The rainfall pattern will also be affected in many parts of the world. For example, some areas will experience flash floods and more snow fall while others will face acute drought leading to loss of vegetation and life. Natural calamities caused by climate change such as hunger, heat waves leading to forest fires, flooding and drought will be rampant (Busby, 2018).

2.1 Climate Variability Trends and Impacts on Agricultural Production

Climate variability related impacts are projected to have a higher magnitude in Africa because it has highest abundance of under developed countries globally (Matata and Adan, 2018). Most African agricultural projects are more susceptible to climate variability because of over reliance on rainfall and poorly developed irrigation systems. A vast majority of farmers in Africa practice small scale farming. This subject them to acute financial constraints, lack of access to relevant information as well as inadequate access to good quality infrastructure (Pereira, 2017).

Food insecurity is highly affected by unfavorable weather events of extreme value such as high temperatures, floods and unreliable rainfall intensity and distribution in Africa (Ngare, 2017). As a result, most people in the continent are most likely to be subjected to poverty since their countries' economies over-relies on agriculture. The flooding of rice paddies is likely to increase the disease prevalence in humans, crops as well as in livestock. Although irrigation fed agriculture increases the yield, it can also lead to biodiversity destruction and wane the subsidiary ecological service (Said, 2017).

Most climate scientists are in agreement that the leading driver of climate change is global warming (Bongaarts, 2018). From the start of the twentieth century the rate of change in the global climate has happened quicker than any other climate recorded in history (Molua, 2002). The main outstanding features of climate variability are drought and flooding (IPCC, 2007). Since the industrial revolution in the late eighteenth-century global warming has significantly amplified the quantity of greenhouse gases in the atmosphere. Consequently, the mean global superficial temperature has risen by 0.85°C between 1880 and 2012 thus altering the precipitation patterns all over the world (Stocker *et al.,* 2013). As a result, IPCC (2012) highlighted that the northern hemisphere snow caps have been decreasing as well as increasing heat waves towards the end of the 20th century. There is also extensive shrinking of mountain glacier in the tropics and sea levels have been rising because of climate variability. It has been also noted by the IPPC (2007) that there is higher prevalence of climate variability as illustrated by extreme weather events such as flooding episodes, prolonged drought. There is also an observed increase in intensity and frequency of tsunami and storms in the recent past all being associated with climate change (IPCC, 2007). These climate variability vagaries are attributed to both natural process (bio geographical) and due to human activities (anthropogenic) (IPCC, 2007; Odjugo, 2009). Furthermore, the IPCC observes that global warming is undisputable and it is mainly being triggered by human activities.

It is predicted that in the near future, anthropogenic climate variability may cause theatrical alterations on earth, which are likely to have detrimental effects on ecosystems, human settlements, water and agricultural production all of which are necessary for life support on earth (IPCC 2007; O'Brien *et al.,* 2007 and Mearns & Norton, 2010). These changes will possibly have extensive repercussions to many individuals and communities at large.

2.1.1 Impact of Climate Variability on Global Agriculture

Effects of climate variability on the Agricultural sector are expected to include; crop failure, reduction in Gross Domestic Product (GDP) from agriculture, Global food market price instability, hunger and starvation and conflicts (Khanal, 2009). Soil physical and chemical properties are likely to be affected by the rising global average temperature. It can also increase the rate at which CO2 is released, thus reducing the optimum condition for plants to grow (Rahman, 2017). Crops are adversely affected by rising temperature beyond the optimum value for a biological process leading to a decline in resultant growth rate and yield. High temperatures distress the entire biological growth and maturing of plants thus hampering their final yield (Khanal, 2009 and Rosegrant *et al.,* 2008). Food crops are predominantly affected by climate variability since crop yields are highly influenced by the climatic conditions of the area especially temperature and rainfall (Palatnik & Roson, 2009).

Agriculture is one of the economic sectors with highest vulnerability to climate change. This is because long term variations in rainfall and temperature besides higher magnitude and frequency of life-threatening weather events and their strong impacts are being observed in agriculture. These effects can be beneficial or harmful depending on the altitude and latitude of a place and the type of crop grown (Devkota, 2018). Tubiello & Rosenzweig (2008) states that a slight increase in temperature in the first half of the 21st century may be beneficial to crops hence boost their yields in the traditionally colder zones.

However, a contrasting outcome of reduction in crop yields in the tropics and the semi-arid lands will be witnessed. Further warming that is projected towards the end of the century will possibly decrease crop yields all over the world (Hertel *et al.,* 2010). As a result of the rising temperatures, it is expected that rainfall will become so unpredictable and we will experience a variety of extreme climate events such as droughts, floods, tsunamis, rising sea levels, storms and cyclones before the end of the 21st century (Fischer, 2002). These vagaries are likely to impact crop farming and agricultural yield negatively (Dupar, 2020). Guiteras (2007) Short-term weather patterns are appropriate for prediction of medium and long-term impacts of the climate and can be relied up on to advise farmers to realize their potential and adapt fast. It is necessary for the farmers to adapt successfully against such damages although instant adaptation may be challenging in developing countries due to limited access to information and capital.

2.1.2 Climate Variability Effect on Rice Production

Rainfall and temperature are the leading Climate variability factors that tend to determine agricultural productivity particularly where recurrent droughts are so prevalent (Bhargava, 2018). For example, rice paddies need continuous supply of water that floods the land regularly in its entire growth period. This means that there must be sufficient rainfall all the time or otherwise irrigation to be performed often to ensure that the soil retain the necessary water magnitude. Rice production is critically subjective to the prevailing weather when it is a rain-fed plantation crop. Thus, the temperature and rainfall variations trend have been well-known to be the major significant climate factors that influence its productivity (Stuecker *et al.,* 2018). A study by Devkota (2018), found that about 80.7 percent of the Nepalese rice farmers' perception is that there is climate variation in temperature and 90 percent believed that rainfall distribution has changed and its intensity declined.

Temperature and rainfall variations may particularly affect the production process of rice because of its over reliance on a lot of water as opposed to many other food crops. Seasonal changes in rainfall intensity and distribution, leading to lack of sufficient irrigation water, is one of the leading challenges faced by rice farmers (Rahman, 2017). Thus, climate variability has influenced rice farming in most rice growing areas of the world. This challenge has driven many agricultural experts to look for a lasting solution through research recently.

Ochieng (2016), observed that rapid population growth and socio-economic strains are making rice farmers engage in practices that are not climate resilient. These activities hamper their yields as well as the overall projected rice production. Research has proven that the prevailing global warming has significantly diminished agricultural production, including reduction in rice yield per hectare (Shakoor, 2015). Agricultural production heavily relies on the climate of the region and it is one of the most dynamic economic drivers in countries that are still developing economically. Climate variability hinders agricultural productivity of any nation all over the world, thus reducing farmers' income (Ochieng, 2016).

Shakoor (2015) observed that there is demonstrated proof linking the prevailing global warming to significant reduction in agricultural productivity, including but not limited to rice growing. Ngare (2017) adds that, climate variability impacts have had a devastating effect on agriculture in Kenya thus leading to a sharp decline in observed yields. According to Cooper (2016), specific and suitable policies for every particular place are necessary to boost rice farmers' adaptation and mitigation efforts in combating the impacts of climate variability. It is important to increase the uptake of sustainable and climate smart modern agricultural practices among rice farmers since very few have embraced it (Westermann *et al.,* 2018). Therefore, all rice farmers should fully benefit from practicing climate resilient farm practices to increase the productivity of their land.

2.1.3 Climate Variability and Food Prices

Farming and crop production are highly vulnerable to extreme weather events that tend to impair food production process, its storage as well as delivery systems. For example, Edelstein (2018), observed that between the year 2006 and 2008, the world average prices increased by 136%, 125% and 107% for wheat, corn and soybeans respectively. Food and Agriculture Organization (FAO, 2015) says that rice is the main food item consumed in some areas of the world particularly in the Middle East nations such as India, Philippines and Thailand. This means that, rice feeds almost half of the world population. Climate change and variability is a major factor that is leading to global increase in food prices and food insecurity due to diminishing productivity (Manyeruke, 2013).

The International Food Policy Research Institute (IFPRI) report on Climate Change: Impact on Agriculture and Costs of Adaptation forecasts that by 2050 rice prices will increase between 32 and 37% as a result of climate change. They also show that rice productivity will reduce by 14% in South Asia, 10% in East Asia and the Pacific, and 15% in Sub-Saharan Africa (FAO, 2015).

2.2 Global Impacts of Climate Variability on Rice Production

It is possible that some regions may experience favorable impacts on rice production due to Climate change (Stuecker, 2018). For instance, an increase in average global temperature may lead to more rice production as a result of improved photosynthesis in the traditionally northern colder regions such as China (Chao, 2014). It may also enable growing of two rice crops per annum in such areas where up to date, they have only one planting season per year. However, the net effect of climate change impacts and the overall impact of climate change on rice are likely to be negative (Van Oort, 2018).

It has been observed that climate indicators such as temperature and rainfall are fundamental factors in determination of crop growth thus influencing agricultural output (Hanemann, 2012). It is predicted that climate variability is likely to affect crop farming and livestock keeping, the key essentials of agricultural schemes and their source and ecological balances (Darwin, 2005). According to FAO report of 2015, evolving variations in rainfall intensity and distribution as well as rising temperatures are likely to affect rice production globally especially around the tropics. Satterthwaite (2010) also observed that the economies for most third world countries heavily rely on agriculture since most of their people live in rural areas. It is in this regard that frequent cases of acute drought or unreliable rainfall will be very harmful to rural population where most of the people live. Sustainable water management and plant nutrient maintenance will be essential in ensuring optimum benefits (Venot, 2010).

2.2.1 Water scarcity

Rice farming needs plenty of water to grow. When rainfall fails during a week in higher land rice-producing regions as well as in lowland rice-growing areas, for roughly two weeks, rice yields can be a considerable reduction. Reduction in average yield in rain-fed, in serious drought years, the percentage of drought-prone regions has risen to 17 to 40 percent, thus resulting in a food shortage as well as production losses (Alemaw, 2015). As a result of the start of climate change, the frequency and intensity of droughts, usually forecasted to rise in rain-fed rice-growing regions and droughts may spread further into irrigated regions when water is scarce (Said *et al.,* 2017). Lack of water affect about twenty-three million hectares of rain-fed Southeast and South Asia rice-producing regions (Bhargava, 2018). Drought has affected approximately 80 percent of Africa's potential 20 million hectares of rain-fed lowland rice. Lack of water also been found to have an impact on rice production in developed countries such as Australia, China and even the USA (Mukamuhirwa *et al.,* 2019).

2.2.2 Pests, diseases, and weeds

During the past decades, surveys have been conducted in hundreds of fields for farmers has shown, climate change has a significant impact on rice illnesses and pests. Lack of water, irregularity patterns of rainfall, as well as other few diseases, such as blast and brown spot become more severe as a result of these water stressors (Trebicki & Finlay, 2019). In addition, Changes in manufacturing processes and new conditions of environment that are adopted by farmers must deal with the issues of climate change and that could lead to reducing of diseases and pests like cutworms and whorl maggot as well as sheath blight (Alemaw & Simalenga, 2015).Others like weed infestation as well as rice-weed competition have been predicted to have increased and would present a major challenge such as that of rice production that is sustainable in Asia (Trebicki & Finlay, 2019).

2.2.3 Increased temperatures

Higher temperatures can lead to decreased yields of rice since they can contribute to sterility of flowers of rice, thus leading to lack of production of grains (Lizumi & Okada, 2011). High losses of respiration are connected to high temperatures and in most cases makes rice less productive as well (Shakoor, 2015).

Different predictions for elevated temperature, humidity changes, and the yields of rice forecasting is difficult due to the interconnections of these factors in the future challenging (Stuecker *et al.,* 2018). Study by IRRI points out that yield of rice forecasting is difficult due to the interconnections of these factors to carbon dioxide production. The study concludes that this may lead to rice yields reduction by about 10% (Chao *et al.,* 2014)

2.2.4 Climate Variability Challenge for Rice Production

Climate variability has global and potential grave challenge for production of rice and so global food security. Systems of land-use in most of the developing countries are vulnerable to issues of climate change and yet they have very little capacity to cope with such consequences. Rice farming conditions for will deteriorate in many areas, through shortages of water, thermal stress, low water quality, floods, sea-level rise, and more intense tropical cyclones. A study by IFPRI (2014) predicts that a fifteen percent decrease in irrigated rice yields in developing countries and a 12% increase in prices of rice due to climate change by 2050 (Matty *et al.,* 2014).

Continents such as Africa are expecting to be more prone to very serious weather patterns arising from climate change, more surprisingly, about more than half of the rice growth in regions like Asian, its yields over the last few decades has been coming from 'delta countries', like Bangladesh and Vietnam as well as the country's which are most prone to sea-level rise as well as extremes of climates (Agrawala *et al.,* 2003). Most of the unique services of ecosystem especially in wetland rice producing areas are currently under threat due the increasing lack of water (Stuecker *et al.,* 2018). The negative impacts that climate variability would have on rice production may end up playing a main role for determination of food security in great parts of the globe. This is especially in some regions such as Asia, where rice itself is the staple food for most of both rural as well as urban poor (Bhargava, 2018). In most cases, negative impacts on produce and rice availability may directly lead to translation of major shortages of food (Manyeruke *et al.,* 2013). Consequently, rice farming is a widespread system of farming in most of the environments that are considered to be 'hot spots' of impacts of climate change. This will lead to effects of domestic rice marketing as well as trade internationally (Mustafa *et al.,* 2019).

Additionally, rice is grown in rain-fed lowland areas that are vulnerable to both floods and drought. In these regions, risks of production would increase under serious climatic extremes. Rice produce will be negatively affected by this higher night-time temperatures (a decline of 10 percent for every 10.00C temperature increase) as well (Lizumi & Okada, 2011).

Alternately, rice production could be a good source of greenhouse gas such as methane due to paddies flooding (Wassmann and Sander, 2021). Like other cropping systems, rice fields emit nitrous oxide as a result of soil and fertilizer nitrogen. Flooded rice areas can also have a large amount of soil carbon that can be produced as CO2 especially in cases of rice paddies which are converted to upland cropping systems (Devkota, 2018). In collaboration with other Consortium of International Agricultural Research Centers (CGIAR) research initiatives, the effects of climate change, as well as possible adaptation and mitigation techniques, will be investigated (Alemaw & Simalenga, 2015)

2.3 Adapting and Mitigation of Climate Variability Effects in Africa

Research by Bongaarts, and O'Neill (2018), has recommended to policy makers to employ adaptation and mitigation approaches in handling climate change menace and reducing its associated effects. It is very crucial for the affected populations and the people most vulnerable to climate variability related impacts to adopt imperative measures immediately. Enactment of each place's precise and most suitable adaptation approaches is necessary in boosting rice farmers' mitigation of climate change impacts (Cooper, 2016).

Climate of a place determines the choice of crop to grow as well as whether to use irrigation, depending on the availability of sufficient water (Alemaw & Simalenga, 2015). In Africa, animal husbandry, choice of irrigation, type of crop to plant and crop switching are some of the commonest coping mechanisms to climate change used by most farmers. Adaptive capacity refers to the ability of a system to acclimatize to the changing environment that empowers such a system to get used to longer term changes over a longer period (Smit & Wandel, 2006). IPCC (2007) defines adaptive capacity, in relation to climate change impacts, as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences". Therefore, adaptation capacity is naturally dynamic and is subjective to many other factors. It is the capacity to deal with unprecedented conditions devoid of losing future (Adger *et al.,* 2007).

Factors affecting adaptive capacity consist of availability of financial capital, economic and natural resources, human resources, information networks, governance, technology, entitlements, and the implementing institutions (Adger *et al.,* 2007). The adaptive capacity to climate variability for the agricultural sector is influenced by a number of factors such as poverty and hunger, the rate of population growth, availability of arable-land and water resources, agricultural extension services, farming technology and access to farm inputs, crop varieties that are used to local environmental conditions, access to information, infrastructure, marketing and storage systems, rural financial markets and economic status of the farmer (Fischer *et al.,* 2002).

Additionally, the adaptive capacity of a system depends on the capability of the local community (Brooks & Adger, 2005). It might decrease with the population growth or scarcity of resources while it escalates when the area develops economically, embraces new emerging technology, improves its participating institutions or improvement of access to finance. Furthermore, when the farmers have a strong bonding and united network, it can raise adaptive capacity through conflicts resolution mechanisms among its members as well as cooperation in addressing climate variability challenges. (Smit & Wandel, 2006; Brooks & Adger, 2005; Pelling & High, 2005). Thus, farmers who adapt better to climate variability or changes in the agricultural systems can face the changing climate confidently and easily deal with it (Smit & Wandel, 2006). Many rice farmers in Mwea are managing the effects of climate variability independently to diminish present stress (Narita *et al.,* 2020). One of the major factors determining the adaptive capacity of a community or the individual farmers is their control over physical, natural, social, financial and human resources (Narita *et al.,* 2020). Generally, poorest people in the world tend to have inadequate access to living resources that enable adaptation. Poor people also lack insurance against income losses (Smit & Pilifosova, 2006; Heltberg *et al.,* 2009).

Ability to access and take control over such limited resources differs from one community to another in a country or even within households (Agrawala *et al.,* 2003). Generally, ability to adapt to climate variability is less in developing countries than in developed nations. Furthermore, the economy in most of the developing countries, particularly in Africa, is agriculture driven, thus making them to be more vulnerable to changing climate and increasing their need for adaptation (Adger *et al.,* 2007). High population growth and poverty coupled with acute degradation of agricultural land are key issues in such countries. These major issues explain why the developing countries lacks capacity to for handling any major crisis associated with the changing climate (Watson *et al.,* 2012). There is a high possibility that adapting Agriculture to climate change would have multiplier effect on other sectors that supports a country's economy (Ottinger *et al.,* 2014). It is also believed that systems that have managed to handle historic cases before or prevailing strains are very much likely to possess high adaptive capacity for pressure related to climate variability (Watson *et al.,* 2012).

The effective climate variability coping strategies in maximizing the resultant benefits though embracing new technology entirely rests on the individual farmer's capacity (Mendelsohn, 2012). For rice farmers, the coping options that one opts for are determined mainly by the financial status of the farmer since poor farmers may not select some of the existing options that are too expensive to implement (Mendelsohn, 2012). It is a collective postulation in the climate variability adaptation literature that wealthier rice farmers tend to have a better access to capital and technology to choose from unlike farmers who are financially stressed. The richer ones thus have more alternatives to enable them in adapting hence they are capable of adapting with ease.

Therefore, rice farmers are supposed to have a paradigm shift and start growing climate resilient rice varieties which don't require a lot of water to cultivate. Furthermore, they ought to change to fast maturing hybrid rice varieties which can easily tolerate climate variability inclination (Zwart, 2017). Other measures being undertaken by rice farmers to minimize the devastating climate change effects on rice farming include harvesting and storing water for irrigation as a substitute to depending on rain-fed farming coupled with responsible use of nitrogenous organic fertilizers so as to hasten the rate of growth (Khatri-Chhetri *et al.,* 2016).

In most cases, climate variability adaptations and mitigation measures and concur when it comes to coping with climate variability impacts. From the study by IPCC (2007), these usually help in improving or alleviating the negative or rather the adverse effects in natural environment. It also involves practicing various actions in trying to manage many risks emanating from climate change and its extreme conditions, giving protection to local communities as well as strengthening the economic resilience (Devkota, 2018).

Consequently, enhanced adaptation information and awareness concerning emerging adaptation choices ought to be well known (Kariuki, 2016). It is noticeable not all adaptation strategies may be beneficial to rice farmers, but then again knowledge on whether rice farmers possess some relevant qualities, such as schooling and familiarity to the concept of climate variability can inspire them to adopt better coping and mitigation strategies. A number of determining features tend to help a lot in coping to climate variability, and the decision by rice farmers on whether to embrace modern technology rely on where the adaptation takes place (Handmer, 2012).

According to Chiueh (2013), estimating the cost of agricultural adaptation to climate variability was began in the late 1990s, although the main objective is basically to enhance understanding of climate variability and not to investigate the costs of adaptation per se. It is paramount to study also the climate change costs on agriculture in order to get the bigger picture. The cost of adaptation to climate change is described as the projected price of evading climate damage in the forthcoming days restricted on some future socioeconomic susceptibility state (Lizumi, 2011). Climate variability coping cost means the total expenditure incurred in scheduling, preparing for, facilitation and implementation of adaptation strategies as well as transitional expenses.

On the other hand, the coping benefits refer to the evaded destruction costs or the accumulated returns that arise from the implementation of adaptation and mitigation measures (Maarten, 2016). These benefits emerge from the successful implementation of the adaptation measures.

Climate variability coping in rice farming involves behavioral adaptation, changes in rice paddy management practices, adopting new technological innovations and compliance to new policy reforms. These adaptation practices tend to be beneficial to the farmer in a number of ways such as increased productivity (rice yield), better capability to uphold diversified farm assets, efficient use of limited resources such as water and less stress on land (rice paddies) (Devkota, 2018). Adaptation is intrinsically a localized challenge as opposed to mitigation which has to be handled from a global perspective.

The mitigation helps farmers across their international boundaries and/or over a larger region even though the costs of implementation of the mitigation measures are not shared across the borders. This implies that adaptation measures are native whereas the accrued costs are a responsibility of the private sector and the participating native government even though the benefits are felt over a larger area (Hanemann *et al.,* 2012). Therefore, when an individual rice farmer adapts his/her own farm to climate variability, it helps the farmer since the benefits are localized whereby the neighboring local farmers also benefits. In order for adaptation to succeed, a procedure of communal, established, and structural education and change ought to be carried out preferably within a wide-ranging and interactive context. Cost and benefit assessment of the possible adaptation decisions is a fundamentally integral undertaking in the entire process (UNFCCC, 2010).

Many populations and especially in Africa depend on agriculture as their main source of income and food and they have come up with ways of coping with climate variability and variability (Alemaw & Simalenga, 2015). For instance, food crop diversification and income sources diversification like livestock keeping, irrigating crops, construction of water dams, soil and water conservation, rainwater harvesting among others (Manyeruke *et al.,* 2013).

2.4 Rice Farming in Kenya

Cultivation of rice was started in Kenya near Kibwezi and Makindu in Makueni County between the year 1901 and 1905 (MOALFI, 2008). This happened during the development of the infamous railway line from Mombasa, Kenya to Uganda by the colonial government.

Data from the Ministry of Agriculture Livestock, Fisheries and Irrigation (MOALFI) show that rice is the third most planted and consumed food crop in Kenya closely following maize and wheat (Atera *et al.,* 2018). Therefore, it is among the three top most grown cereals in the country. According to MRGM report of2020, Basmati 370, locally known as Pishori and the International rice (IR 2793) are the most commonly grown varieties in Mwea region of Kenya (MRGM, 2020) (Plate 4.1).

However, rice farmers in Migori, Kuria, Tana Delta, and Msambweni also grow these varieties mainly in small scale for subsistence. Nevertheless, the extra produce is locally traded to create revenue for the farmers. A study by Makihara (2018) indicates that about 81% of rice farmers in Kenya plant rice on irrigation schemes which are developed and controlled by the government. The four major irrigation schemes developed by the government of Kenya to supply rice are; Mwea, Bunyala, Ahero and Kano.

Plate 4.1: Basmati 370 (Pishori) rice in a paddy in Mwea

Most of the irrigated rice in Kenya (more than 60%) is grown at the Mwea irrigation scheme (MIS) in Kirinyaga county, central Kenya (Mathew *et al.,* 2019). Very little rice (approximately 30%) of the total yield is cultivated purely under rainfall (Nderitu, 2010).

The Kenya National Rice Development Strategy (NRDS), 2008-2018, found out that some shortcomings of the rice farmers prevent their adoption of contemporary climate resilient agricultural practices (Narita *et al.,* 2020). Some of these shortcomings are; level of education of the individual farmers, the rice farm size, big family size, rice paddy management practices, farmer's experience and capability of the rice farmer to embrace contemporary farming practices,

2.4.1 Rice Consumption Levels in Kenya

According to the MOALFI (2008) report, rice is consumed more in urban centers than in rural communities hence it is a staple food for most of the population living in towns. In the course of the year 2007, consumption of rice in major towns was higher than other popular cereals taken in the towns. For instance, maize had a 4% rise in consumption rate whereas wheat had 1%. On the other hand, rice consumption had increased by 10% (Atera *et al.,* 2018). The most usually consumed rice types were Basmati 370 (Pishori) and pure aromatic. These rice varieties are locally grown and packed in the expansive government-controlled irrigation schemes in Mwea, Bunyala, and Ahero (Alemaw & Simalenga, 2015))

This rapid growth in rate of consumption of rice in Kenya may be accredited to significant reduction in feeding on maize and wheat products by many people. The total annual national rice demand is projected to be approximately 450,000 tonnes against supply capacity range of between 120,000 to 160,000 tonnes (KNBS, 2019). The discrepancy gap is filled by importing the commodity mainly from Asia. For instance, in 2016, quantity of rice imported in Kenya grew to a high of 261,819 tonnes. The ratio of rice imports to population was lowest in 1974 (Atera, 2018). Adaptation to climate change related whims that hamper production of rice by practicing climate resilient agriculture and according the necessary support to rice farmers will enhance their income, promote self- reliance and the general wellbeing of the people living in rice growing regions in Kenya.

2.5 Impacts of Climate Variability on Rice Production in Kenya

Compound climate variability forms have been witnessed in Kenya whereby extreme rainfall was experienced during El Nino between 1997 and 1998. The driest incident was realized during the La Nina period between 1999 and 2000 (Huho & Mugalavai, 2010).

Since 1960s, the country has been experiencing rising average temperatures by about 0.12oC per decade with variations in both maximum and minimum temperatures generally increasing over time (Kariuki, 2016). Some of the most collective challenges faced by the rice farmers in Kenya related to climate variability include insufficient irrigation water in the dry season, over flooding of rice paddies during rainfall season, high pests, which are resistant to pesticides, and disease incidence, and low soil fertility forcing majority of them to over-rely on fertilizers (Kariuki, 2016).

Study has revealed that when maximum and minimum average temperatures increase, it negatively impacts on Basmati 370 and IR 2793-80-1 rice quantity harvested under System of Rice Intensification (SRI) model. (Nyang'au, 2014). The research carried out by Nyang'au concluded that average rainfall and temperature in Kenya have a direct impact on rice yield under SRI hence ought to be well-thought-out in order to increase the country's food security. Average annual maximum rainfall has been noticed to be declining in Kenya for highest rainfall amount witnessed during the long rain season since 1960s (Kariuki, 2016).

2.6 Amplified Climatic Variability Risks to Rice Farming

According to Zwart (2017), the major rice farming limiting climate factor is rainfall and not carbon dioxide. This means that rain-fed rice does not derive great benefits from carbon dioxide application. FAO (2015), noted that climate variability has somehow altered the normal rice production. This is in addition to other challenges affecting rice production such as water scarcity, suitability of land and soil resources. For instance, Zwart (2017) argues that rainfall amount of about 800mm and more as well as its distribution along the year are factors that are observed to have a greater influence on rain-fed rice production. In addition, inadequate soil moisture leads to death of rice in some cases especially in areas that receive about 200mm of rainfall in some days and fail to receive any for about twenty days. Moreover, if rice production experiences prolonged drought at one point of their growing stages, there can be a total failure of rice production (Mukamuhirwa *et al.,* 2019).

However, Venot *et al.* (20I0), point out that in some instances, lack of enough soil moisture may not be necessarily be caused by climate variability, but also by conflicts that are very common between upstream and downstream water users. In this case, there can be a complete rice production failure. For instance, as a result of uncoordinated water management by upstream water users in South Indian Krishna Basin, it was revealed that downstream water users especially rice farmers were becoming prone to water supply stress. These findings were supported by that of Cook *et al.* (2009), who revealed that almost a similar scenario. In their studies, they found out that expansive irrigation developments deny those other potential downstream water users from utilizing the same resource.

According to Darwin *et al.* (2005), approximately, almost all lands classified as "primary land class" for rice production in tropics may show rice yield reduction in the following century. This is mainly due to climate variability as well as related conditions such as global warming. This can lead to prolonged droughts that would result to soil moisture stress.

Report by Speranza (2010), in other instances, countries such as Kenya came up with Climate Change Institutions and Policy Since 1992. This was mainly formulated by the Kenyan government to provide policies as well as created a number of institutions and committees so that they are able to address climate variability and its related conditions. During this time, they were able to identify the most affected sectors, and they included among them the sector of agriculture and water. Having done that, the full Action Plan implementation was desired to address various challenges faced by farmers' particularly small-scale rice farmers as a result climate variability.

In Kenya, the quantity of rice harvested from irrigation schemes tends to increase when carbon dioxide fertilization is employed. This is because the country experience optimal temperatures especially during the planting season. However, through reduced precipitation, climate variability has greatly reduced the available water for flooding the rice paddies. This has significantly reduced the rice production level as observed in Mwea in the year 2016 (Atera, 2018). The year recorded very low amount of rainfall in Mwea.

This caused rivers Thiba and Nyamindi which provides irrigation water in Mwea to dry up, hence very little rice was harvested that year.

2.7 Effort for Addressing Climate Variability

According to IPCC (2007), efforts for addressing climate variability seem to be the most challenging thing facing majority of population in recent years. In this case therefore, international interventions are greatly taking place in dealing with such impact and causes. This is especially, with respect to agricultural production. For instance, International Rice Research Institute working together with other relevant researchers such as Africa Rice Development Association (ARDA) is in the process of developing a variety of rice that could be suitable to different climatic conditions (Mathew *et al.,* 2019). Such varieties include "New Rice for Africa" (NERICA) which was developed by Africa Rice Development Association. This kind of rice variety is mainly cutting across Asian as well as African rice varieties. It is also showing better adaptation to most of climatic stresses like drought and poor soil inputs especially in Africa.

From the study by Hossain (2004), it is clear that some of the technologies are underway in trying to raise farm productivity as well as efficiency use of farm inputs especially in irrigation systems. This hence contributes to more rice production increase. In addition, this new rice plant type would be expected to increase production by about 25 percent (Rahman, 2017). Nyamai *et al.* (2012), argues that in countries such as Kenya, production of rice is usually involved with huge farm inputs like fertilizer, water, seed, as well as labour. This therefore makes it a very expensive activity for most of small-scale farmers. Rice is one of the widely consumed foods in the world. Many scholars have interests on doing research on rice farming. It is from this point of view that in 2004 United Nation General Assembly declared an International Year of Rice (Hossain, 2004).

2.8 Knowledge Gaps

This literature review has shown possible climate variability impacts on rice farming, and its consequential repercussion to the rice farmers' income. Therefore, the susceptibility to climate variability impact on rice quantity yielded demands for a thorough study to address the issue. Currently, farmers are very susceptible to effects of climatic threats to agriculture thus necessitating rapid adoption of mitigation and coping strategies to improve productivity.

However, from the reviews, there is still an urgent need to carry out rigorous research to redress the vulnerability effect of climate variability on rice farming. This will improve food security and reduce the skyrocketing global price of the commodity. Since there are different ways of coping to climate variability depending on farmer's knowledge and financial capability, it is fundamental to study how rice farmers in Mwea cope to climate variability.

Finally, the extent to which rice yield is affected by climate variability is another gap that need to be addressed. In conclusion, the review of scholarly work has shown how climate variability has impacted on rice farming hence necessitating need for a study to find out its impacts on rice growing in Mwea.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Study Area

This research was carried out in Mwea West sub-county, Kirinyaga County. The sub-county has four wards, which are; Mutithi, Kangai, Thiba and Wamumu as shown on figure 3.1. The study focused on Mutithi and Thiba wards due to their accessibility and higher intensity of rice plantations. According to the 2019 housing and population census, Mwea West total population was found to be approximately 104,828 people with an estimated 34,720 households KNBS (2019). The sub- County covers an area of approximately 239 km^2. The area is densely populated with a population density of 438 persons per km^2 (KNBS, 2019). The sub-county is very much recognized for its massive stretches of rice plantations and thus it is no doubt the leading rice producing area in Kenya. The region is also a major exporter of superior quality *Basmati 370* rice in the continent. The elevation of Mwea is 1,188m above sea level (Mathew, 2019). The area predominantly has black cotton soil which makes it favorable for rice farming. However, on some areas where rice is not planted, there is red soil. Most of the trees have been cut down to pave way for rice plantation, thus during off season when the crop has been harvested, the land is left almost bear, save for a little grass. That notwithstanding, there are exotic trees to provide shelter in the clustered homesteads.

The GPS coordinates of the area of study are within the latitude 37°13' E and 37°30'E and longitude 0°32'S and 0°46'S. The main commercial activity for the local population in Mwea is agriculture with rice being the most dominant grown crop. Households in the area are clustered together to pave way for the vast rice fields which have no human settlement due to their flooding nature. The climate of the place is mainly hot and wet with a mean annual temperature of 26.5°C. On the other hand, the average annual rainfall is 807mm (Narita *et al.,* 2020). Nevertheless, with the occurrence of climate variability, there is observed variation from the aforementioned annual means for different years recently.

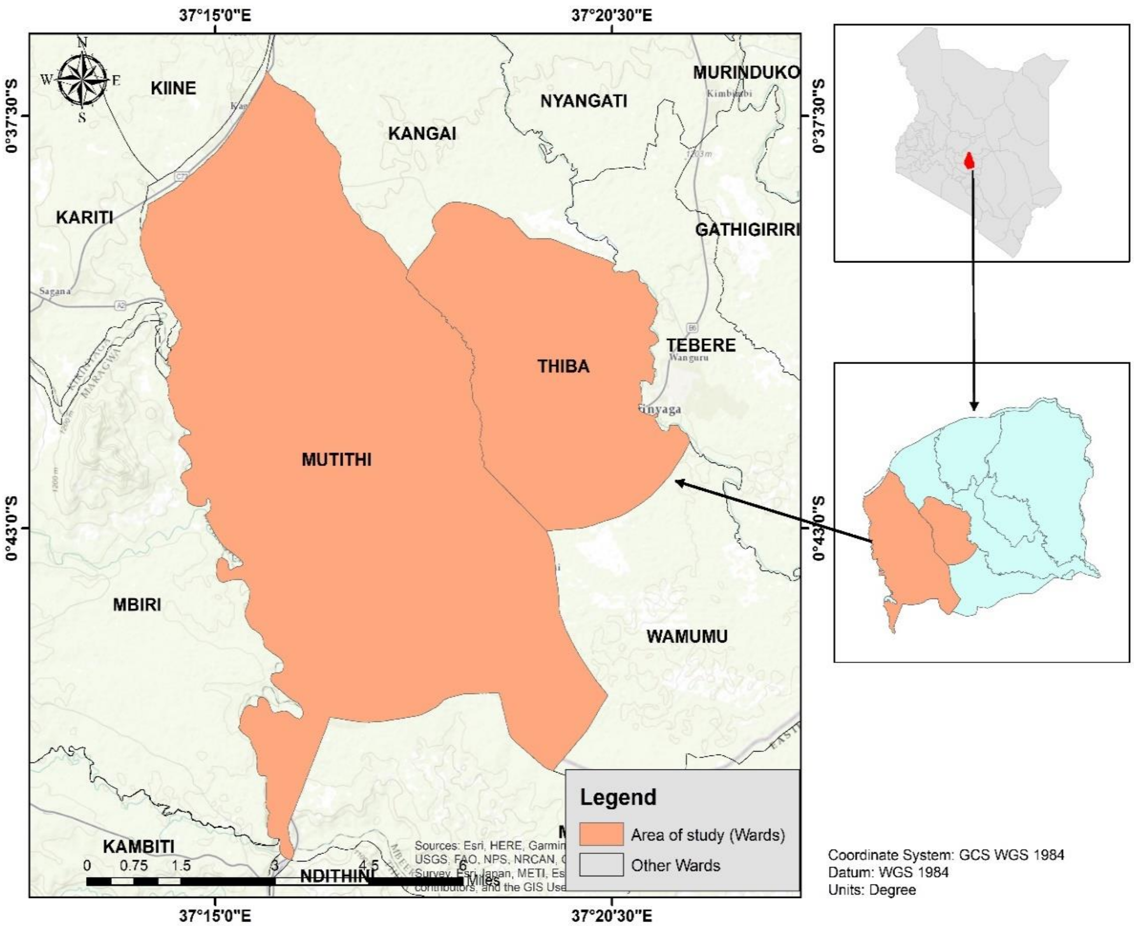

Figure 1.1: Study Area Map, source: Kirinyaga County Integrated Development Plan, (2019)

3.2 Study Design

Questionnaires were used to collect primary data from the local rice farmers, NIA officials and the MRGM (Mwea Rice Growers Multipurpose Co-operative Society) personnel who reside within Mwea. A camera was used to take photographs in the most relevant areas of the study to assist in highlighting the key issues in the report. The most important secondary data was mainly obtained from the NIA weather station at Kandongu, MIAD (Mwea Irrigation and Agricultural Development) and MRGM rice production data banks.

3.3 Target Population

According to the latest census report conducted in 2019, Mwea has got a total population of 294,467 (KNBS, 2019). The interviewees were sampled from among 7,022 rice farmers within Mwea, all of whom are found in Mwea region (MRGM, 2020). It comprises of Thiba North, Thiba South and Mutithi wards with a population of 47,785, 14,125 and 11,724 respectfully (KNBS, 2019). The 7,022 rice farmers were evenly distributed in the study area. Therefore, to obtain the target population, a fraction of the total rice farmers was obtained by simple calculation of the total population percentage in the three wards as shown below;

$$\mathrm{N} = 7{,}022 \text{ X} \frac{(47785 + 14125 + 11724)}{294467}$$

$$\mathrm{N} \cong 1{,}756$$

3.4 Sampling Procedure

The research entailed simple random sampling in selecting 144 individuals who grow rice in the region. Purposive Sampling was further employed in selection of respondents in each of the three wards (Thiba North, Thiba South and Mutitithi) according to the population density of the ward (see Table 1). This purposive sampling was done in consideration of farmer's knowledgeability of the variables under study. According to Kothari (2012), when using purposive sampling, the researcher can use judgement to select the subjects under study.

The same sampling procedure was used to select professionals working in the NIA weather station at Kandongu, Mwea rice millers which is run and owned by the state and managed through MIAD and the private MRGM rice processing millers in Wang'uru, Mwea. One individual was picked form each office.

3.5 Sample Size

The right sample size of 144 rice farmers was decided using the following Nassiuma (2000) formula:

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where;

n=sample size;

N= population size;

e= standard error

C= coefficient of variation

The formula equation shown above was applied to the total population of the rice farmers to determine the number of rice farmers to be interviewed in the survey. Nassiuma (2000) observed that in most surveys, an error range of 2% $\leq e \leq$ 5% and a coefficient of variation 21 %$\leq$ C $\leq$30% can be used. The study therefore used coefficient of variation of 25% and a standard error of 2%. Substituting these values, we get;

$$n = \frac{\mathbf{1756}\ \boldsymbol{x}\ \mathbf{0.25}^2}{\mathbf{0.25}^2 + (\mathbf{1756} - 1)\mathbf{0.02}^2}$$

Hence a total of 144 respondents were interviewed in the research survey.

Table 1: The study sample size

Category (sub county)		**Farmers' Population**	**Sample size**
Rice farmers in Thiba North	Male	566	46
	Female	572	47
Rice farmers in Thiba South	Male	168	14
	Female	170	14
Rice farmers in Mutithi	Male	138	11
	Female	142	12
Total		**1,756**	**144**

3.6 Data Collection Instruments

Survey design was used to collect data for this study. The research heavily depended on primary and secondary sources of data. This survey depended on diverse data gathering methods which included; questionnaires, recorded reports and general field observation. The primary data was collected by use of controlled assessment enquiry questionnaires. At first, the questionnaires were piloted on a target of ten farmers to check for their reliability, cogency, exigency, precision and flow of ideas. The questionnaires were then issued to the sampled rice farmers within the population by the research assistants. Field observations were very vital in establishing the degree of climate features variation effect to rice farms.

Furthermore, discussions with relevant field professionals were held to help in gathering of qualitative data from the rice plantations.

3.6.1 Data Collection Procedures

According to Kenyatta university research guidelines, authority to conduct the study was obtained from the National Commission for Science, Technology, and Innovation (NACOSTI) which approved the research and issued a research permit upon approval. Later on, permission to collect the data from the rice farmers was sought from the national government officers in the study area.

This research involved both primary and secondary methods of data collection. Primary data collection involved administration of questionnaires to the selected respondents. Rice production records for the period under study were obtained from MIAD and MRGM. Secondary data method involved literature from the meteorology department of the NIA. Secondary data was mined from National Irrigation Authority (NIA) weather station in Kandongu area in Mwea, in form of recorded monthly rainfall and temperature data for the past three decades (1990-2019). The MIAD weather station was chosen because it is located in the midst of the rice plantations, thus making the obtained data more valid. On site general observations were made and important aspects captured using a digital camera.

3.6.2 Piloting

Piloting of the data collection questionnaires on a sample of ten rice farmers selected at random was carried out in order to determine their appropriateness. The answers of the rice farmers were keenly evaluated to ascertain if the questionnaires required to be adjusted. The results were used to make any necessary corrections in the questionnaire.

3.7 Data Analysis

The research gathered both qualitative and quantitative raw data sets. Microsoft excel sheets were used to organize and code the data for numerical analysis. It was then subjected to “R” software for analysis.

Pearson correlation(r) was used to measure the linear dependence between rice quantity (x variable) and weather variables (temperature and rainfall); y variables. Shown below is the Pearson’s product moment correlation co-efficient equation.

$$r = \frac{\sum(x-m_x)(y-m_y)}{\sqrt{\sum(x-m_x)2\sum(y-m_y)2}}$$

x and y are two vectors of length n

m_x and m_y correspond to the means of x and y, respectively. The p-value (significant level) of the correlation in this case was calculated using correlation coefficient table for degree of freedom: *df* = *n-2*, where n is number of observations in x and y variables. The reports were represented in pie charts, tabulated as well as graphical formats and the findings used to make statistical interpretations by testing of the research hypotheses. Finally, conclusions and recommendations were made based on the outcomes.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Preview

This chapter presents results and discussion for the study regarding objectives of the study. It begins with background information of the respondents which is followed by findings for the four objectives: to examine temperature and rainfall variation trend for the past three decades, that is; 1990-2019, to evaluate effect of climate variability on rice production and to ascertain climate variability adaptation strategies employed by rice farmers.

4.2 Background Information of the Respondents

The variables under background information of the respondents which were scrutinized included: Education level, occupation, gender and farmers' reasons for planting other crop(s) apart from rice. The data were collected using open ended questionnaires from the respondents in the study. It was important to examine the various characteristic of the respondents who participated in this study research as it was useful to determine their levels of knowledge and the various challenges they were facing as famers of rice in relation to climate variability effects.

4.2.1 Education Level of Respondents in the Sub-County

Generally, education level of the farmers would enable them to acquire vital skills regarding knowledge on impact of climate variability in regard to rice production. Out of the 144 rice farmers interviewed during the study, 6.25% (n=9) had no formal education, 41.67% (n=60) had access to primary education and those with secondary were 27.78% (n=40), while the rest (tertiary education) composed of 24.30%(n=35) (Table 4.1).

The participants who had no education at all in comparison to those others who had already attained tertiary, secondary or primary levels of education were few. In this case therefore, the results implied that the uptake rate on rice farming and on climate variability issues would be high due to the higher number of educated respondents. This is as a result of percentage of those with no education being very small (6.25%) of respondents in comparison to those with education (Table 4.1).

From study, the findings indicated that 93.75% of the respondents at least had access to education (n=135), and only 6.25 percent (n=9) who had not attained any education. This therefore showed that the data collection was done from a sample of population whose education level was enough to give out information with better knowledge and hence becoming reliable and useful in the study.

Table 4.1: Education Level of Respondents

Education	**Frequency(N)**	**Percentage (%)**
None	9	6.25
Primary	60	41.67
Secondary	40	27.78
Tertiary	35	24.30
Total	**144**	**100**

In addition, knowledge on climate variability increases with increment in the number of years of schooling, in this case therefore farmers who have got higher level of education are more likely to have more knowledge, a great ability in understanding and responding to anticipated climatic variability. Mohamed *et al*. (2014), who studied on 'Factors Affecting Farmers' Adaptation Stategies to Environmental Degradation and Climate Change Effects: A farm Level Study in Bangladesh" argue that at the same time, they have greater accessibility to the information related to climate issues such as rainfall and temperature in the process of doing their daily farming activities.

The study by Mohamed *et al*. (2014) on "Linkages Between Land Management, Land Degradation and poverty in Sub-Saharan Africa:The Case of Uganda" explain that attaining basic education showed greater understanding on the farming of crops of maize seed in Tanzania. Moreover, each addition of number of years of education like secondary education increases their general knowledge on climate and agriculture by 20 percent.

4.2.2 Occupation of Respondents in the Sub-County

Table 4.2 shows occupation of respondents tabulated from the data collected during the study. Different rice farmers indulged in other occupations for their socio-economic wellbeing. The findings from the respondents, showed that some rice farmers were employed (18.06%), practiced business (38.88%), kept livestock (34.72%) and others (8.34) didn't engage in any other activity apart from rice farming (Table 4.2).

Table 4.2: Occupation of Respondents

	Business		**Livestock keeping**		**Employment**		**None**		**TOTAL**	
Sex	n	%	n	%	n	%	n	%	N	%
Male	26	18.06	30	20.84	17	11.81	6	4.17	79	54.86
Female	30	20.84	20	13.89	9	6.25	6	4.17	65	45.14
Total	**56**	**38.88**	**50**	**34.72**	**26**	**18.06**	**12**	**8.34**	**144**	**100**

From the findings, 6.25% (n=9) of female were employed compared to their male counterparts 11.81% (n=17) of the total 26 (N=144). The findings showed that compared to the female and male genders, the male gender that was employed and practiced rice farming was higher than the female gender. This might have been caused by the societal expectation of the masculine gender to provide for their families. It could be also due to the fact that men are taken as the main care giver in most of families. Swinkels *et al.* (2019), explains that male caregivers are common and the intensity of doing a lot of work such as rice farming in order to continue supporting their families and their number is higher compared to that woman.

The other category of rice farmers in the area were those doing business and rice farming. The results from the study showed that, the female gender dominated this category by 20.83% (n=30) with male recording 18.06% (n=26). This could be because the females may have been given family businesses to run as the male engage in other activities such as rice farming. At the same time more females are getting involved in business in comparison to males. For instance, in the study carried out by Ondiba & Matsui (2019), on 'Social attributes and factors influencing entrepreneurial behaviors among rural women in Kakamega County', it was revealed that most of the women get engaged in businesses than men, and this is due to the fact that they are very good in establishing social networking. These networks include groups like merry-go-rounds among others that usually inspire them in finding new entrepreneurship opportunities leading to improvement of their businesses.

There was a category of rice farmers that kept livestock such as chicken and dairy cattle to supply eggs and milk respectively. This was observed to be mainly due to economic support system during rice farming off season. From the study by Mustafa *et al*. (2019), most of populations are changing their old attitude of going for food crop diversification. This is in place of specializing on a few main crops as well as keeping livestock of different species.

From the findings, 20.83% (n=30) were male with 13.89% (n=20) being female from the total respondents 50 (N=144). The results showed that from the total, the male dominated this occupation compared to the female gender. This might have been resulted by male finding livestock keeping a better rewarding occupation unlike the female.

Majority,91.67% (n=132) of respondents engaged in other economic activities other than rice farming to boost their income. This is an indication that the farmers can not entirely rely on rice farming possibly due to negative climate variability effects leading to reduced production levels. From the total, 40.97% (n=59) were female and 50.69% (n=73) were male. The findings showed that more male farmers than female farmers engaged in another activity other than rice farming. They surpassed their female counterparts by 8.34% (n=12) (Table 4.2).

4.2.3 Crop Diversification

From the results, 89.58% (n=135) of the farmers indicated that they plant a different crop other than rice due to a number of reasons. These other crops were observed to be planted on different proximities other than on the rice paddies. Out of the 144 farmers, 41.67% (n=60) engage in maize farming whereas 20.83% (n=30) planted tomatoes. Another 16.67% (n=24) planted beans, 8.33% (n=12) onions while only a paltry 1.39% (n=2) planted Irish potatoes and 0.69% (n=1) pumpkins (Table 4.3).

Table 4.3: Crop Diversification

Other crop(s)	Frequency (n)	Percentage (%)
Beans	24	16.67
Maize	60	41.67
Irish potatoes	2	1.39
Onions	12	8.33
Pumpkins	1	0.69
Tomatoes	30	20.83
None	15	10.42
Total	144	100

4.2.4 Farmers' Reasons for Planting Other Crop(S) apart from Rice

The rice farmers gave different reasons they considered for planting other crops apart from rice. For majority 51.38% (n=74) of the farmers, their main consideration was to boost their income from rice farming. This means that these other crops came second to rice farming which was their main economic activity. Another 33.33% (n=48) planted other crops to supplement their food basket since they couldn't feed on rice alone.

A further 4.2% (n=6) planted other crops to boost their yields while 3.46% (n=5) did it due to their tendency to tolerate drought incase rice doesn't perform well in case of reduced rains. For 0.69% (n=1) of the farmers, they plant other crops for both food supply and income supplication while a similar number does it because the other crops tend to withstand pests and diseases better than rice (Table 4.4).

Table 4.4: Considerations for planting other Crop(s) apart from Rice

Reason	Frequency(n)	Percentage (%)
Food supply	48	33.33
Income	74	51.38
Income, Food supply	1	0.69
Pest and diseases tolerance	1	0.69
Tolerance to drought	5	3.46
Yield	6	4.2
None	9	6.25
Total	**144**	**100**

This could be that climate variability has been resulting to rice production failure thus making them think and shift to additional food crops.

This study is similar to what was done by Ochieng *et al.* (2016), which showed that planting more than one crop in the same piece of land ***can be a crucial*** climate variability strategy for management of more production as well as risk of price. The findings also concur with that of Feliciano (2019), who explains that crop diversification increase has led to opening of markets for many families, as well as contribution to self-reliance on food crop production and consumption. Therefore, in this case, diversifying crops of different species seems to be adding more benefit to the famers that dealing with only one crop.

4.2.5 Awareness of Climate Variability Impacts to Rice Farming

33% of the responded disagree that climate variability has resulted to an increase in floods episodes while 38% have no idea on the same. High numbers of respondents (43%) seem to have no idea on effects of climate variability to land degradation, 27% disagreed while 8% agree and strongly agree on the same respectively. Majority (41%) of the respondents strongly agree on occurrence of pest and diseases, 3% strongly disagree, 15% had no idea, 35% agree while only 6% disagree on the same.

Majority (50%) of them respondents strongly agree on the aspect of production decline as climate variability impact, 45%of them agree, 1% disagree, 3% had no idea, while minority

(1%) strongly disagree. On the issue of prolonged drought climate variability impact, 49% agree, 7% disagree, 19% had no idea, 24% strongly agree, while only 1% strongly disagrees. Climate variability impact of rainfall pattern change, majority (37%) agree, 12%disagree, 26% had no idea, 18% strongly agree, while 7% strongly disagree.

About rainfall reduction, majority (36%) agree, 12% disagree, 10% had no idea, 38% strongly agree, with minority (4%) strongly disagree. On the issue of temperature increase, majority (42%) agree, 11% disagree, 13% had no idea, 21% strongly agree while only 13% strongly disagree on the same. This is shown in Figure 4.1.

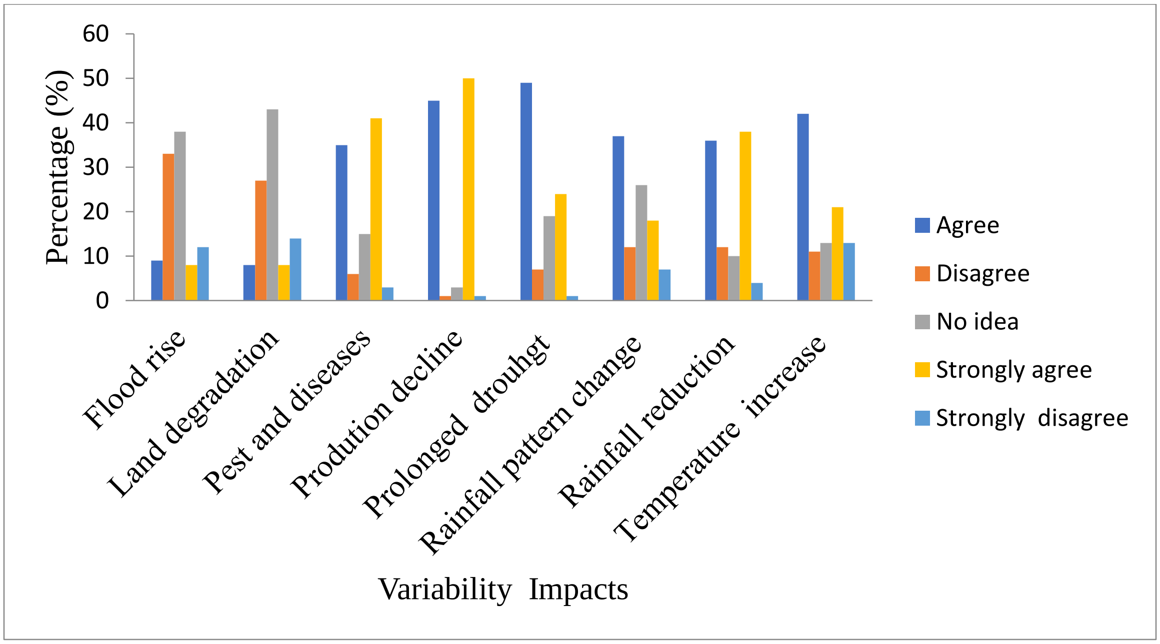

Figure 2.1: Awareness to climate variability Impacts

The result revealed that farmers have high awareness (45%) to the existence of three major climate variability indicators that is; persistent drought/lack of irrigation, change in rainfall intensity and pattern as well as occurrence of pesticide- resistant pests in rice farms. The findings indicated that medium awareness (37%) to the existence of climate variability indicators is evident in; deforestation, increase in average environmental temperature and also unreliability of climate forecast and information. In addition, the results farther indicated that there is very low awareness (18%) on over flooding of rice paddies as indicated in Figure 4.2.

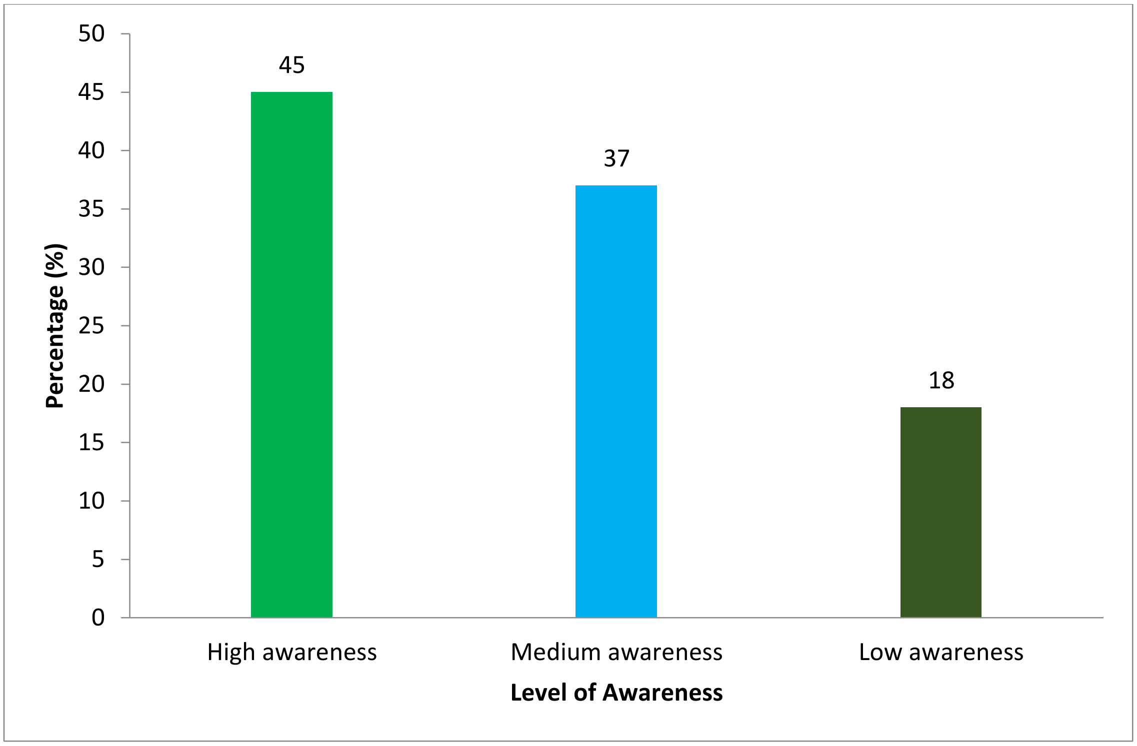

Figure 4.2: Level of Climate variability awareness

This could be that due to experience of in farming and the occurrence of climatic conditions, these farmers must have noticed the differences in climate related phenomena. At the same time, due to increased use of social media and advanced means of communication such as television, most of the respondents must have heard and about climate change hence the great awareness.

This study agrees with that of Elia (2017), who points out that most of farmers have great awareness and knowledge on climate variability which have forced them to come up with many coping strategies. However, he adds that even though famers are aware of it, and are practicing such coping strategies, they still lack clearer understanding on climate change and variability.

From past studies by Pandve *et al.* (2011) on 'Assessment of awareness regarding climate change in an urban community' it was revealed that deforestation significantly contributes to climate variability. In addition, they explain those persistent droughts are as a result of climate variability related issues.

From an analysis based on the degree/extent of acceptance on the impacts caused by climate variability to rice farming, 94% of the respondents agreed that climate variability led decline in rice production. While 75% agreed to occurrence of rice pests and diseases due to climate variability, 74% agreed that climate variability reduced amount of rainfall and 73% agreed to prolonged drought effects of climate variability on rice farming (Figure 4.3).

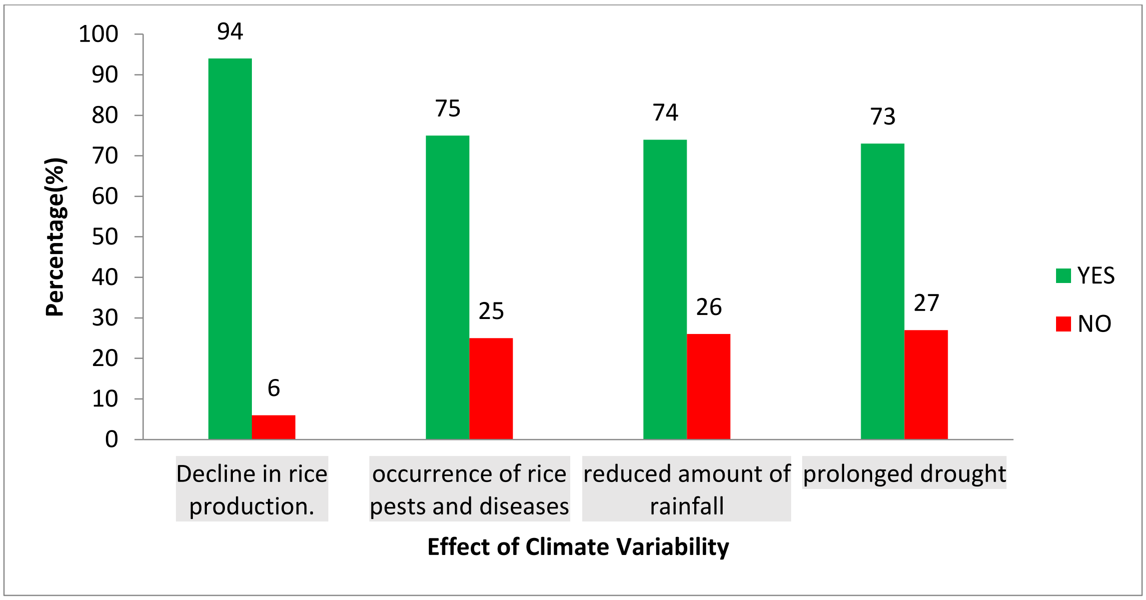

Figure *4.3*: Awareness of Climate Variability Impacts to Rice Farming

There are different levels of acceptance regarding climate impacts. This could be that the respondent may have not been keen on issues to do with climate. There could also be the fact that the means of getting the information on the same is poor. The findings concur with that of Elia (2017), who argues that there a number of factors that influence farmers understanding in climate change issues and they include communication media, lack of farmers' interest to know about climate, communication gap, unreliability of information, low budget and amount of income.

Temperatures seemed to be increasing from the study by Tabi *et al.* (2016). It is argued that, naturally, production of rice can be very sensitive to changes in climate and hence this can be the main cause of the declining rice production. For instance, in the study carried out by Van Oort & Zwart (2018), it reveals that at very high temperatures the rate of photosynthesis can significantly reduce thus causing decline in rice production. In addition, increased temperatures can lead to decreased rice produce since they can adversely affect rice flowers by making them sterile, and this means that no rice grains are produced.

Study by Trebicki & Finlay (2019), points out those changes in atmospheric carbon dioxide, temperatures, rainfall patterns, among other climatic conditions can influence abundance, distribution as well as spread of pest and diseases in farms. This means that rice production will be adversely affected thus leading to reduced yields. According to the study by Pereira, (2017), most of the small-scale farmers are normally aware of the aspects of risks generally. But, some of these famers seem to be having low awareness especially of the many aspects in the ministry of water, agriculture among others. For instance, Pereira (2017) explains that, most of famers are aware of what affect them in their farms and not what does not.

From the study by Van Oort & Zwart (2018), awareness of farmers can be negatively connected with experience in farming, income levels, size of farms, as well as accessibility to receiving information from the ministry of agriculture. For instance, those famers who receive higher crop yields do not necessarily mean that they are aware of the climate variability and coped with it. In this case, mostly it means that they have big parcels of land (Pereira, 2017). However, to improve on this, there is always need to develop extension services and programs so that there can be distribution of the useful information regarding crop production effectively.

This study is in agreement with that of Mukamuhirwa *et al.* (2019), who argue that the incidences of increased temperature together with frequent occurrence of droughts seem to be not favoring production of rice. For instance, drought seems to adversely affect rice at the seedling and tilling stages. This hence contributes to drastic reduction of rice yield for all the rice varieties.

4.3 Climate Variability Trend in Mwea from 1990 to 2019

4.3.1 Time-Series Rainfall and Temperature Variation Trend in Mwea

A 30 years' time series weather trend analysis was conducted for Mwea region. The analysis shows a high variation trend in annual rainfall and temperatures averages (minimum and maximum temperatures). 1992 was the wettest year while driest average precipitation was recorded in 1999 immediately after the El-Nino rains (Figure 4.4).

From the analysis on trends of rainfall and temperature in the study area, Mwea has experienced climate variability of both temperature and rainfall and so this makes it very unreliable and unpredictable for rice farming as well as other crop production in the area. These study findings corroborate with that of Kurukulasuriya *et al*. (2006) who reports that in Africa and especially in Sub-Saharan Africa it is predicted that these parts will be greatly hit by extreme climate variability such as increased temperatures, droughts, rainfalls and floods.

In addition, Kenya experienced two major drought events, in years 1995 and 1996 as well. These were associated with decreased farm produce and rice is inclusive. According to Ochieng (2016), natural disasters in many parts of Kenya are normally related to extreme climate variability such as occurrence of dry spells, increased temperatures and these mainly affect agricultural sector.

There was an upward trend in rainfall and a constant trend in minimum temperature observed from 2016 to 2019 (Figure 4.4). Upwards and downwards shifts in maximum temperature trends were recorded in the same years. Highest maximum average temperatures were recorded in 1996 and 1997 while highest minimum average temperatures were recorded in 2011 (Figure 4.6).

These findings go hand in hand with the past studies carried out by Dupar, (2020), who explains that there was an extreme drought that occurred in the year 1999 to 2000, which severely affected people's livelihoods including livestock, forests among others. According to the study by Dupar (2020), this was as a result of influence by weather patterns and systems as well as local systems like the Monsoons as well as the El Nino – Southern Oscillation (ENSO) cycles.

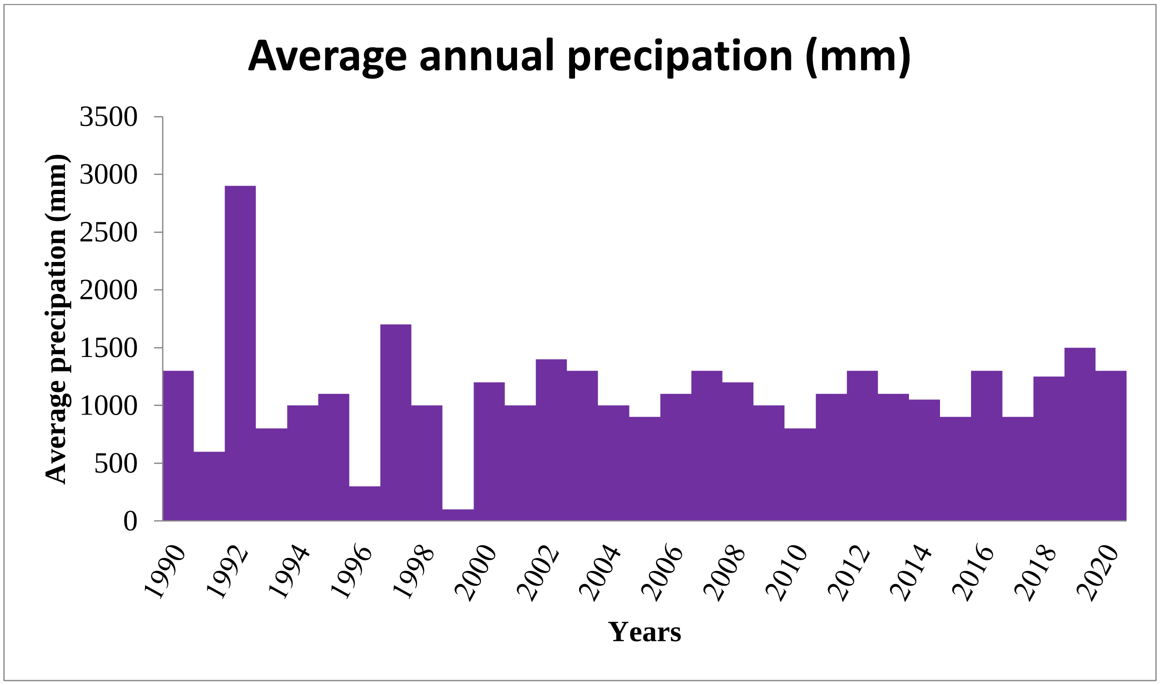

Figure 4.4: Average annual Rainfall trend

4.3.2 Rainfall and Temperature variation from long term mean

Analysis based on rainfall and temperature variations from mean variables of 1107.62mm (Appendix 3) shows a great deviation both positive and negative. Rainfall variation was more between 1990 and 1999. There was a positive variation trend for 3 consecutive years between 2017 and 2019. This shows a significant increase in the amount of rainfall in the three years (Figure 4.5).

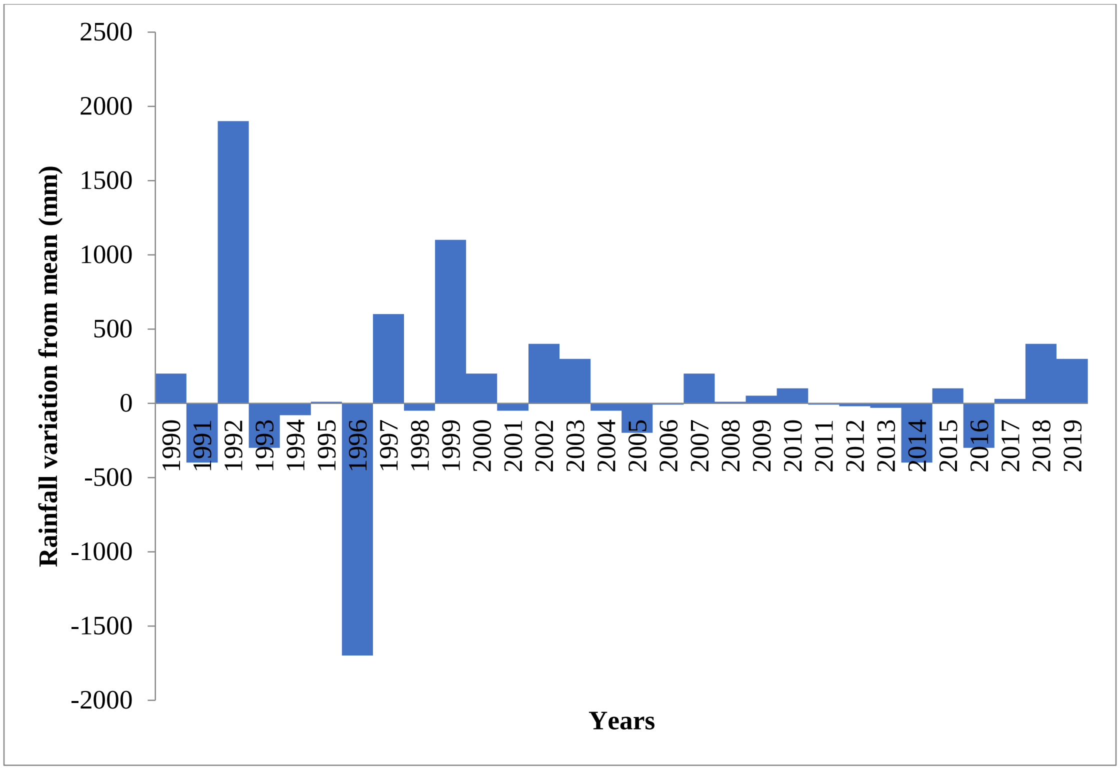

Figure 4.5: Rainfall variation from mean

A similar six consecutive years' positive variation trend was observed with temperature variables, 2019 having the highest positive variation from the mean variable of 28.36^{0}C (Appendix 3). 1995 was the coldest year from the study period (Figure 4.6). Temperature increase goes together with drought, from the past studies by (IPCC, 2019) phenomena such as La-Nina are becoming common not only in Kenya but also globally. This in turn adversely affects rice farming since drought is associated with water stress in plantations. For instance, from the study by Mathew *et al.* (2019), during the severe droughts, rice yields reduce by almost half since only half of the MIS plantation is cultivated thus leading to rice scarcity and so famine.

In the last ten decades, Kenya recorded about 28 severe droughts, 3 of them in the last ten years. The occurrence, severity and frequency of such long droughts seems to be increasing in Kenya over time (Huho & Mugalavai, 2010). Among the impacts is the total food crop failures and loss of livestock and sometimes human beings thus resulting to severe food scarcity in Kenya. According to Ochieng *et al.* (2016), this pattern is pronounced mainly in Arid and Semi-Arid Lands (ASALs). For instance, between the year 1993 to 2010, the

Kenyan government has declared about seven national disasters out of which five are drought related (Huho & Mugalavai, 2010). In addition, these declarations were made following droughts of the years 1992-93, 1996-97, 1999-2000, 2005-06 and 2008-09.

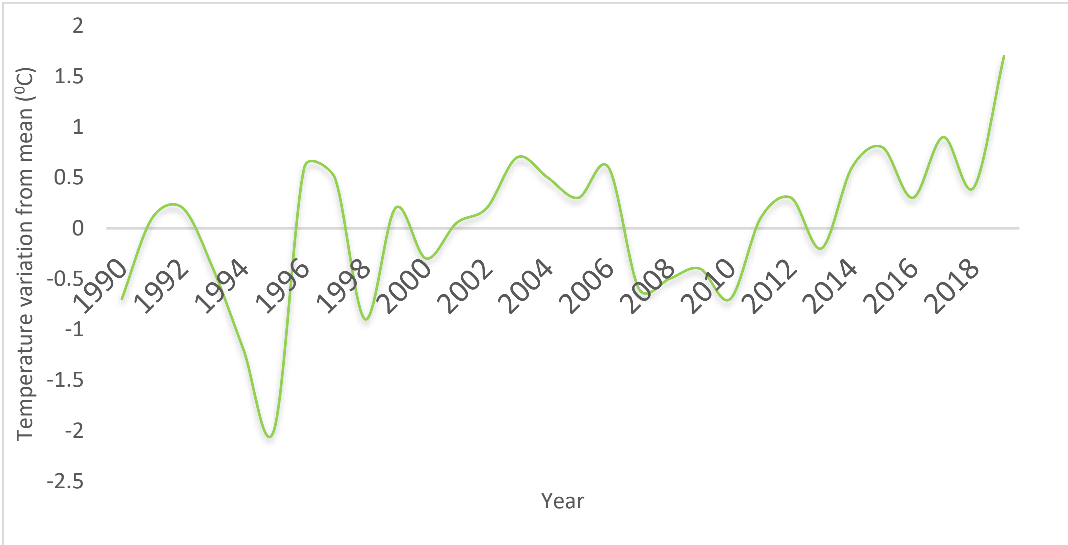

Figure 4.6: Annual Maximum Temperature variation from mean

4.3.3 Average Monthly Rainfall

The month of January recorded a mean monthly rainfall of 40mm, February had 45mm, March recorded 189mm, April recorded 245mm (Figure 4.7). May and June showed 170mm and 25mm, respectively. July recorded 12mm, August showed 9mm, and September recorded 16mm. The months of October and November recorded 149mm and 173mm, respectively, while the month of December recorded 70mm. From these findings, the wettest months were found to be March to May as well as October to November.

As anticipated in rainfall patterns, the long rains come in the months of March to May. However, the month of April recorded the highest mean monthly rainfall of more than 245mm while the month of August recorded the lowest mean monthly rainfall of 9mm.

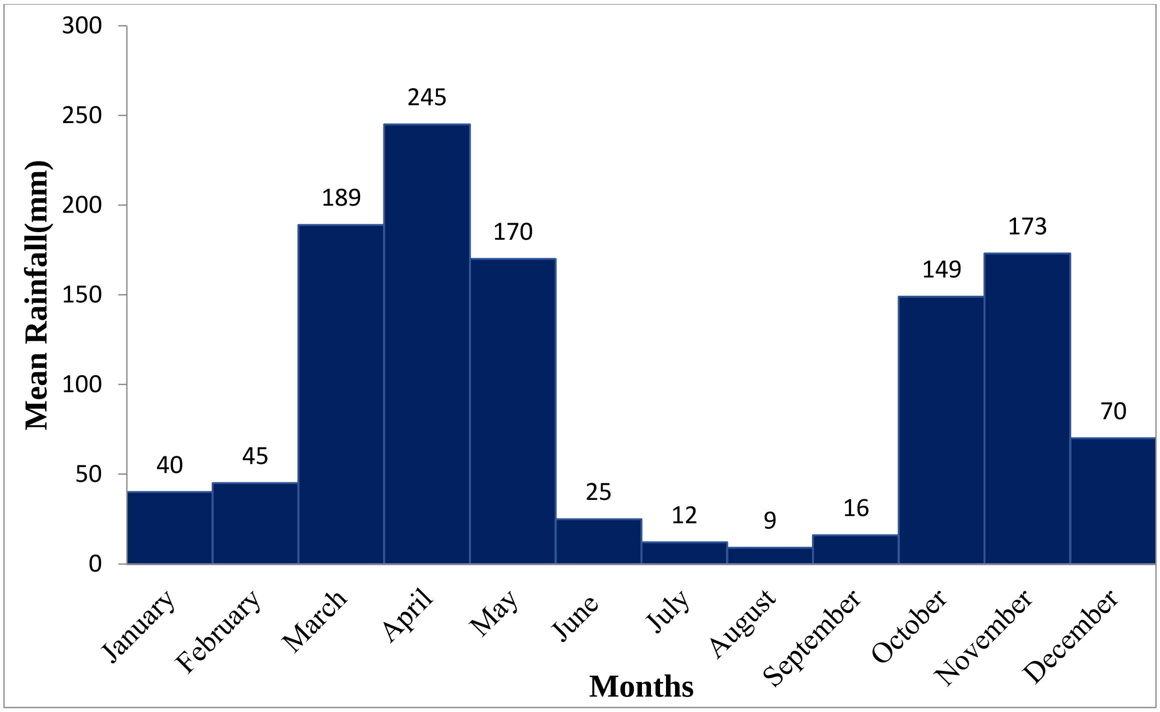

Figure 4.7: Monthly average rainfall pattern

From the findings, the long rainy season goes for three months; that is, March(189mm), April(245mm), and May(170mm). This is followed by a dry season that runs from June (25 mm), July (12 mm), August (9 mm) and September (16 mm). This dry season is then immediately followed by a short rainy season which starts from October(149mm) to December(173mm). Atera *et al.* (2018) reveals that in most cases, farmers in Mwea area usually experience an increase in rice production after long rains.

These findings are in agreement with that of Kilavi *et al.* (2018), who explain that long rains in central parts of Kenya, occurs in months of March, April and May and if it prolongs, it can cause flooding, while short rains come in the moths of October, November and December. It is during this long rain that rice production is found to increase in Mwea hence enhanced productivity.

4.2.4 Monthly Average Temperature

Mean monthly analysis trends of maximum temperature shows that the hottest months were February and March while the coldest month was July (Figure 4.8). This trend shows a regular decline in temperature from March to July followed by increase in mean maximum temperature from August to October. This shows that the two climate indicators, temperature and rainfall, have experienced a significant variation in the study period. This supports the alternative hypothesis that Mwea has experienced climate variability effect between 1990 and 2019.

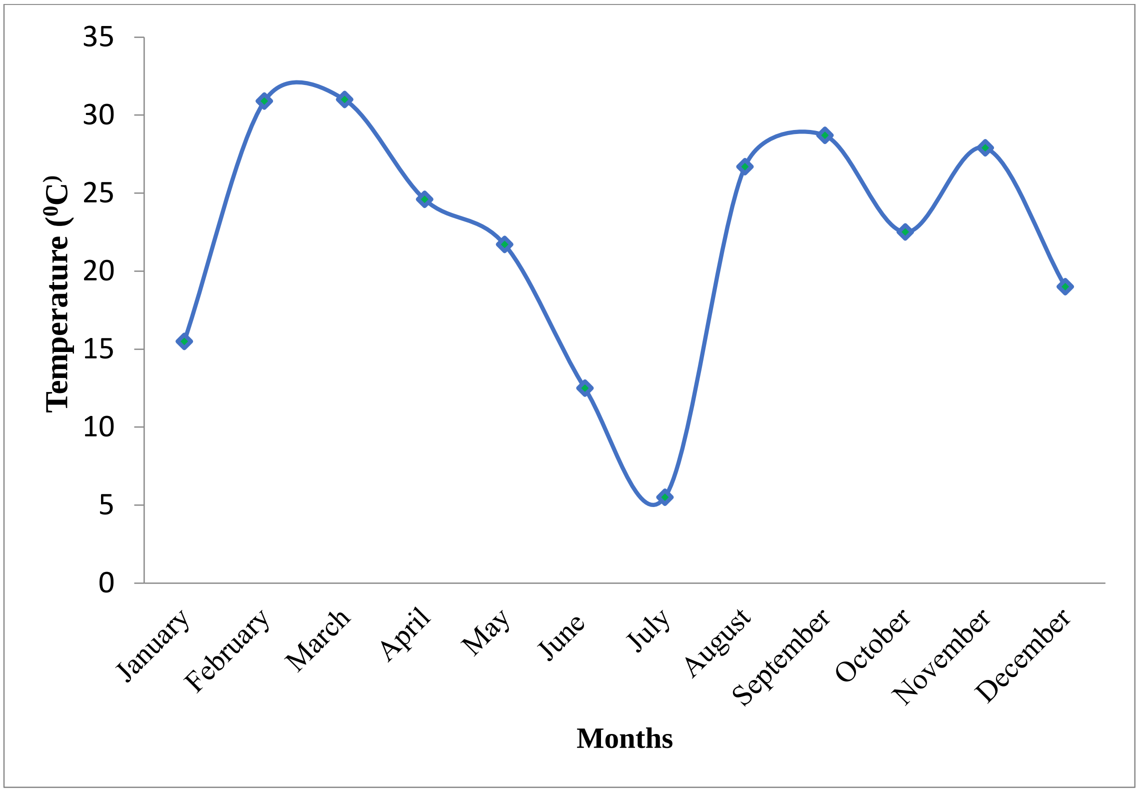

Figure 4.8: Monthly average temperature trend

4.4 Impact of Climate Variation to Rice Production

This research identified the two leading rice collection centers in Mwea, namely MRGM run by the farmers' co – operative society and the government owned MIAD. The quantity of rice received by the two collection centers from 1990 to 2019 was recorded and analyzed. Most (57%) farmers supplied their rice produce to MIAD, while only 16% opted for the SACCO (MRGM). The total quantity distributions per supply center were 402 tons (68%) to MIAD, 62, tons (11%) to MRMGM SACCO and124 tons (21%) to private millers (Figure 4.9). This could be one of the main reasons as to why majority of the rice famers opted to supply their rice to MIAD. This could be due to the fact that MIAD do research and they really help ricer famers in giving advice and ideas regarding rice farming. From the past studies, MIAD has been helping the rice farmers in doing research and giving advisory services to rice famers regarding rice production (Atera *et al.,* 2018).

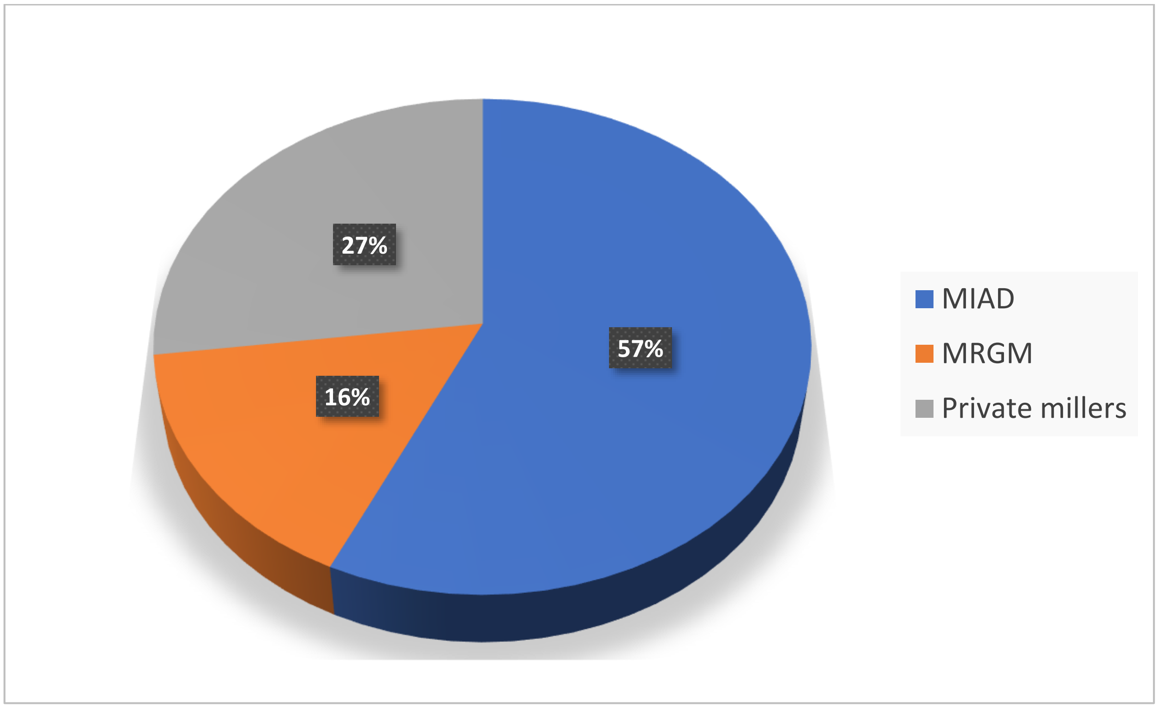

Figure 4.9: Rice distribution per supply center

According to Pandey *et al.* (2010), research in rice farming helps in productivity growth in the field of rice. This includes economic growth which mainly depends on ensuring increase in rice productivity, for instance the issue of profit maximization as well as reduction of production cost (Pandey *et al.,* 2010). Moreover, the research also helps in knowing how rice production can be maximized with continued impacts associated with climate variability.

Noticeable extremes in production trend were observed in the year 1992, 1999,2007 and 2018. Between the year 1990 and 2019, the highest rice yield (11,264,481 Kgs) in MIS was recorded in the year 1992 (Table 4.5). Another year that recorded a significant increase in yield in the recent past was 2018 which recorded 2,894,988 Kgs of rice grain. However, the level of production was 548.2551Kgs/hectare, less compared to 2007 which was 765.6674 Kgs/hectare. This can be highly attributed to the good El-Nino rains that were recorded in 2007-2008. This implies that between the year 1990 and 2019 more land has been put under rice cultivation, thus leading to a general increase in yields despite lower production for some years. The highest level of rice produced per hectare was recorded in 1992 at 2,424.324Kgs/hectare. This can also be linked to the good rains that were recorded in that year since rainfall data (Table 4.5) shows that 1992 was the wettest year under the study period.

Table 4.5: Rice production levels in Mwea between 1990 and 2019

Year	Particulars	MRGM	MIAD	Total	Average
1992	Total Rice quantity collected (Kgs)	1,021,805	10,242,676	11,264,481	5,632,241
	Land under cultivation (Hectares)	300	7,100	7,400	3,700
	Level of production (Kgs/hectare)	3,406.017	1,442.63	4,848.647	2,424.324
1999	Total Rice quantity collected (Kgs)	23,967.85	240256.2	264,224.05	132,112
	Land under cultivation (Hectares)	500	7,400	7,900	3,950
	Level of production (Kgs/hectare)	47.9357	32.46705	80.40275	40.20138
2007	Total Rice quantity collected (Kgs)	466,279.9	4,674,037	5,140,316.9	2,570,158
	Land under cultivation (Hectares)	500	7806	8,306	4,153
	Level of production (Kgs/hectare)	932.5598	598.7749	1531.3347	765.6674
2018	Total Rice quantity collected (Kgs)	525,210.8	5,264,766	5,789,976.8	2,894,988
	Land under cultivation (Hectares)	850	11,000	11850	5,925

	Level of production (Kgs/hectare)	617.8951	478.6151	1,096.5102	548.2551

Conversely, the lowest total production was a total of 23,967.85 Kgs recorded in 1999. In that year, the production rate was 47.9357 Kgs/hectare (Table 4.5). This was because of the drought that was experienced in Mwea that year. The drought led to drying of river Thiba and its associated canals (Plate 4.1) leading to lack of water for irrigation. A closer scrutiny of the results revealed that MIAD owns larger rice plantations than MRGM. This leads to more yields being recorded at MIAD despite its relative lower production level.

Plate 4.2: Dry canal in Kandongu area (0^0,39',32.83" S, 37^0,17',40.71" E)

4.4.1 Correlation Between Rice Quantity and Rainfall

Correlation test for rice quantities and rainfall was conducted to produce correlation coefficient and the significant level (p-value) of the correlation. The p-value of the correlation test between the two variables (rice quantities and rainfall) is 0.000000001324, which is less than 0.05 (5%) alpha value (Figure 4.10). This shows that there is a linear relationship between the two variables, thus supports the alternative hypothesis that rainfall affects quantity of rice produced in Mwea.

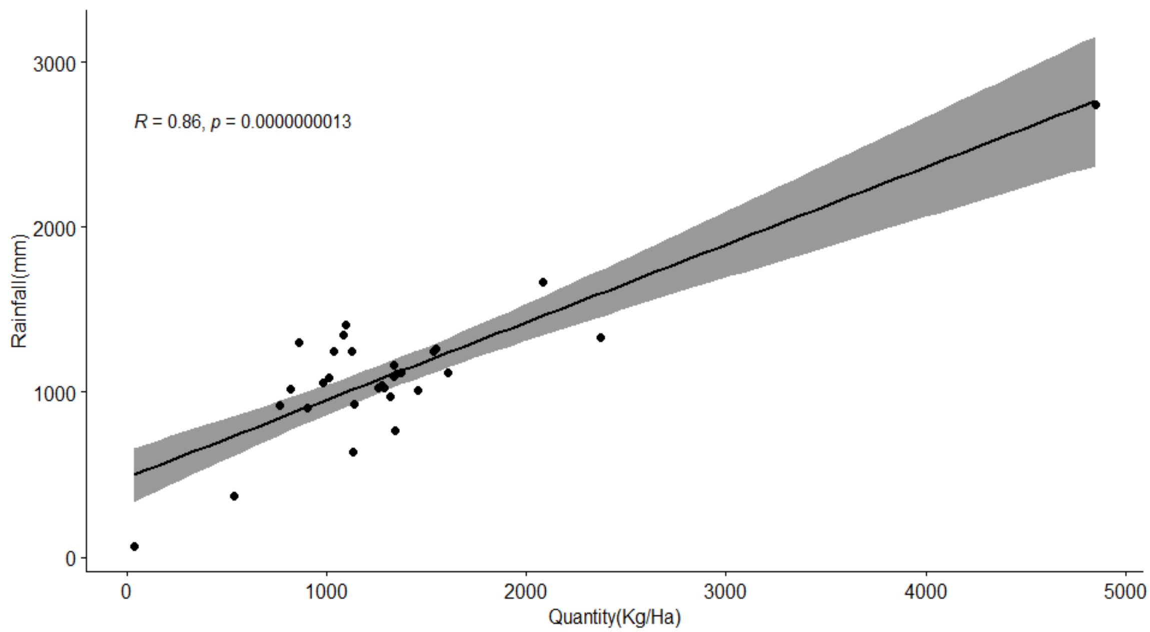

Figure 4.10: Correlation between Rice Quantity and Rainfall

In comparison, the p-value at 0.39 shows a correlation coefficient of +0.16 for the relationship between quantity of rice produced and rainfall (Figure 4.10). The correlation coefficient in this case is statistically significant showing a very low positive correlation between the average rainfall and quantities of rice produced in Mwea. This could be that decreased rainfall affected rice production thus leading to decreased yields. This study concurs with that of Kilavi *et al.* (2018), who argues that increased rainfall favors rice production and so increased yields.

According to Devkota (2018), the issue of climate variability on rice production on rain fed rice produce has been decreasing due to increase of temperature. For example, temperature has been affecting rice production in that it contributes to cutting back of the rice growing season. Additionally, precipitation that has sharply decreased due to climate variability has also shown decreased rain fed rice yields. This could be as a result of increased temperatures which are associated with drought and water stress hence decreased rice yields. For instance, according to the study done by Devkota (2018), they reveal that rice production decreased with increased temperatures and water stress.

4.4.2 Correlation between Rice Quantity and Temperature

Correlation test for rice quantities and temperature was conducted to produce correlation coefficient and the significant level (p-value) of the correlation. In comparison, the p-value at 0.39 shows a correlation coefficient of -0.16 for the relationship between quantity of rice produced and temperature at 95 percent confidence level (Figure 4.11). The correlation coefficient in this case is statistically significant showing a very low negative correlation between the average temperature and quantities of rice produced in Mwea. This shows that there is a linear relationship between the two variables, thus supports the alternative hypothesis that temperature affects quantity of rice produced in Mwea.

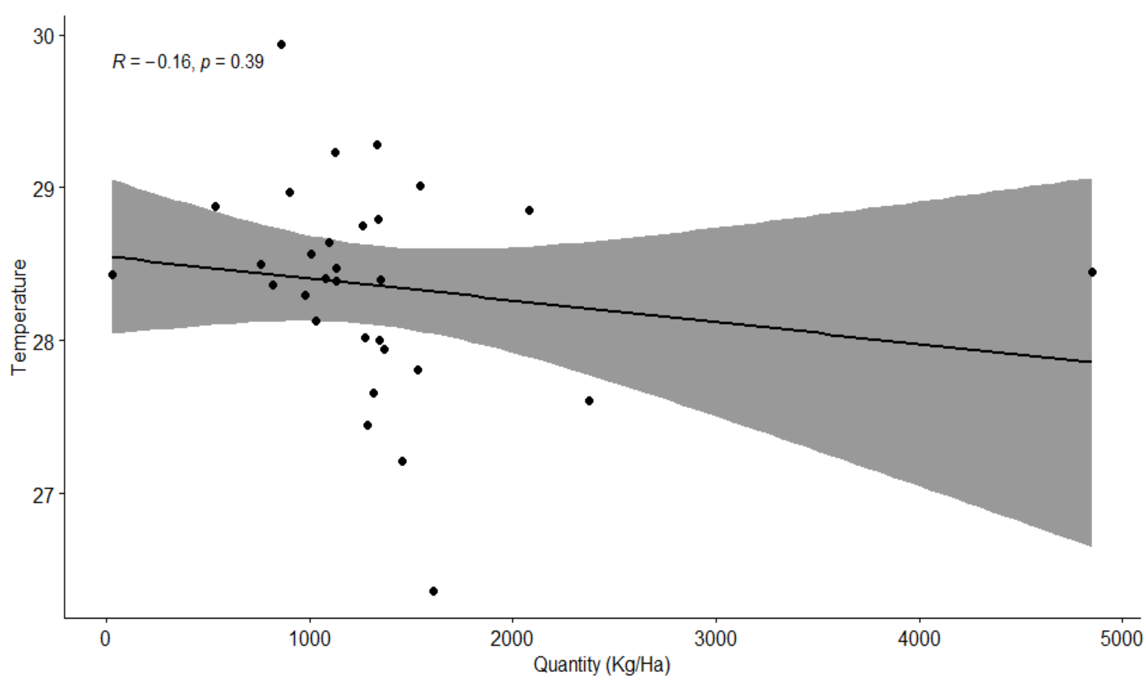

Figure 4.11: Rice quantity and annual maximum temperature correlation graph

A past study by Huho & Mugalavai (2010) revealed that there has been an increase in severity and frequency of dry spells together with increased temperatures in Kenya for the previous 30 years. They add that, most farmers have been affected thus leading to reduction in crop yields and so food security. This also affects rice production (Huho & Mugalavai, 2010). Ochieng *et al.* (2016), argue that as climate variability proceeds, there is likelihood of many populations becoming vulnerable to food shortage. In addition, there could be the incidence of most of populations moving away from the most affected areas to better places. This will in turn mean that migrations from arid lands will be expected, which will result to threaten agricultural production in such areas.

4.5 Climate Variability Adaptation Strategies

Rice farmers in Mwea adopted different strategies to counter the effects of climate variability. Most (64%) of farmers prefer applying chemical fertilizer to boost the yield of rice, while 22% plant as early as possible to cope with climate variability. A few (12%) of the respondents however prefer use of weeds and pest control while only 1% plant climate smart varieties and a similar percentage don't cope to climate variability in anyway (Figure 4.12).

The heavy use of chemical fertilizers could be due to the fact they are readily available, easy to use them and even the outcome could be better compared to other strategies. From the past studies by Omoyo *et al.,* (2015), it is explained that climate variability comes with adverse impacts on many sectors and especially that of agriculture. This therefore has forced many famers to come up with many adaptation strategies.

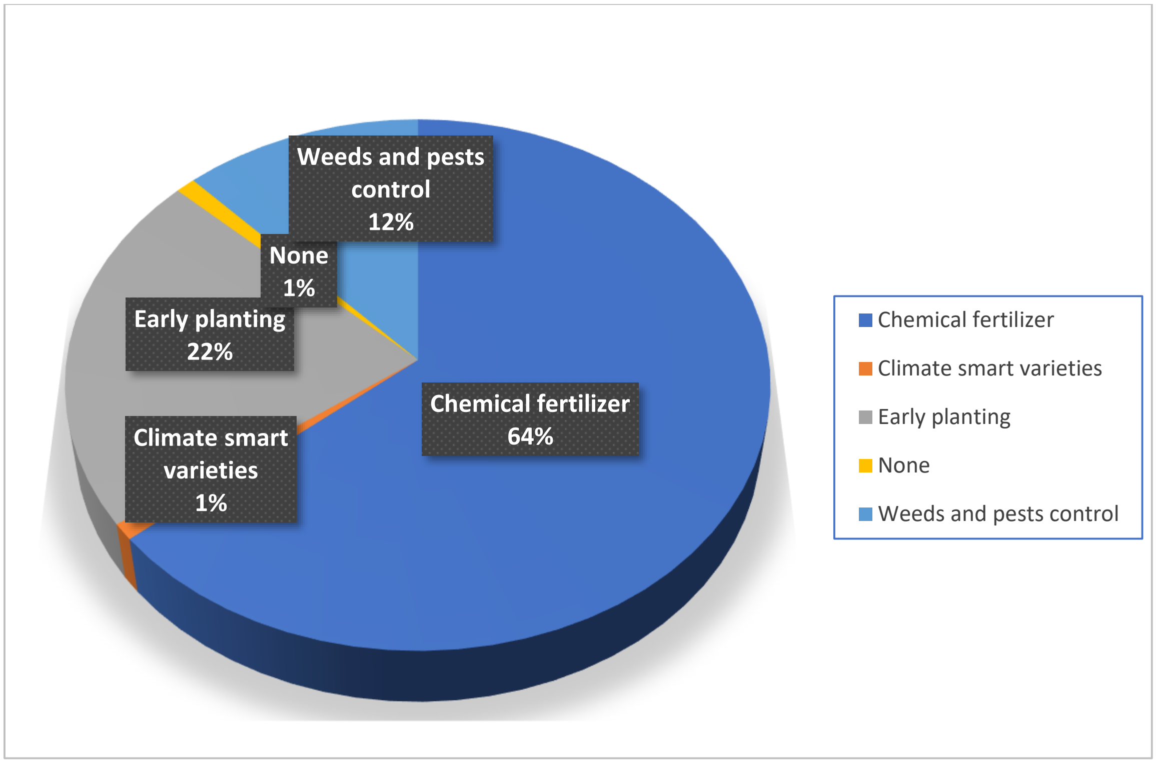

Figure 4.12: Climate Variability Coping Strategies Pie Chart

This study agrees with the one carried out by Moe *et al.* (2019), on the 'Effects of Integrated Organic and Inorganic Fertilizers on Yield and Growth Parameters of Rice Varieties'. They argue that fertilizers enhance many of the growth parameters and yields of the rice variety. Early planting could help in increasing rice yields. For instance, from the study by Devkota (2018), it reveals that adjusting planting dates such as early planting leads to increased rice produce. This is especially because it enables the famers to manage ratoon rice before the rains decline, thus leading to dependence on rainfall for irrigation (Plate 4.3).

The findings concur with that of Ochieng *et al.* (2016), who point out that there has been increased rainfall unpredictability. In this case therefore, coming up with adaptation strategies at farm or local, county and national levels should come as the first priority. In addition, there should be policies that ensure prevention of environmental destruction (Ochieng *et al.,* 2016). They add that this would help in addressing challenges associated with climate variability. However, Huho & Mugalavai (2010) argue that, some of the coping strategies undertaken by local farmers are not very sustainable and so they might lead to more population experiencing food shortages. They explain that due to increased frequency of drought, most of the people in Kenya will live under very serious food shortages. The various coping mechanisms highlighted in this section supports the alternative hypothesis that rice farmers in Mwea are coping to climate variability impacts.

Plate 4.3: Preparation of the ratoon rice in Mwea (0^0,40',46.08" S, 37^0,20',37.52" E)

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

- There is a high variation trend in annual rainfall and temperatures averages. From the findings, the year 1992 was the wettest year while driest was recorded in the year 1999. This was immediately after the El-Nino rains. It is indicated further that there was an upward trend in rainfall and a constant trend in minimum temperature as observed from 2016 to 2019. Upwards and downwards shifts in maximum temperature trends were recorded in the same years. Highest maximum average temperatures were recorded in 1996 and 1997 while highest minimum average temperatures were recorded in 2011.
- Variation for rainfall variables was more between 1990 and 1999. There was a positive variation trend for 3 consecutive years between 2017 and 2019. This shows a significant increase in the amount of rainfall in the last three years. A similar six consecutive years' positive variation trend was observed with temperature variables, the year 2019 having the highest positive variation from the mean variable of 28.36.
- The wettest months were found to be within long rains (March-May) and short rains (October and November) as anticipated in rainfall patterns. April recorded the highest mean rainfall of more than 200 mm. The findings further indicated that the monthly average temperature trends showed that the hottest months were found to be February and March while the cold month was July. This trend shows a regular decline in temperature from March to July followed by increase in mean temperature from August to October.
- From the findings, correlation between quantities of rice produced and weather variables showed that rice is adversely affected by increased temperatures and this hence leads to reduced rice yields. Majority (94%) of the respondents agreed that climate variability led to decline in rice production**.** Farmers adopted different coping strategies to counter the effects of climate variability. Most (64%) of farmers prefer applying chemical fertilizer to help fasten the growth rate in the face of limited rainfall, while 22% plant as early as in the month of July. Minority (1%) of the respondents however prefer to plant climate smart varieties.

5.2 Conclusion

- The study concluded that there is a significant variation trend in annual rainfall and temperatures averages in Mwea, Kirinyaga County with 1992 and 1999 being the wettest and driest respectively. There was an upward trend in rainfall and a constant trend in minimum temperature as observed from 2016 to 2019. Highest maximum average temperatures were recorded in 1996 and 1997 while highest minimum average temperatures were recorded in 2011.
- There was a great positive and negative deviation in regard to long term mean rainfall and temperature variation. There has been a positive variation trend for 3 consecutive years between 2017 and 2019 thus showing a significant increase in the amount of rainfall in the last three years. A similar six consecutive years' positive variation trend was observed with temperature variables, 2019 having the highest positive variation from the mean variable of 28.36. The wettest months were found to be within long rains (March-May) and short rains (October and November) as anticipated in rainfall patterns. April recorded the highest mean rainfall of more than 200 mm. The monthly average temperature trends showed that the hottest months were found to be February and March while the cold month was July.
- Rice is adversely affected by increased temperatures and this hence leads to reduced rice yields with majority agreeing that climate variability led decline in rice production**.** Farmers have high awareness to the existence of three major climate variability indicators that is; persistent drought, change in rainfall intensity and pattern as well as occurrence of pesticide- resistant pests in rice farms.
- Farmers adopted different strategies to counter the effects of climate variability. Most of them preferring application of chemical fertilizer to boost the yield of rice, others plant early while the minority prefer use of weeds and pest control

5.3 Recommendations

1. The government, through the National Irrigation Authority (NIA), or other interested non-governmental organizations (NGOs) to construct a high-capacity central water storage reservoir upstream, more canals around all rice fields and establish several community dams for harvesting and storage of rainwater. Some rice cultivated areas do not

have access to water from the main irrigation canals. Therefore, construction of a central water reservoir upstream would ensure continuous flow of water at a higher level, which possesses sufficient pressure to reach all the paddies. Increasing the canals network coverage around the rice fields, and establishing community dams to store runoff water are good solutions to address the short-term needs of water when rains are insufficient.

Rice farmers have also experienced hotter temperatures and reduced rainfall. When temperatures are so high, evaporation of flooded water in the rice paddies increases. To mitigate this, farmers should be introduced to drip irrigation techniques to effectively use the receding water supplies. They can also be encouraged to use geo-membrane plastic sheets for personal water storage. These actions would minimize wasting water as well as washing soil nutrients from the land when it rains heavily.

2. Carry out research and development of new rice crop varieties that are more tolerant to flood and drought.

The relevant government agencies such as KARI, KARLO, MIAD as well as private firms that deal with rice seeds should conduct a thorough research to come up with new rice varieties that can withstand persistence flood and drought. This study has found that rice yields are affected by extreme weather events such as high temperatures and lack of enough irrigation water hence the need for new rice crop varieties that need less water and are more tolerant to high temperature, extreme cold, weeds, pests and diseases. Above all that, the developed rice varieties should yield more, mature fast and satisfy the market expectations.

3. NIA to develop and improve irrigation system.

The canal network Irrigation systems identified in the study area have been very supportive to farmers in ensuring the survival of their rice crop when during off- season planting and when rains are insufficient. Increasing the geographical coverage of irrigation systems in areas where water doesn’t flow in plenty drought is one of the most vital adaptation strategies. While doing this, NIA should ensure that the irrigation water is utilized effectively to avoid wastage. Punitive measures should be taken against farmers who divert water to their paddies illegally as well as those who block the local canals, thus preventing flow of water to the neighboring paddies. All the main canals should be cemented at the bottom to reduce soil erosion as well loss of volume flux long the way due to water absorption by soil. Irrigation water should be supplied effectively to all rice paddies equitably without favoritism in a sustainable way.

4. Establish Kenyan rice- based farming systems for responding to climate variability effects. System of Rice Intensification (SRI) is a rice farming system that can assist rice farmers in adaptation and mitigation of climate change. However, this structure is still not usually used by Kenyan rice farmers. Draining of the rice paddies mid-season or discontinuous irrigation can be applied in order to reduce emissions of methane from the rice fields. The Kenyan government, through the MOALFI bodies such as NIA and MIAD ought to encourage rice farmers to exercise SRI and apply these methane reduction strategies. It is possible to establish Clean Development Mechanism (CDM) projects if the farmers adopt these new practices leading to a significant reduction of the quantity of CH_4 produced from the rice fields.

5. Timely weather forecasts and broadcast.

Since the normal farming calendars are becoming often unreliable, it is important to ensure that rice farmers have access the meteorological information on time. They ought to be updated on the anticipated weather patterns upfront. This can be achieved by use of the mainstream mass media such as TVs, radios, newspapers as well as social media platforms like twitter, Whatsapp, facebook and telegram among others. This will enable them to access knowledge and information on how to interpret short- and long-term weather forecasts and climate variability data. Currently, weather information which is usually broadcasted by mass media is normally regarding the general temperature and rainfall in major towns and cities. Therefore, farmers are not updated on drought forecasts or local precipitation from the mass media. This makes it difficult for them to organize themselves in advance ahead of climate events, particularly droughts. Since rice production in Mwea is mainly rain-fed, rainfall forecasts for the region is fundamental for the farmers to know upfront so that they can best decide on their agriculture activities, such as the rice variety to plant. To ensure that this is achieved, the Kenya Meteorological Department (KMD) should upgrade their capacity so as to provide accurate, timely, and recurring weather forecast information to rice farmers.

The county government of Kirinyaga should create awareness among the farmers on how to effectively use the information for their own benefits in rice cultivation. Additionally, the MOALFI can build its capacity through the relevant government agencies so that it can institute a strong disaster cautioning mechanism which could propagate consistent projected climate information to farmers and the general public on time. Alternatively, famers should be working closely with agricultural extension officers, and other relevant bodies such as the National Drought Management Authority (NDMA) in curbing the effects of prolonged drought when it occurs. In this case therefore they can be getting information related to rice and other crop farming as well as that of climate variability.

5.4 Further Research

From the literature reviewed, it is observed that there are many varieties of rice that have done very well despite the occurrence of climate change. Therefore, research needs to be done on the best rice varieties that matures faster can yield better in Mwea even with existence of climate variability. The current variety of *Basmati 370* takes four months to mature, hence requires a lot of water. These can particularly be the rice breeds that don't require flooding due to recurrent water shortage and rationing attributed to climate change.

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APPENDICES

Appendix 1 – The main Questionnaire for Rice Farmers

S. NO. ________ GPS (___º____'____ " S, ___º___' ____"E)

IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

Questionnaire for small-scale rice farmers

NB; All the information filled in this questionnaire will be treated with utmost confidentiality.

Section 1: Background Information

Do not write your name anywhere in this form.

Interview date………………… Ward ………………………….

Preferred rice storage center/Miller……………….

Kindly fill the table below appropriately

Gender:	male ( )		female ( )	
Marital status:	married ( )	single ( )	Widowed ( )	separated ( )
Education level:	None ( )	Primary ( )	Secondary ( )	Tertiary ( )
Age:	(in completed years)			
Duration of stay:	(in completed years)			
Farming experience:	(in completed years)			

Kindly fill in the blank spaces below appropriately (Tick in the brackets where necessary)

What else do you do other than rice farming? E.g. Employment Business, etc. ________________________

How big is your rice paddy in acres? _______ acres.

How much is your rice yield per season in Kg? ________ Kg

Which rice variety do you often plant?

Basmati (*Pishori*), ( )

International rice (IR) ( )

Others ________________(Specify)

Which MAIN practice have you adopted to boost your rice yield?

Applying chemical fertilizers ( )

Early planting ( )

Weeds and pests control ( )

Planting fast maturing varieties ( )

None ( )

Others ____________ (specify)

Other than rice do you grow any other crop? (Tick the main one only)

Maize ( )

Beans ( )

Tomatoes ( )

Onions ( )

None ( )

Others ______________ (specify)

Why do you grow the other crop mentioned above? (Tick the main reason only)

To boost Income ( )

Supplement food ( )

Crop pests and diseases tolerance ( )

Drought Tolerance ( )

Others ______________ (specify)

<u>Section II: Rice farmers' awareness to climate variability</u>

Kindly indicate how much you know about the climate variability indicators listed below (tick accordingly)

Climate Variability indicator	**Low (1)**	**Med (2)**	**High (3)**
Change in rainfall intensity and pattern			
Increase in average environmental temperature			

Increase in environmental temperature					

Unreliability of climate forecasts and information			
Persistent drought/ lack of irrigation water			
Over flooding of rice paddies			
Desertification			

How do you get information about climate variability?

TV set ( )

Agricultural officers ( )

Radio ( )

Newspapers ( )

Journals ( )

Colleagues ( )

Formal gatherings ( )

Internet ( )

Other sources _____________(Specify)

On a scale of 1-5, rate your agreement with the climate variability effects to rice farming listed below

Climate variability effect	**Strongly agree (5)**	**Agree (4)**	**No idea (3)**	**Disagree (2)**	**Strongly disagree (1)**

Prolonged drought					
Reduction in rice yield					
Unpredictable rainfall distribution					
Flooding					
Decline in rainfall intensity					
Land degradation					
Occurrence of rice pests and diseases					
Increase in environmental temperature					

The end. May God bless you. Thank you for your time.

Appendix 2: 1990-2019 Rainfall data for Mwea west sub-county

S. NO. 101 GPS (0° 39' 25.111" S, 37°17' 20.774"E)

Date; 4th September, 2020

IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

Climate data form B

Monthly maximum Temperature and Precipitation (1990-2019)

Months	Average temp		Average Total Precipitation
	Min	Max	
January	15.56842	29.29474	38.32105
February	16.19474	30.92632	42.23158
March	17.49474	30.97368	186.3105
April	18.4	29.33684	242.8
May	18.03684	27.77895	165.6789
June	16.96842	26.42632	28.18947
July	15.86316	25.71053	11.88421
August	16.15	26.625	8.23
September	17.11	28.62	14.2415
October	18.055	29.485	146.97
November	17.72	27.93	181.68
December	16.595	27.86	69.565

Appendix 3: Rainfall and Temperature data for Mwea

S. NO. 102 GPS (0^o 39' 25.111" S, 37^o17' 20.774"E)

Date; 4th September, 2020

IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

Climate data form A

Annual Average Temperature and Precipitation (1990-2019)

Year	Annual Average Temp(^{0}C)		Annual Average Total Precipitation (mm)
	Minimum	Maximum	
1990	16.07	27.61	1334.50
1991	15.88	28.39	637.70
1992	15.95	28.45	2738.70
1993	16.11	28.00	763.66
1994	16.39	27.21	1013.40
1995	16.52	26.36	1118.00
1996	16.44	28.88	373.17
1997	16.53	28.85	1663.80
1998	16.30	27.45	1026.00
1999	15.94	28.43	64.24
2000	16.54	28.13	1247.32
2001	16.43	28.36	1021.57
2002	16.91	28.41	1347.81
2003	17.49	29.01	1261.77
2004	16.35	28.75	1027.41
2005	15.97	28.47	925.71
2006	16.71	28.79	1091.26
2007	16.22	27.81	1249.75
2008	18.27	27.94	1117.39

2009	17.19	28.02	1041.47
2010	18.91	27.66	975.60
2011	19.30	28.40	1110.60
2012	18.57	28.57	1085.10
2013	19.10	28.30	1053.90
2014	16.85	28.97	904.60
2015	16.42	29.23	1244.60
2016	16.68	28.50	922.80
2017	16.72	29.28	1159.50
2018	16.63	28.64	1407.70
2019	17.26	29.94	1299.70
Average	16.88833	28.36033	1107.624

Thank you for your cooperation.

Appendix 4: Rice Production data for Mwea west sub-county

Rice quantity data from rice collection centers

S. NO. 103 GPS (0 ^{O} 41'3.43" S, 37^{O}21'18.77"E)

IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

Centre Name MRGM **Date** 8/9/2020 **Variety** Basmati 370

Year	Rice quantity (Kg)	Size of land in hectares	Rice grain total per hectare
1990	317900.1	300	1659.667
1991	237924.9	300	793.0831
1992	1021805.0	300	3406.017
1993	284920.4	300	949.7348
1994	378098.1	400	945.2451
1995	417124.2	400	1042.81
1996	139229.2	400	348.073
1997	620761.3	500	1241.523
1998	382799.1	500	765.5982
1999	23967.9	500	47.9357
2000	465373.3	1070	434.9283
2001	381146.3	1156	329.7113
2002	502865.9	1156	435.0051
2003	470764.5	500	941.5291
2004	383325.2	500	766.6503
2005	345381.0	500	690.7621
2006	407147.5	500	814.295
2007	466279.9	500	932.5598
2008	416896.6	500	833.7932
2009	388570.9	518	750.1369
2010	363994.9	375	970.6532

2011	414363.2	433	956.959
2012	404849.2	644	628.6479
2013	393208.6	645	609.6257
2014	337504.9	576	585.9461
2015	464358.4	675	687.9384
2016	344295.3	787	437.4782
2017	432607.8	467	926.3549
2018	525210.8	850	617.8951
2019	484916.2	1160	418.0312

Thank you for your cooperation

Rice quantity data from rice collection centers

S. NO. 104 GPS (0^{O} 40’ 55.29” S, 37^{O} 21’ 43.09”E)

IMPACTS OF CLIMATE VARIABILITY ON RICE FARMING IN MWEA, KIRINYAGA COUNTY, KENYA

Centre Name MIAD **Date** 7/9/2020 **Variety** Basmati 370

Year	Rice quantity (Kg)	Size of land in hectares	Kg per hectare
1990	2991000	7,022	427.285
1991	2384984	7100	335.9132
1992	10242676	7100	1442.63
1993	2856071	7300	391.2426
1994	3790093	7400	512.1748
1995	4181295	7400	565.0398
1996	1395647	7400	188.601
1997	6222575	7400	840.8885
1998	3837217	7400	518.5428
1999	240256.2	7400	32.46705
2000	4664949	7806	597.6107
2001	3820649	7806	489.4503
2002	5040779	7806	645.757
2003	4718991	7806	604.5339
2004	3842490	7806	492.2483
2005	3462135	7806	443.5222
2006	4081288	7806	522.8398
2007	4674037	7806	598.7749
2008	4179013	7806	535.3591
2009	3895074	7431	524.1656
2010	3648722	10526	346.639
2011	4153619	10629	390.7817

2012	4058250	10629	381.8092
2013	3941562	10629	370.831
2014	3383184	10629	318.2975
2015	4654776	10629	437.9317
2016	3451251	10629	324.7014
2017	4336504	10629	407.988
2018	5264766	11000	478.6151
2019	4860849	11000	441.8953

Thank you for your cooperation.

Appendix 5: Weather Data Collection Authorization Receipt

NATIONAL IRRIGATION BOARD
ISO 9001:2008 CERTIFIED

NATIONAL IRRIGATION BOARD
UNYUNYIZI HOUSE
LENANA ROAD - P.O. Box 30372-00100
NAIROBI-KENYA ,
FAX: +254 020-2722821/020-2711347,
E-MAIL:enquiries@nib.co.ke,
WEBSITE:www.nib.or.ke

OFFICIAL RECEIPT:

No. RC163661
Received from SIMON MUTISYA MATI
Scheme Code MIAD
Currency: KES
Date 9/9/2020
Narration METROLOGICAL WEATHER STATION DATA

NATIONAL IRRIGATION AUTHORITY
MWEA IRRIGATION AGRICULTURAL DEVELOPMENT CENTER
09 SEP 2020
PAID CASH
P.O. Box 210 - 10303, WANG'URU

Description	Pay Mode	Chq./Slip No.	Amount	Total
Miscellenious Income	Cash		5,000.00	5,000.00

Amount Excl VAT	KES	5,000.00
Amount Incl. VAT	KES	5,000.00

Amount in words **** FIVE THOUSAND AND 0/100

Signature: ....

You were served by: NIA\JMUTEMI
Time 4:24 PM