

**SEASONAL RAINFALL VARIABILITY EFFECTS ON MAIZE YIELDS AND
THE SMALLHOLDER FARMERS' ADAPTIVE STRATEGIES IN NYERI
COUNTY, KENYA**

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DECLARATION AND APPROVAL

Declaration

This thesis is my original work and has not been presented for a degree in any other university or for any other award.

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DEDICATION

This thesis is dedicated to Jesus Christ, Mary and Joseph, to whom I owe all that I am and have, and to my late father Peter Kabata, for reading through my thesis, and for teaching me that hard work pays.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASALs	:	Arid and semi-arid lands
ASDSP	:	Agricultural Sector Development Support Programme
ENSO	:	El Nino Southern Oscillation
EPZA	:	Export Processing Zone Authority
ESRI	:	Environmental Systems Research Institute
FAO	:	Food and Agriculture Organization
GDP	:	Gross Domestic Product
GOK	:	Government of Kenya
IFPRI	:	International Food Policy Research Institute
IPCC	:	Inter-governmental Panel on Climate Change
KNBS	:	Kenya National Bureau of Statistics
LR	:	Long Rains
MAM	:	March-April-May rainfall season
MoA	:	Ministry of Agriculture
NDMA	:	National Disaster Management Authority
NEMA	:	National Environmental Management Authority of Kenya
NCCRS	:	National Climate Change Response Strategy
OND	:	October-November-December rainfall season
RMA	:	Risk Management Agency
SR	:	Short Rains
SSA	:	Sub-Saharan Africa
SST	:	Sea Surface Temperatures
SWOT	:	Strengths, Weaknesses, Opportunities and Strengths
UNDP	:	United Nations Development Program
UNEP	:	United Nations Environment Program
WFP	:	World Food Program

OPERATIONAL DEFINITION OF TERMS AND CONCEPTS

- Adaptation Strategies** : Describes adjustments to long-term trends, which have transformational character and contribute to the exploration of positive opportunities (Bryan *et al.*, 2013).
- Adaptive capacity** : Is a system's ability to adapt to climate change, particularly rainfall variability, in order to mitigate possible harms, seize opportunities, or deal with the consequences. Adaptation can be spontaneous or intentional, and it can be done in response to or in preparation of climate changes.
- Cessation** : Cessation refers to the conclusion of the effective rainy season. It does not refer to the last day of rain, but rather to the point at which rain cannot be assured or effective any longer.
- Climate change** : A shift in the state of the climate that may be characterized by changes in the mean and/or variability of its attributes and that lasts for decades or more. It could be caused by natural internal processes, external forcing, or chronic anthropogenic changes in atmospheric composition or land use systems.
- Climate variability** : Climate variability on temporal and geographic scales beyond individual weather occurrences, as well as other statistics (such as the occurrence of extreme occurrences). Extensive droughts, floods, and conditions connected to El Nino or La Nina episodes are examples (IPCC, 2007). Internal variability (internal variability) or anthropogenic forcing (external variability) can both cause variability in the climate system (external variability).
- Coping strategies** : Describes a system's capacity to absorb shocks while maintaining function, exhibiting thereby similarities with

	the concept of resilience (Folke, 2006).
Household	: A person or a group of people who share the same cooking and investment arrangements and live in the same compound.
Inter-seasonal temporal rainfall variability	: Is the degree to which rainfall levels change over time between the seasons of Long Rains and Short Rains.
Intra-seasonal temporal rainfall variability	: Is the degree to which rainfall levels fluctuate over time within the seasons of Long Rains and Short Rains.
Maize yields	: This is the total maize yields produced in an area measured in kilograms per acre.
Mitigation strategies	: Mitigation reduces exposure to the risk, by taking measures/ acting upon the origin and attributes of the stressor (Gallopín, 2006).
Onset	: Sawa <i>et al.</i> (2011) define onset as the time when an area receives enough rain to support agricultural growth.
Rainfall Onset	Sawa <i>et al.</i> (2011) define onset as the time when an area receives enough rain to support agricultural growth.
Rainfall Cessation	: Sawa <i>et al.</i> (2011) defines cessation as the conclusion of the effective rainy season. It does not refer to the last day of rain, but rather to the point at which rain cannot be assured or effective any longer.
Rainfall Variability	: Refers to the fluctuating inter-annual or intra- or inter-season rainfall regimes as a consequence of climate change
Seasonal rainfall variability	: This is the degree to which seasonal rainfall amounts vary across an area or through time.
Vulnerability	: Refers to how vulnerable a system is to the negative effects of climate change, such as climate unpredictability and extremes, or how unable it is to cope with them.

ABSTRACT

Agriculture is Kenya's economic backbone and a source of income for the vast majority of the population. The primary goal of the agriculture sector is to achieve national food security. Because most agricultural activities in Kenya rely on rainfall patterns, short- and long-term variations in rainfall patterns affect crop productivity. The purpose of this study was to investigate the effects of seasonal rainfall variability on maize yields and assess the adaptive strategies of smallholder farmers in Nyeri County's Kieni East sub-County. The specific objectives were to determine the inter and intra seasonal temporal rainfall variability in Kieni East sub-County between 1988 and 2018, analyze the effects of seasonal rainfall variability on maize yields in the sub-County between 2009 and 2018, and assess smallholder maize farmers' adaptive strategies to the effects of seasonal rainfall variability. The following data sets were used in the study: rainfall data (1988-2018), maize data (2009-2018), a household survey (N=223), and in-depth interviews with MoA, meteorological personnel, and local administration (N=8). Structured questionnaires were used to collect data from smallholder maize farmers in the sub-County. Rainfall data was evaluated using trend analysis, standard deviation, correlation of variation, running means, and the variability index, to assess if there is variability in rainfall annually, within and between the two rainfall seasons. Similarly, maize yield data acquired from the MoA in Nyeri County was used to conduct trend analysis and calculate the variability index on an annual and seasonal basis. A correlation analysis was carried out to investigate the relationship between annual and seasonal rainfall and maize yields. According to the findings, yearly rainfall mean was 780.07mm, a standard deviation (SD) of 156.38mm and a correlation of 0.20. For the long rains, a mean of 260.86mm, an SD of 84.49mm and a correlation of 0.32. The short rains mean was 276.55mm, an SD of 126.09mm and a correlation of 0.46. The Karl Pearson Correlation test revealed a relationship between annual rainfall and annual maize yield of $r(10) = 0.821, p = 0.004$. Similarly, the Karl Pearson Correlation test found $r(10) = 0.634, p = 0.009$ for rainfall and maize yield under the long rains. The Karl Pearson Correlation test between rainfall and maize yield following short rains yielded $r(10) = 0.918, p = 0.000$, showing a strong significant positive relationship. According to the findings of the study, most farmers in Kieni East sub-County respond to rainfall variability by planting maize varieties that are early maturing (82.9 %) and drought tolerant (57.5 %), high yielding (77 %), disease resistant (57.6 %), use manure and fertilizers (92 %), seek extension training (29.6 %), and employ various water harvesting strategies. The outcomes of the research will be used by the MoA, other policy-makers and stakeholders to develop policies that address rainfall variability. The information will be used by smallholder maize farmers to evaluate their adaptive tactics and develop successful techniques for dealing with extreme rainfall variability. This will increase food yield and resilience to rainfall fluctuation, supporting the country in meeting the United Nations' Sustainable Development Goals (SDGs) 2 and 13, which aim to eliminate hunger and address climate change, respectively.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Some studies in rainfall evolution in many areas show that climate change translates into altered weather conditions such as rainfall variations and extreme events (WMO, 2013). Climate extremes are anticipated to grow more frequent and severe as a result of global warming, according to the IPCC (2012). Maize (*Zea Mays*) is a cereal crop that may be cultivated in a variety of agro-ecological situations. It is, after wheat, the world's second most significant food crop. Maize is farmed in various places of the world and in some places like in the tropics throughout both long and short rainy seasons, and matures in 90-190 days depending on the seed type (Schroeder *et al.*, 2013).

Rainfall in Africa is extremely varied, and it is influenced by both climate change and human activity (Muchuru & Nhamo, 2019). Due to its critical relevance in supporting life on earth, notably in the sector of agriculture, it is one of the most important climatic factors in developing countries (Wagesho, 2016). Several precipitation studies demonstrate that Africa is now warmer than it was 100 years ago, with increased inter-annual and intra-seasonal variability in rainfall (Cooper & Coe, 2011). Climate change is expected to increase climate variability, as well as the frequency and severity of extreme weather events in Africa and other parts of the world (Thornton *et al.*, 2011; Coumou & Rahmstorf, 2012; IPCC, 2012). Maize production in Africa is rain-fed, according to FAO (2009), making it extremely vulnerable to extreme weather events like rainfall variability. Variability in rainfall is observed in both seasonal and annual trends,

influencing various household livelihoods. Crop productivity is reduced by more variable rainfall patterns and unpredictable high temperature periods (Kumar *et al.*, 2012).

In Sub-Saharan Africa, maize is the most abundant crop, followed by sorghum and wheat (Macauley & Ramadjita, 2015). Muller *et al.* (2011) suggests that climate-induced risks, particularly those linked to rainfall, are the most significant drivers of crop production uncertainty in the majority of Sub-Saharan African regions.

Maize is an important cereal food crop in East Africa, with 7.3 million hectares grown each year, accounting for 21% of arable land and 41% of cereal land (Erenstein *et al.*, 2011). Maize yields vary greatly in the region, both geographically and temporally. Heavy rainstorms are projected to grow more prevalent in Eastern Africa, posing a threat to crop output (Herrero *et al.*, 2010). East Africa could lose 40% of its maize yield by the end of the twenty-first century due to a drop in existing farming acreage, due to drought (Lobell *et al.*, 2011). Limited seasonal length, heat stress, and severe weather all contribute to this decrease.

Climate is the most important predictive element in rain-fed agricultural systems in Kenya, and its impact is considerably higher especially in the Arid and Semi-Arid Lands (Herrero *et al.*, 2010). The amount, timing, and distribution of rain have all changed, resulting in lower agricultural productivity (Huho & Kosonei, 2013). Despite rising rainfall unpredictability in Kenya, rain-fed small-scale agriculture accounted for 75% of the country's agricultural production (Herrero *et al.*, 2010). The country's food security is challenged by a decrease in maize yield mixed with an increase in demand. Since the year 2000, Kenya has depended on maize imports and food aid because domestic production

has continuously fallen short of the country's consumption demands (Herrero *et al.*, 2010). According to FAO (2013) studies, maize is farmed on an estimated 1.5 million hectares in the country each year, yielding approximately 26 million bags of maize. This is less than the 34 million bags of maize that is predicted to be consumed in the country each year (Kang'ethe, 2011). Kenya has thus so far been unable to achieve maize self-sufficiency. Furthermore, maize output has expanded slowly, averaging roughly 2% per year, which is less than the 3.5% annual population growth rate (GoK, 2013; FAOSTAT, 2015).

Monthly rainfall variability is somewhat more noticeable in the drier zones of Kenya's central highlands, where maize farming is the staple food for 90% of the population and where Kieni East sub-County is located. The rainfall patterns in Nyeri County have altered, with amounts declining every 3-4 years (Karienyé *et al.*, 2012). Maize is mostly produced under rain-fed agricultural systems and rainfall may occur during 4-7 rainy months (Jaetzold *et al.*, 2007), but with high seasonal variations (Micheni *et al.*, 2004). Maize yields in 90kg bags were 61,531,000 in 2015, 13,028,000 in 2016, 18,114,000 in 2017, and 12,866,000 in 2018, according to a joint report by Kenya Food Security Steering Group (KFSSG) and Nyeri County Steering Group Nyeri County, Feb (2018), indicating variability, attributable in part to climatic hazards such as rainfall variability.

Rainfall distribution is getting increasingly variable and unpredictable in the county and in Kieni East sub-county. Prolonged cold seasons, increased frost incidences (typically coupled with dry spells), extended rainy seasons, and, in some locations, such as Kieni East, prolonged drought (MoALF, 2016), are further signs of climate extremes. In the

year 2013, floods resulted in a 15% reduction in agricultural areas in Kiamathaga in Kieni East sub-County, as well as an equal loss in maize yields (Orre *et al.*, 2013). As a result, changes in precipitation patterns are expected to have a negative influence on annual and seasonal maize yield.

Adaptive strategies will be critical in ensuring people's food security in the face of climate change and variability. Adaptation is a multidimensional, dynamic process that occurs at all temporal and geographic domains (Below *et al.*, 2010). The spectrum ranges from individual planting decisions made by smallholder farmers (at the micro-level) to long-term strategic decisions made by regional or national governments (macro-level). Both levels are intricately related to one another. Institutional and governance factors on a larger scale both impede and support local adaptation decisions (Eakin *et al.*, 2014). Smallholder farmers in Kenya are especially vulnerable to the effects of rainfall variability due to their limited adaptation capacity. In its Climate Change Adaptation Strategy 2009-2030, Kenya's government recognizes that adaptation to climate change and variability is the country's top priority. Adaptability to rainfall variability is critical when it comes to national food security (GoK, 2013). Among the most often reported adaptation tactics of smallholder farmers to climate change include changes in crop variety, planting dates, irrigation, soil conservation measures, water harvesting, and crop types (Bryan *et al.*, 2013).

Many sections of the country still lack proper institutional framework conditions, leaving resource-poor smallholder farmers fighting climatic and economic difficulties on their own. This is the case in the Kieni East sub-County. Lack of an appropriate policy and

legal framework that is conducive to the operations of the agriculture department still remains an issue in spite of some progress having been made, according to the Nyeri County strategic plan 2018/19-2022/23. Traditional adaptive techniques in the country, notably in Kieni East sub-County, Nyeri County, are likely to be overwhelmed by increased frequency of rainfall variability and shocks. As a result, there is a need to better understand, document, and reinforce existing adaptation techniques, which served as the foundation for this study.

1.2 Statement of the problem

Maize is the second most important food crop grown in most parts of the world, and it is a staple food in Kenya, especially in Kieni East sub-County. Due to decreasing land sizes as a result of land fragmentation, the majority of maize farmers in Kenya are smallholders. Kenyan maize production is rain-fed, making it more subject to variations in rainfall. According to climate data simulations, there is still a high possibility that climatic circumstances will become more unfavorable in the future. In its Climate Change Adaptation Strategy 2009-2030, Kenya's government recognizes that adaptation to climate change and variability is the country's top priority. Farmers have enhanced their resilience and adaptive potential through indigenous knowledge through the years. However, the rising variety, frequency, and severity of rainfall shocks are expected to outstrip their existing adaptation methods.

Furthermore, as low-income producers who frequently lack institutional backing from national and county governments, they lack the wherewithal to invest in long-term adaptive technologies and tactics at the local level. Although existing programs and

projects geared to support growing resilience and are in accord with current frameworks, policies, and initiatives in the County and in the Kieni sub-County, there is a mismatch between policies and programs. The amount of policy adoption is uncertain and ambiguous, as seen by the Nyeri Climate Change Policy Framework, creating a gap that necessitated this study. Lack of an appropriate policy and legal framework that is conducive to the operations of the agriculture department still remains an issue in spite of some progress having been made, according to the Nyeri County strategic plan 2018/19-2022/23. This study sought to fill this gap by analyzing the effects of seasonal rainfall variability on maize yields, as well as to understand the existing adaptive strategies used by smallholder farmers in the study area, as well as their costs and constraints to the farmers, and to document them so that relevant authorities, such as the Ministry of Agriculture, Nyeri County, can strengthen them in order to improve yields.

1.3 Study Objectives

1.3.1 General Objective

The study's general objective was to contribute to a better understanding of the effects of seasonal rainfall variability on maize yields and smallholder farmers' adaptive strategies in Kieni East sub-County, Nyeri County, Kenya.

1.3.2 Specific Objectives

The study's specific objectives of the research were to:

- (i) To determine the intra- and inter-seasonal rainfall variability in Nyeri County's Kieni East sub-County between 1988 and 2018.

(ii) To analyze the effects of seasonal variability of rainfall on small-holder farmers' maize yields in Kieni East sub-County between 2009 and 2018.

(iii) To assess the existing small-holder farmers' adaptive strategies to the effects of seasonal rainfall variability on maize yields in Kieni East sub-County, Nyeri County.

1.4 Research Questions

- (i) How has the inter- and intra-seasonal rainfall variability been in Kieni East sub- County between 1988 and 2018?
- (ii) Is there a significant relationship between maize yields and seasonal rainfall variability in Kieni East sub-County between 2009 and 2018?
- (iii) What are the current smallholder farmers' adaptive strategies to the effects of seasonal rainfall variability on maize yields in Nyeri County's Kieni East sub-County?

1.5 Research Hypotheses

H₀1: There is no significant inter- and intra-seasonal rainfall variability in Kieni East sub-County between 1988 and 2018.

H₀2: There is no significant relationship between both seasonal and temporal rainfall variability and smallholder farmers' maize yields in Kieni East sub-County between 2009 and 2018.

1.6 The study's justification and significance

Agriculture is a key occupational sector in many Sub-Sahara Africa (SSA) nations and a source of income for the rural population (UNEP, 2011). Maize is grown on around 100 million hectares in the developing countries, according to estimates. According to FAOSTAT (2010), the medium and lower income earners account for almost 70% of total maize yield in these nations. In Sub-Saharan Africa, rain-fed agriculture accounts for nearly 90% of staple food production (Cooper & Coe, 2011). Smallholder rain-fed agricultural systems (averaging 0.2-0.3 ha in size) dominate Kenyan food production, accounting for 75% of total agricultural output and 70% of marketed agricultural items (Hickey *et al.*, 2012; Bryan *et al.*, 2013; Barasa *et al.*, 2015).

Rainfall is the most important climatic component in affecting crop production distribution in space (Makenzi *et al.*, 2013), with agricultural activities following rainfall patterns, especially in tropical regions (Huho *et al.*, 2012). According to studies, climate variability will continue to be an issue for rural communities that rely on agricultural production. The majority of Kenyan households farm maize, the country's principal staple crop that sustains over 85% of the population (Mohajan, 2014), on approximately 17% of the country's geographical area USAID (2010). Her national food security is intrinsically related to her ability to cultivate enough maize to fulfill rising domestic demand from an increasing population. Kenya's Agricultural Sector Development Strategy (2009-2020), and the Vision 2030 emphasizes the need for increasing productivity, commercialization and competitiveness of the agricultural sector as well as the need for efficiency and better management in the utilization of public resources. The ASDS aims at positioning the agricultural sector in the lead as a key driver for delivering the 10% annual economic

growth rate envisioned under the economic pillar of Vision 2030. Furthermore, maize output has expanded at a marginal rate of around 2% per year, which is lower than the 3.5% annual population growth rate. As a result, to attain self-sufficiency, maize production must increase by more than 4%. As a result, Kenya continues to be a net importer, with more than 40% of the population living in poverty. Furthermore, a reliance on imports may cause development funding to be diverted to food purchases (Mutimba *et al.*, 2010; FAOSTAT, 2015).

According to studies, climate variability will continue to be an issue for rural communities that rely on agricultural production. The rainfall patterns in Nyeri County have altered, with amounts declining every 3-4 years (Karienyee *et al.*, 2012). Maize yields in 90kg bags were 61,531,000 in 2015, 13,028,000 in 2016, 18,114,000 in 2017, and 12,866,000 in 2018, according to a joint report by Kenya Food Security Steering Group (KFSSG) and Nyeri County Steering Group Nyeri County, Feb (2018), indicating variability, attributable in part to climatic hazards such as rainfall variability. In the year 2013, floods resulted in a 15% reduction in agricultural areas in Kiamathaga in Kieni East sub-County, as well as an equal loss in maize yields (Orre *et al.*, 2013). The maize crop was therefore chosen because of its importance in the local diet of people in central Kenya, notably in Kieni East sub-County, where the majority of farmers are smallholder farmers who rely on rain-fed agriculture, as well as its extensive cultivation throughout the country.

Understanding climatic parameters, particularly rainfall, is critical to enhancing the socio-economic well-being of smallholder maize farmers in the sub-County. The outcomes of

the research will be used by the MoA, other policy-makers and stakeholders to develop policies that address rainfall variability. The information will be used by smallholder maize farmers to evaluate their adaptive tactics and develop successful techniques for dealing with extreme rainfall variability. The findings will also serve as a foundation for ongoing learning and the selection of farmer innovations that are likely to improve smallholder farmers' adaptive strategies.

1.7 The Study's Scope and Limitations

The research was carried out in Nyeri County's Kieni East sub-County. The small-holder sub-county's maize farmers were the target population. The primary goal of the study was to examine the effects of seasonal rainfall variability on maize yields in the sub-County, as well as to evaluate small-holder farmers' adaptive strategies. The parameters that were examined on seasonal rainfall were rainfall onset, peaks and cessation in both MAM and OND seasons. The study was carried out between October 29th and November 30th, 2019. A timeframe of 30 years was chosen for the study because it is a standard period of climate change as specified by the World Meteorological Organization (WMO, 2017) and hence long enough to detect any significant changes in rainfall as a climatic variable. One of the study's limitations was the maize farmers' reluctance to offer precise information on total yields from their farms, but they were promised that the study was solely for academic purposes and that the information acquired would be held in the strictest confidence.

Data on annual and seasonal rainfall (MAM and OND) and annual and seasonal maize yields were similarly difficult to come by. Only data from one of the five sub-county's

rainfall stations (Loruku farm) was used. The availability of complete data, that is, more than 10% as recommended by the World Meteorological Organization (WMO), for 30 years, a timeframe adequate for a climatological analysis (Atheru, 1999) and relevant to the current study, influenced station selection. Because there was no available recorded data from the Ministry of Agriculture, Livestock, and Fisheries in the County for the earlier years in the sub-County, annual and seasonal maize yields were analyzed for 10 years from 2009 to 2018. Other factors influencing maize yields, such as pest and disease infestation, poor farming practices, and socio-economic concerns, were considered to be absent in this study, while accepting that maize yields are also influenced by non-climatic factors.

Due to data limitations, the study purposely focused solely on one climatic element, rainfall, while excluding others and acknowledging that water, warmth, light, and air fit within the four fundamental criteria for plant growth. The study also concentrated on the maize crop, eliminating other food crops grown in the area, because the Kieni East sub-County is mostly a maize-growing area. It's probable that recent climatic occurrences, acute socio-economic challenges, as well as hopes of immediate advantages from the study, influenced the questionnaire answers. Despite these flaws, the study's integrated design (questionnaire, interview, and analysis of rainfall variability) provided checks and balances that resulted in more informed responses and less subjectivity.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the existing literature on rainfall variability, its effects on maize farming, smallholder farmers' adaptation strategies to rainfall variability, and theoretical and conceptual frameworks that demonstrate the interrelationships between independent, dependent, and intervening variables in the study.

2.2 Intra and Inter-Seasonal Rainfall Variability

Climate change is now a fact, and its effects are being felt all across the world. Global evidence of climate change is accumulating as a result of rising carbon emissions and other greenhouse gases (GHG) entering the atmosphere. Climate and weather variability, particularly rainfall variability, are projected to increase as the globe warms, with unforeseeable consequences in many parts of the world. Climate change is increasing the variability of inter-annual rainfall as well as the frequency of extreme events (Ojwang *et al.*, 2010). Changes in the frequency and severity of extreme climate events, as well as weather pattern variability, will have far-reaching consequences for human systems (Thornton *et al.*, 2014). Recurrent extreme weather events have significant economic consequences for impacted households and can lead to food insecurity, significantly influencing the economic well-being of affected areas and limiting or impeding long-term progress (IFPRI, 2011).

Climate change is expected to increase climate variability, as well as the frequency and intensity of extreme weather events in Africa and elsewhere (Muller *et al.*, 2011; Thornton *et al.*, 2011; Coumou & Rahmstorf, 2012). However, when it comes to climate change and extreme events, Africa is lacking in expertise (Herrero *et al.*, 2010). Droughts, which have plagued Africa for decades, have caused rural residents to adapt to climate variability stress factors (Mertz *et al.*, 2011). According to the IPCC (2012), an increase in the frequency of heat stress, drought, and flooding events is predicted for the rest of the century, with several severe implications in addition to those induced by changes in mean variables alone. Temperatures in Sub-Saharan Africa (SSA) are predicted to rise, as are changes in rainfall intensity and distribution, as well as an increase in the occurrences of extreme weather events (such as droughts and floods), pests, weeds, and disease epidemics (FAO, 2015; Connolly-Boutin & Smit, 2015). Thus, rain-fed agriculture is likely to be increasingly impeded in many parts of Africa as a result of increased climate-related threats.

According to Niang *et al.*, (2014) climate variability is projected to enhance precipitation fluctuations in East Africa. Farmers in this region have always had to contend with a great deal of variance in rainfall, both within and between seasons, and their farming practices have never remained consistent (Cooper & Coe, 2011). According to studies, many farmers in Kenya and Uganda are noticing climate changes such as changes in the commencement and termination of rainy seasons, increased rainfall variability, and decreasing rainfall (Osbahr *et al.*, 2011; Ogalleh *et al.*, 2012; Simelton *et al.*, 2013). In studies that have explored onset over East Africa, onset and cessation are defined as the global maxima and minima of a time series of station rainfall (Camberlin *et al.*, 2009) or

an accumulation of daily precipitation anomalies (Dunning *et al.*, 2016). The mean dates and variability of the onset and end of rains in Kenya and Tanzania have been determined for the two rainy seasons, long rains and short rains (Philippon *et al.*, 2015). Camberlin and Okoola (2003) and Mugalavai *et al.* (2008) investigated the start and end of rainfall in Kenya and linked it to atmospheric, oceanic, and local factors (winds, water body, vegetation cover and topography). The onset of the long rains has been linked to equatorial zonal winds across Kenya and Tanzania (Camberlin & Okoola, 2003).

Climate change is already causing changes in precipitation patterns and more frequent and irregular extreme events such as floods and droughts in Kenya (Badege *et al.*, 2013). Climate change and variability have sparked debate among policymakers and agricultural practitioners about the implications for smallholder rain-fed farming (Jokastah *et al.*, 2013). According to Huho and Mugalavai (2010), the great majority of Kenya is classified as ASALs, which include the Kieni East sub-County. According to Omwoyo *et al.* (2015), Kenya's arid and semi-arid counties experience significant climate variability, which has major implications for maize yields and food security, and climate change-related agricultural constraints range from pronounced seasonality of rainfall to severe and recurrent droughts. As a result of these findings, Barron *et al.* (2003) recommended characterizing rainfall variability at a local level as a first step in on-farm management.

In East Africa less attention has been paid to onset and cessation than to seasonal totals (Nicholson, 2017). According to a study by Bryan *et al.* (2011), farmers are more concerned about growing variability and seasonal differences, which limits their ability to predict rainfall patterns and plan their farming activities accordingly. Therefore the study

of variables such as rainfall volume, rainy days, growing season duration, and frequency of dry spells, as well as within-season and inter-season rainfall variability, has piqued interest in the past and continues to do so now. This knowledge gap necessitated this study to examine and provide data on inter- and intra-seasonal rainfall variability in Kieni East sub-County, Nyeri County, Kenya, between the years of 1988 and 2018.

2.3 Effects of Rainfall Variability on Maize Farming

The agricultural sector is severely influenced by changing climatic circumstances, as accumulating evidence reveals (Lobell *et al.*, 2011; Khanal & Mishra, 2017), and the severity of which is anticipated to increase in the near future, with poorer countries being the most affected (IPCC, 2012, 2014). Climate models have been used in some studies to project future climatic situations in order to advise policymakers about what to expect and possibly put policies in place to address the changes that are expected to occur (Urban *et al.*, 2012). Long-term climate change has a huge impact on world food production. Weather anomalies and rapid onset of extremes (dry spells, droughts, and floods) have a negative impact on crop yields through pest and disease outbreaks (Gornall *et al.*, 2010), changes in soil fertility (Clair & Lynch, 2010), moisture content, and, most importantly, water quality and resources (Malek, 2018). Furthermore, climate-related impacts, according to the IPCC (2014), will increase the likelihood of food insecurity and food system disruption.

Drought and heat effects on crops have been studied extensively using both empirical (Lobell *et al.*, 2013; Troy *et al.*, 2015; Zipper *et al.*, 2016), and model-based methods (Glotter & Elliot, 2017). Despite accessible field and experimental evidence, extreme

rainfall has received little attention (Shaw & Meyer, 2015). Rainfall unpredictability will reduce global production of essential crops like maize, wheat, and rice (Lobell *et al.*, 2011; Sage *et al.*, 2015). Heat, drought and severe rainfall have all increased dramatically in the United States since 1980 (Mazdiyasi & AghaKouchak, 2015; Wuebbles *et al.*, 2017). Climate extremes have already wreaked havoc on maize production in the United States (Lobell *et al.*, 2013; Troy *et al.*, 2015; Zipper *et al.*, 2016), and they are predicted to become more common and severe in the future (Wuebbles *et al.*, 2017).

According to Khuram and Rasul (2011), the most basic requirement for crop growth from planting to maturity is soil water (whose main input is rainfall). Khuram and Rasul (2011) discovered a 61% and 60% correlation between rainfall and maize grain yield during the vegetative and productive seasons, respectively. Total rainfall over the growing season ranged from 135 to 530mm, which was consistent with the results. With rainfall totals of 300mm, 277mm, and 168mm throughout the growth season, vegetative phase, and reproductive phase, respectively, they had the highest yields. These rainfall events with the highest yields were regarded ideal rainfall occurrences in Pakistan's desert region.

Climate change is seen as one of the primary concerns hampering Africa's efforts to achieve food security, due to the continent's reliance on rain-fed agriculture and smallholder farmers' limited ability to adapt to climate change and variability (IPCC, 2014; Phirri *et al.*, 2016). In SSA, a predominantly agricultural-based economy, small-scale farmers account for 75% of agricultural production and 75% of employment (Salami *et al.*, 2010). Climate variability has been cited as a major factor in rural

subsistence farmers' low crop yields (Kamau *et al.*, 2011). For example, climate variability, notably rainfall variability and related droughts, have exacerbated food insecurity and famine in Ethiopia (Conway & Schipper, 2011; Demeke *et al.*, 2011; Rosell, 2011). Several studies have found that rainfall amount and distribution is the most important factor influencing inter-annual crop output changes in Ethiopia, and that it has had a significant impact on the country's economy and food production during the previous three decades (Araya & Stroosnijder, 2011; Conway & Schipper, 2011; Demeke *et al.*, 2011). Food production must be considerably increased to feed an ever-increasing population (Thornton *et al.*, 2011).

The Sub-Saharan Africa (SSA) has been identified as one of the most sensitive to the effects of climate change (Bryan *et al.*, 2013; IPCC, 2014). Crop yields in Southern and Western Africa could decline by 18-45% by the end of the century, with an overall mean decline of 24 % in most of Sub-Saharan Africa, according to Waha *et al.* (2013), based on three general circulation models (GCMs: MPI-ECHAM5, UKMO-HadCM3, and NCAR-CCSM3) using the SRES A2 emission scenario. Rain-fed agriculture, particularly in tropical and semi-arid climates, is characterized by poor crop yields that are significantly below potential yields attainable in the location, as well as significant on-farm water losses. Rain-fed cereal yields in tropical and semi-arid Sub-Saharan Africa, for example, have been reported to be around 1 ton ha⁻¹ (Rockstrom, 2001), compared to potential yields of 3-5 tons ha⁻¹ in the region (Barron, 2004). This substantial disparity demonstrates that there is a significant opportunity to boost rain-fed agriculture crop yields.

According to Muga (2010), increased crop variability (deviation from the mean) is also a major concern for farmers in Eastern Africa. Any change in climate variables has a negative impact on the stability and availability of agricultural products (Gregory *et al.*, 2011). Drought at the flowering stage prevents pollination and severely reduces yield (Schroeder *et al.*, 2013). Warm ENSO occurrences, also known as El Nino occurrences, result in exceptionally heavy precipitation in parts of equatorial East Africa, causing flooding and reduced agricultural productivity.

Maize farming is also rain-fed in East Africa, and it is grown at a variety of latitudes, altitudes, moisture regimes, slopes, and soil types (Livingstone *et al.*, 2011). Small-scale family farms grow maize mostly for domestic consumption and local markets (Erenstein *et al.*, 2011). The region's maize yield is very variable both spatially and temporally. Large-scale spatial variability is explained by differences in rainfall and soil characteristics (Harvest Choice, 2010; Smale *et al.*, 2011; Yengoh, 2012), whereas small-scale variability is influenced by farm management decisions such as sowing dates, weeding, pests, diseases, fertilizer application, and tilling method. Conversely, biophysical factors such as rainfall, soil characteristics, elevation, and floods are blamed for small-scale variability (Sacks *et al.*, 2010; Vyas *et al.*, 2013; Nathan, 2014).

The inter-annual fluctuation of rainfall and temperature, which results in recurrent droughts in the region, is a key determinant of maize yield temporal variability (Magehema *et al.*, 2014). This wide range of yields emphasizes the importance of assessing and monitoring yields throughout the growing season. According to Zhao *et al.* (2013), the most sensitive stage of the maize crop when soil moisture must remain

optimal is during the reproductive stage, which is very prone to water stress. When the amount of water lost in the soil exceeds the amount absorbed, maize yields may be reduced. When a large amount of water is lost, the maize crop will be unable to absorb nutrients from the soil, resulting in the plant's weakness and vulnerability to pests and diseases. The result is either a total crop loss or a reduction in maize output (Sheng *et al.*, 2014). East Africa has larger inter-annual rainfall variability than other tropical regions with similar average climatic conditions (Camberlin, 2010). In addition to inter-annual variability, intra-season variability can affect crop output (Cooper *et al.*, 2008).

Kenya's rain-fed food yields are anticipated to plummet by half by 2020 (Ojwang *et al.*, 2010). Due to rainfall variability, Kenya was projected to continue to lose output of important commodities such as maize across the country (Herrero *et al.*, 2010). In Kenya, studies of the influence of climate change on crop productivity have focused on the implications of climatic means, rather than individual climate variables like as rainfall (Bilham, 2011; Cheserek, *et al.*, 2015). In some locations, rainfall variability, especially the severity and frequency of extreme events, is predicted to increase, and such changes are anticipated to have a greater negative effect on crop yields than changes in climate alone (Rowhani *et al.*, 2011).

Rainfall variability, according to Herrero *et al.*, (2010), decreases the output of not only staple food crops like maize, but also other significant crops like tea, sugarcane, and wheat. Rainfall is significant in farming because it is a signal of long-term changes in the climatic system. The pattern of rainfall, on the other hand, is more important to farmers (Falaki *et al.*, 2013). Furthermore, different roles played by intra-seasonal and inter-

annual rainfall variability on crop production fluctuations in the tropics in general, and East Africa in particular, and so therefore in the study area, remains poorly understood. It is for this reason that this region must be prioritized in terms of research. As a result of this gap, this study therefore sought to empirically determine the effects of seasonal rainfall variability on maize yields by smallholder farmers in Kenya's Kiambu East sub-County, Nyeri County.

2.4 Smallholder Farmers Adaptive Strategies to Rainfall Variability

Adaptation to climate variability refers to system changes that reduce the negative effects of climatic variability while maximizing the beneficial effects. Communities have been adapting to climate change for a long time using indigenous knowledge, but most of these adaptations are discrete and reactive (UNDP, 2010). Sustainable adaptation methods have long been recognized as a way to mitigate the detrimental effects of climate variability on agricultural production (Kabubo-Mariara, 2007). Sustainable adaptation strategies are derived from the United Nations' Sustainable Development Goals (SDGs) 2 and 13, which address zero hunger and climate action, respectively. The primary areas of concern for the two SDGs are food productivity and climate resilience initiatives. The essential characteristics of adaptation are three pillars: dependable, affordable, and acceptable practices.

Adaptation actions can be divided into two broad categories (Vermeulen *et al.*, 2013): i) practices that have evolved over time as a result of farmers' long-term experiences in response to perceived impacts, and ii) planned adaptations to current and future climate

change, such as integrated packages of improved agricultural technologies like breeding, agronomic practices, and policy options.

Globally, technical advancements have given farmers the ability to adjust to climate constraints and opportunities through time. Farm households employ adaptive strategies to environmental and socio-economic changes as part of their production and consumption decisions based on their long-term experiences and subjective risk assessments (Thornton *et al.*, 2010).

Climate adaptation strategies can alternatively be classified as autonomous or self-contained, and planned or public-sector adaptation plans. Non-state actors such as farmers, communities, organizations, and/or businesses engage in private adaptation strategies in response to the effects of climate variability. Switching crops, modifying planting dates, engaging new management methods for a certain climate regime, modifying irrigation systems, and adopting various farming technologies are all examples of sustainable adaptation strategies, according to Bruin (2011). Public adaptation involves actions taken by local, regional and/or national government to provide infrastructure and institutions to reduce the negative impact of climate variability. Development of new irrigation infrastructure, transportation or storage infrastructure, land use arrangements and property rights, and water shed management organizations are all examples of public adaptation strategies (World Bank, 2010).

Climate change and fluctuations have a significant negative influence on Sub-Saharan Africa (Niang *et al.*, 2014). Increased temperatures, along with irregular rainfall and uncertainty about when the rains will arrive, have serious consequences for millions of

people's livelihoods (Dube *et al.*, 2016). This variability will worsen current vulnerabilities and offer issues for many rural households unless proper adaptation is made (IPCC, 2014). Varied asset bases can lead to divergent adaptation techniques across households in a single community, according to studies (Jain *et al.*, 2015). Replanting, selling assets, reducing consumption, and borrowing assets are popular techniques used by poorer people to alleviate the effects of drought, floods, and pest and disease impacts (Tongruksawattana, 2013). Adaptive capability will play a big role in people's ability to maintain food security in the face of climate and weather changes. The relationship between risk perception, socio-economic restrictions, and adaptation activity has not been fully examined in Sub-Saharan Africa, a knowledge gap that necessitated this study. Understanding the decision-making process of farmers is critical for forecasting future behavior and appreciating the factors that influence the process (Le Dang *et al.*, 2013).

In most parts of Kenya, smallholders see rainfall variability as a threat to agricultural productivity (Bryan *et al.*, 2013). Semi-arid regions, such as Kitui County, for example, are particularly vulnerable to rainfall variability because a large population is less able to buffer and recover from climate stress (Oremo, 2011). Lack of resources, poor water access, and a lack of awareness are all important impediments to the adoption of more expensive farming practices (Bryan *et al.*, 2013). Diversification with cash crops, according to Herrero *et al.* (2014), can be a crucial intensification strategy for smallholders as the socio-economic backdrop changes and land size and labor costs reduce. Adjustments in planting dates (Ogalleh *et al.*, 2012; GoK, 2013) are commonly applied, however, changes in water or land management strategies, such as building an irrigation system or agro-forestry, are underutilized (Kristjanson *et al.*, 2012; Bryan *et al.*,

2013). Age, gender, agricultural experience, and education have all been found to have an impact on the adoption of specific adaptation strategies (Below *et al.*, 2014). Cultivating high-value crops in mixed farming systems may allow farmers to take advantage of high market prices during dry seasons, raise their income, and improve their drought resilience (Waha *et al.*, 2013). Such solutions, however, are confined to places with sufficient water supply and irrigation infrastructures (Claessens *et al.*, 2012). In this sense, adaptive measures have a lot of geographic variety between countries, regions, systems, and groups. This undercuts the significance of taking local level issues into account when researching adaptation solutions (Ogalleh *et al.*, 2012; Below *et al.*, 2014).

Kenya's government realizes that adaptation to climate change is the country's top concern. When it comes to national food security, the agriculture sector, in particular, plays a critical role (GoK, 2013). In order to maintain recent positive agricultural growth, defend the national economy, and protect rural lives, a number of initiatives, programs, and governmental entities have been established, one of which is the *National Drought Management Authority (NDMA)*, which was established in 2011. Special attention is given to drought impacts in arid and semi-arid lands (ASALs), which are highly vulnerable to climate change impacts and host 30% of the country's population (GoK, 2013).

Although these strategies exist on paper, the benefits have not yet reached the majority of smallholder farmers in Kenya. Many of these national strategies have been criticized for being unable to incorporate already existing knowledge and technologies at local level (Ogalleh *et al.*, 2012). Adaptation to climate variability requires that households

appreciate that there exists climate variations and recognize useful adaptation options, choosing among a wide range of strategies at their disposal. As a result, households in the same geographical location utilize different adaptation strategies in response to climate variability (Micah & Absalom, 2014). Simultaneously, there is a substantial body of literature devoted to the effects of climate change on individual crops at the field scale (Thornton *et al.*, 2010; Rurinda *et al.*, 2014). The goal is to generate generalizable data that can be used by adaptation planners to encourage broader adoption of better farming techniques. Investing in adaptation measures at the national, county, and local level is, nevertheless, critical. More research is needed to determine how agricultural policies aid or hinder smallholder farmers' ability to adjust to climate change and rainfall variability (Lal *et al.*, 2015).

Climate change impacts and adaptation options are frequently assessed using aggregated data from country or regional levels in research (Wood *et al.*, 2014). Furthermore, scientific literature rarely addresses climate change perception as it relates to adaptive behavior at the individual farm level. With the right adjustments at the home level, food yield can be increased (Di Falco & Veronesi, 2013; Di Falco, 2014). This study was inspired by the urgent need for micro-level data to enable policy-makers and extension officers to adapt national programs to local realities and promote targeted interventions. Thus, the study sought to fill this gap by assessing the existing adaptive strategies of the small-holder maize farmers in Kieni East sub-County to the effects of seasonal rainfall variability, as it is the micro-level decision-making of smallholder farmers that matters in boosting maize yields.

2.5 Theoretical Framework

The resilience theory underpins the research. The term 'resilience' was coined in the 1970s in the field of ecology from the research by Holling (1973), who described it as "a measure of persistence of systems and their ability to absorb change and disturbance while maintaining the same correlations between population or state variables" (Holling, 1973). The ability to adapt successfully in the face of danger or calamity is referred to as resilience. Some variables of resilience that are relevant in this study are adaptability, perseverance and a high tolerance of uncertainty. Resilience in social systems has increased people's ability to plan for the future. Humans are a part of the natural world, and because environmental changes are unavoidable, they devise coping methods to ensure their survival. According to the theory, it is not the form of hardship that matters, but how we respond to it. Resilience helps us bounce back when we experience hardship, tragedy, or frustration. It enables us to survive, recuperate, and even thrive in the face of adversity. Ethnicity, color, gender, age, and economic status, among other things, all have an impact on resilience. This results in a variety of responses as well as adaptive strategies in the face of adversity. To respond successfully to a hazard effect, a community requires social, institutional, and informational resources (Zhong *et al.*, 2010).

He goes on to define it as a system's ability to absorb disturbance and reorganize itself while changing while maintaining essentially the same purpose, structure, and identity. A disaster-resilient nation is one in which communities develop adaptive techniques to sustain vital community services and recover swiftly when big disasters occur, as a result of mitigation and pre-disaster planning. Initially, livelihood plans are formed in response

to catastrophic events that farmers must deal with (Morton, 2007). Some of these solutions gradually become part of the farming system's DNA, reducing overall vulnerability to variability (Morton, 2007).

Inter-annual rainfall variability and the frequency of extreme events are growing as a result of climate change (Ojwang *et al.*, 2010). Repeated extreme weather occurrences can have significant economic consequences for impacted households and lead to food insecurity. Natural dangers abound in the Kieni East sub-County of Nyeri County, Kenya, and the most common of which being adverse weather change (GoK, 2010). Maize represents about 90% of the population's staple diet, and it is grown in rain-fed circumstances. Increased frost, extended wet seasons, pests and diseases, and protracted drought are all examples of climate extremes in the research area, according to MoALF (2016). Agricultural activities follow rainfall patterns, especially in tropical regions (Huho *et al.*, 2012), and with amounts decreasing every 3-4 years (Karienyé *et al.*, 2012), maize yields are significantly affected in Nyeri County, and therefore in Kieni East sub-County.

As a result, this study sought to examine inter and intra-seasonal rainfall variability as the independent variable, with a particular focus on parameters such as seasonal rainfall onset, peak, cessation, rainfall amount, and their effects on smallholder farmers' maize yields as the dependent variable. It also assessed the farmers' adaptive strategies as the intervening variables, such as early planting, soil and water conservation, and management methods, all of which are crucial in increasing maize yields, as an indication of adaptability, perseverance and a high tolerance of uncertainty to seasonal rainfall

variability. The study is in keeping with the National Climate Change Response Strategy's (NCCRS) goals of improving Kenyans' abilities to deal with climate change concerns and ensuring a climate-resilient nation. This would help Kenya accomplish the Millennium Development Goals (MDGs), as well as Kenya's Vision 2030, which aims to improve local environmental resource management and rural livelihoods that are resilient to rainfall variability.

2.6 Conceptual Framework

The independent variable in this study was rainfall variability, and the dependent variable was maize yield in 90kg bags per acre in Kieni East sub-County. The study examined the inter- and intra - seasonal rainfall variability, using rainfall onset, cessation, peak months, and total rainfall amount as parameters, as well as their effects on maize yields during both short and long rains. It also evaluated how small-holder maize farmers adopted to the effects of seasonal rainfall variability, which were the adoptive strategies. The adaptive strategies include early planting, soil and water conservation and management methods, drought-tolerant crop planting, irrigation, intercropping, crop rotation, manure and fertilizer use which are essential factors in increasing maize yields. Intervening factors include socio-economic factors, pests and diseases, environmental factors, institutional and legal framework and storage which play a part in influencing maize yields.

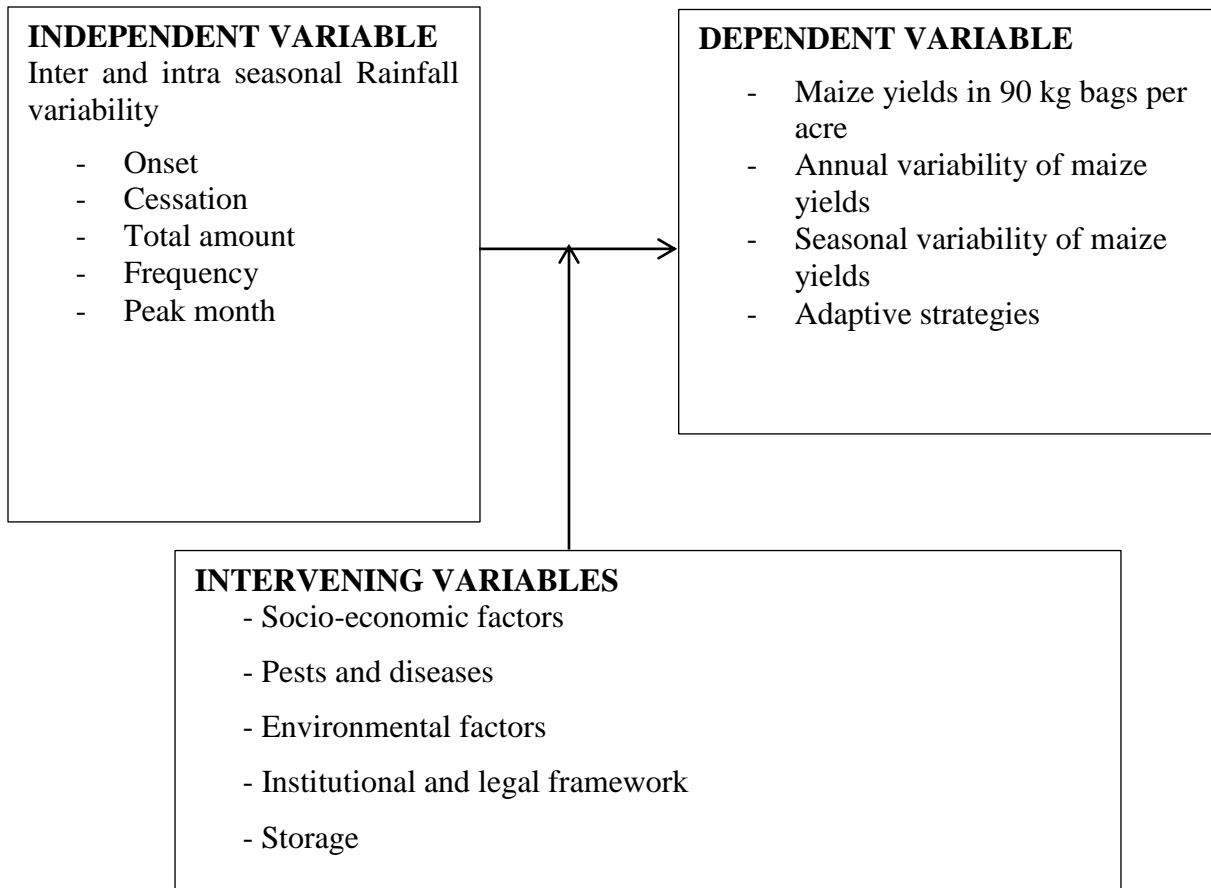


Figure 2.1: Conceptual framework on the effects of seasonal rainfall variability on maize farming

Source: Adapted and modified from Kiprono (2009)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The research design, study area, sampling techniques and procedures, data collection techniques, data analysis, and ethical considerations are all covered in this section.

3.2 Description of the Study Area

3.2.1 Location of the Study Area

The research was carried out in Nyeri County's Kieni East sub-County. Narumoru/Kiamathaga, Kabaru, Thegu, and Gakawa are the four wards that make up the sub-County. It has a population of 96,500 persons and 29,012 households (KNBS, 2010). The study used the 2010 population data because the population census of the year 2019 had not yet been done by the time the study was carried out. It is expansive, covering an area of 817.1 km² (GoK, 2013). The sub-County is located between latitude 0⁰ 00' and 0⁰ 24' S and longitude 37⁰ 00' and 37⁰ 12' E. According to the study area map Fig 3.1, it borders Meru central sub-County to the north, Mathira sub-County and Nyeri municipality to the south, Mt. Kenya to the east, and Kieni west sub-County to the west. The size of the land per household varies by sub-County, but averages 2 hectares (Jaetzold *et al.*, 2007).

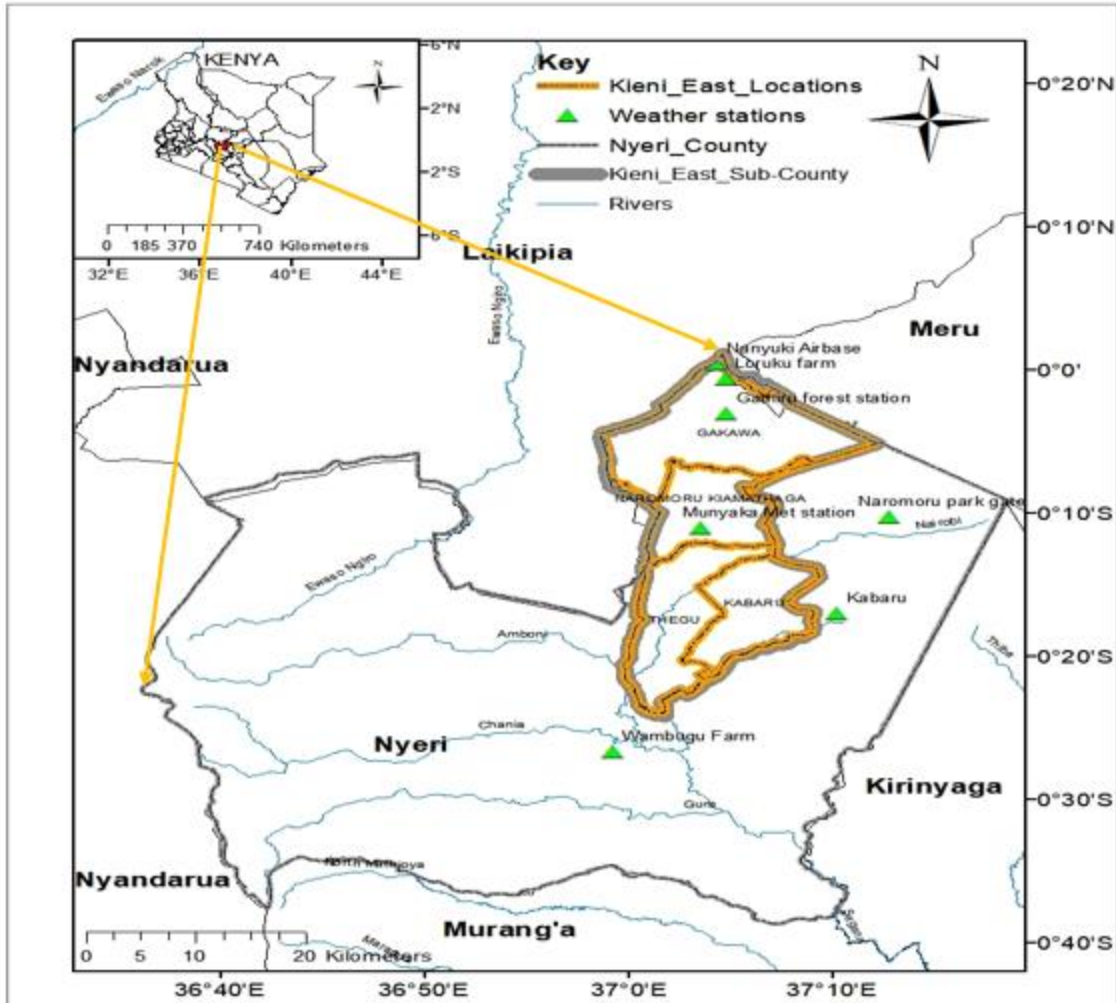


Figure 3.1: Map of the study area showing study sites

Source: (ESRI, 2017).

3.2.2 Land Tenure System, Climate and Soils

The majority of the farms are small scale and land ownership is primarily freehold. Rainfall patterns dictate the growing seasons, with two different rainfall seasons happening between March and May (MAM) and October to December (OND), with average annual rainfall ranging from 500mm to 850mm (MoALF, 2016). Tropical-Alpine, Upper Highlands, Lower Highlands, and Upper Midlands are the four primary

agro-ecological zones identified by Jaetzold and Schmidt (2007) in the study area. It should be noted that these agro-ecological zones are mainly based on climatic data with limited considerations on soil condition; hence hardly any coffee and tea are grown in Kieni (Wamicha, 1993). The altitude rises between 1500m at Kiganjo, which is the lowest area, and 2400m at Kabaru forest reserve. The driest areas are Kiganjo and Naromoru within the agro-climatic zones V and VI respectively. The soils are complex due to influence by variations in relief, climate and underlying rock types. The major soils include the fibric histosols, humic andosols, humic nitosols, luvic phaenzems as well as vertisols, fluvisols and gleysols (Sombroek *et al.*, 1982).

3.2.3 Economic Activities of the Area

Maize is the most commonly grown food crop, and it is regarded as a crucial staple food by the population, accounting for 80% of the food supply in the form of coarse grain and flour. Other crops grown include beans, potatoes, and wheat. Beans are the second most important food crop after maize, and they are traded throughout livelihood zones. Potatoes are grown all year in rain-fed conditions for both commercial and subsistence needs, accounting for 60% and 40% of total production respectively, according to the Kenya Food Security Steering Group (KFSSG) and the Nyeri County Steering Group joint report in February (2018). Wheat is grown for both household use and income, although it is currently suffering from moisture stress throughout the blooming and booting periods. Irrigated horticulture is primarily practiced in the upper mixed farming areas that border Mt Kenya, and because water sources have been flowing at or below base levels, most plots are experiencing moisture stress, prompting most farmers to switch to more stress tolerant crops such as kale and spinach from cabbages.

3.3 Research Design

A mixed research design was used in this study. The goal of using qualitative and quantitative approaches in a mixed research design was to broaden and heighten the study's knowledge and validity (Schoonenboom & Johnson, 2017). Furthermore, studies that use both techniques have been shown to be more inclusive than studies that only use one (Creswell & Plano, 2011). This strategy ensured that enough data and information was gathered. The information gathered helped to explain the effects of rainfall variability on maize yields in Nyeri County's Kieni East sub-County.

3.4 Sampling Procedures and Sample Size

The term "population" refers to a large collection of people or elements who share at least one characteristic (Kombo & Tromp, 2009). The requirement to have it manageable enough and obtain detailed data at an acceptable cost in terms of time, money, and human resource are the primary aspects to consider when establishing the sample size (Neumann, 2000). The researcher purposively targeted smallholder maize farmers in Kieni East sub-County in Nyeri County, with 29,012 households as illustrated in Table 3.1; since most farmers are actively involved in maize farming as it is their major staple food. Using the Nassiuma (2000) formula, which employs a coefficient of variation (c) in the range of 21% to 30% and a standard error (e) in the range of 2% to 5%, the estimated sample size was 223 smallholder maize farmers from the target population. The sample was wide enough to justify the results being generalized for Kieni East sub-County, hence a 30% coefficient of variation was adopted as the upper limit. A standard error of 2% was used to ensure that there was minimal error. To cover all of the wards and stratify the samples, the study used stratified random sampling. An independent random sample

size equivalent to the size of each stratum was taken from each stratum. Nassiuma's (2000) formula was used to calculate the sample size for each stratum, and the sample was made up of households. Proportional allocation was used to determine the number of farmers from each ward who participated in the study. Table 3.1 shows the proportionate distribution of respondents, and after the interval was set, the actual respondents were chosen from the wards using systematic random selection. Personnel for in-depth interviews were picked from KMD personnel, MOA, local administration, and extension agricultural officials from each ward through a process of purposive sampling. The sample size formula is as shown below;

$n = \frac{NC^2}{C^2 + (N-1)e^2}$. n= the sample size, N= the households size (29,012), C= the coefficient of variation (30%), e= the margin of error (2%).

$$= \frac{29012 \times 0.3^2}{0.3^2 + (29012 - 1)0.02^2} = 223$$

Table 3.1: Sample Size Distribution

Location	Households (N)	Sample (n)per ward	%
Narumoro/kiamathaga	9976	$9976/29012 \times 223 = 77$	$77/223 \times 100 = 35$
Kabaru	6205	$6205/29012 \times 223 = 48$	$48/223 \times 100 = 21$
Thegu	4734	$4734/29012 \times 223 = 36$	$36/223 \times 100 = 16$
Gakawa	8097	$8097/29012 \times 223 = 62$	$62/223 \times 100 = 28$
Total	29012	223	100

Source: KNBS, (2010)

3.5 Data Collection

Data was collected over a one-month fieldwork period between October 29th and November 30th, 2019, and included both qualitative and quantitative data. Primary and secondary data were used to compile this report. Household structured questionnaires and in-depth interviews were used to collect primary data. There were both open-ended and closed-ended questions on the surveys. The open-ended questions were chosen to sensitively handle bias-prone areas including farmers' views of seasonal rainfall variability. Closed-ended questions were used to measure rainfall variability and adaptation mechanisms. The emphasis was placed on a logical order of questions as well as clear and specific wording in order to facilitate comprehension and translation of the questions. Furthermore, according to Mayer (2008), after 40 minutes to an hour, interviewees' focus and desire to answer questions starts to wane, therefore the interviews lasted about 30 minutes. Secondary data on annual and seasonal rainfall, annual and seasonal maize yields, and adaptive strategies was gathered from both published and unpublished publications. This strategy ensured that enough data and information was gathered which helped to explain the effects of seasonal rainfall variability on maize yields in Nyeri County's Kieni East sub-County.

3.5.1 Primary Data

Structured questionnaires as indicated on Appendix 1 were administered to randomly selected smallholder maize farmers and used both open-ended and closed-ended questions. This was in order to establish the general information of the farm characteristics, socio-economic characteristics, rainfall distribution and availability to the maize crop and the socio-economic effects of seasonal rainfall variability to maize yields

as well as the farmers' current adaptive strategies. Illiterate farmers were assisted in filling the questionnaire after being explained the rationale behind the research. A list containing names of all the farmers in the four wards was generated and systematic random sampling technique was used to identify the specific respondents per ward. The number of respondents sampled per ward were Naromoru/Kiamathaga (77) , Kabaru (48), Thegu (36) and Gakawa (62). This method was unbiased, providing a random chance to any of the respondents to answer the questions.

In-depth interviews using interview schedules as shown through appendix 11-VI of other key informants like senior officers, one from KMD, 4 extension agricultural officers as well as 3 local administration officers who were purposively sampled were also conducted to provide relevant data related to the research topic. This was in order to obtain detailed information about a particular issue. This enabled the study to generate qualitative and quantitative data that provided the perception of the problem of seasonal and temporal rainfall variability in relation to other socio-economic challenges. The results of the in-depth interviews were compared to the results from the household surveys, and literature review for consistency.

3.5.2 Secondary Data

Data was acquired from secondary sources, including rainfall characteristics from the Loruku farm rainfall station, where monthly and annual rainfall data was acquired in Kieni East sub-County between 1988 and 2018, as indicated in appendix (VI), utilizing a rainfall data collection sheet as indicated on appendix (V). The information was recorded on a summary sheet. The Kenya Meteorological Department (KMD) in Nyeri provided

rainfall data, which was used to examine trends in total annual rainfall, seasonal rainfall, and within-season characteristics such as rainfall onset, cessation, and peak months for the MAM and OND seasons. Rainfall was chosen because it is the most important climatic parameter critical for small-scale farmers' survival, particularly in relation to crop growth (AGRA, 2014), and because it, along with temperature, has the longest and widest data coverage in the country, and is the most common climatic variable considered in many studies in SSA (Ochieng *et al.*, 2016).

Annual and seasonal maize yields data was obtained from the Ministry of Agriculture, Livestock and Fisheries, Nyeri County, for the last 10 years since there was no maize yields data available before year 2009, and from the Nyeri County Annual Progress Report as well as a Joint Report by Kenya Food Security Steering Group (KFSSG) and Nyeri County Steering Group, February (2018). Data was also obtained on the total number of households in every ward, and on the existing adaptive strategies of the small holder maize farmers to the effects of the seasonal rainfall variability from the Nyeri County Integrated Development Plan 2013-2017 and 2018-2022 and other County abstracts, KNBS (2010), unpublished reports, journals and periodicals, books and government reports.

3.6 Pilot Study

A reconnaissance and pilot study were prerequisites to the study. The reconnaissance was used to determine the number of rainfall stations in the sub-county and also provided an understanding of the administrative units of the sub-county, the general physiography and transport network of the area. This provided critical information on planning for data

collection and also enabled the researcher to be able to identify and recruit research assistants with the help of the local administration. The researcher was also able to seek permission from the governor's office and from the County commissioner where the study was conducted. The County Ministry of Agriculture personnel, the local administration officers and the Meteorological personnel were also visited so that the researcher could introduce herself and get acquainted with them since they were involved in the research. Sampling of the farmers households was done during this period. The pilot study was carried out in Mweiga ward in Kieni west sub-county which has similar climate as in the study area also involved pre-testing the questionnaire so as to determine its reliability and to adjust or clarify some questions that were not clear.

3.7 Validity and Reliability

3.7.1 Validity of the Questionnaire

Using simple random sampling, a pilot research was conducted with small-holder maize farmers from the surrounding maize-growing sub-County. A total of 23 smallholder maize farmers were chosen for this study, accounting for 10% of the total study sample size of 223 people. Piloting the study instruments, according to Mugenda and Mugenda (2003), necessitates a sample of 10% of the overall study sample. The aim was to reduce item ambiguity, identify problems with data instrument administration, test data collection instruments, estimate the response rate and duration of an interview, determine the study's feasibility, and correct any procedural issues. The research's objectives and potential to improve the status of smallholder maize farmers were explained, as well as the importance of incorporating the farmers as much as possible in the data collection process.

Thorough background literature review was conducted before, during and after the fieldwork period. The Kenya Meteorological Department-Nyeri provided rainfall data for five rainfall stations in the Kieni East sub-County. The data was scrutinized in order to look for missing data as well as inaccuracies. Loruku Farm was chosen for the study because it had no missing data based on a low percentage of missing data (less than 10% for any given year, as specified by the World Meteorological Organization (WMO, 2017). This is due to the fact that the person involved was always available to collect data. Three rainfall stations, Kabarú Forest station, Gathiuru Forest station, and Naromoru met station, were not used since they are located within forests where maize farming is not carried out. Munyaka rainfall station had rainfall data starting from 1991 and with several gaps with the missing data amounting to 16.1%, more than the 10% recommended by the WMO.

3.7.2 Reliability of the instrument

According to Mugenda and Mugenda (2003), research equipment should produce consistent results when tested repeatedly under similar settings. The Cronbach's Alpha reliability test was used to verify the consistency of the measuring instrument in returning the same measurements when utilized at different times. This reliability test calculates internal consistency by looking at how test items relate to each other and to the entire test (Gay, 2009). Internal consistency is regarded adequate when the Alpha index is 0.7 or higher (Nichols, 2004). The following is the formula:

$$\alpha = \frac{n}{n-1} \left(1 - \frac{\sum_i V_i}{V_t} \right)$$

Where;

N=the number of items

C=average covariance between item pairs

v=average covariance

3.7.3 Response rate

Out of the 223 questionnaires administered, 217 were filled and returned, which represented 97% of the response rate and was considered satisfactory to make conclusions for the study. This high response rate can be attributed to a 3-day training of the enumerators prior to data collection which included introduction to the questionnaire, translation of sensitive questions, role games, a pre-test with 23 farmers, and data collection procedures, whereby the objectives of the research and its potential to improve the existing situation of the smallholder maize farmers were explained. The researcher and three research assistants administered the questionnaires and collected the filled ones after one week. According to Mugenda and Mugenda (2003), a 50% response rate is adequate, 60% is good and above 70% response rate is very good.

3.7.4 Normality

The Shapiro-Wilk test was used to evaluate if the sample size was chosen from a regularly distributed population (1965). It's one of the most extensively used diagnostic tests for normalcy assumptions. It has high power attributes and is based on correlation within given data and associated normal scores (Keya & Rahmatullah, 2016). Since the

Shapiro-Wilk test (w-value) was more than 0.05, the study was considered acceptable.

The formula is as follows:

$$W = \frac{\left(\sum_{i=1}^n a_i x_{(i)}\right)^2}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

Where;

The $x_{(i)}$ are the ordered sample values ($x_{(1)}$ is the smallest) and the a_i are constants generated from the means, variances and covariances of the order statistics of a sample of size n from a normal distribution.

3.7.5 Data Consistency Tests

3.7.5.1 Consistency of Rainfall Data

To test the consistency of the rainfall data, the researcher drew a mass curve. A single mass curve with a straight line implies data homogeneity. The resultant R-square value was found to be 0.9993, which is quite close to 1, based on the trend line illustrated in Figure 3.2. This demonstrates that the rainfall data was consistent and hence suitable for further investigation.

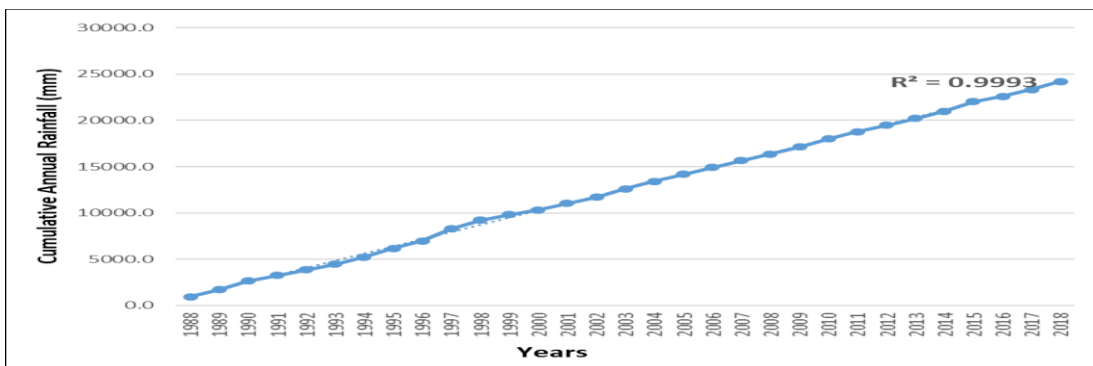


Figure 3.2: Cumulative Annual Rainfall Trend (1988 – 2018)

Source: Field Data, 2019

3.7.5.2 Consistency of Maize Yield Data

The study plotted a mass curve to determine the consistency of the maize yield data. From the trend line as shown in figure 3.3, the resultant R-square value was found to be 1. This shows that the maize yield data was consistent and therefore fit for further analysis.

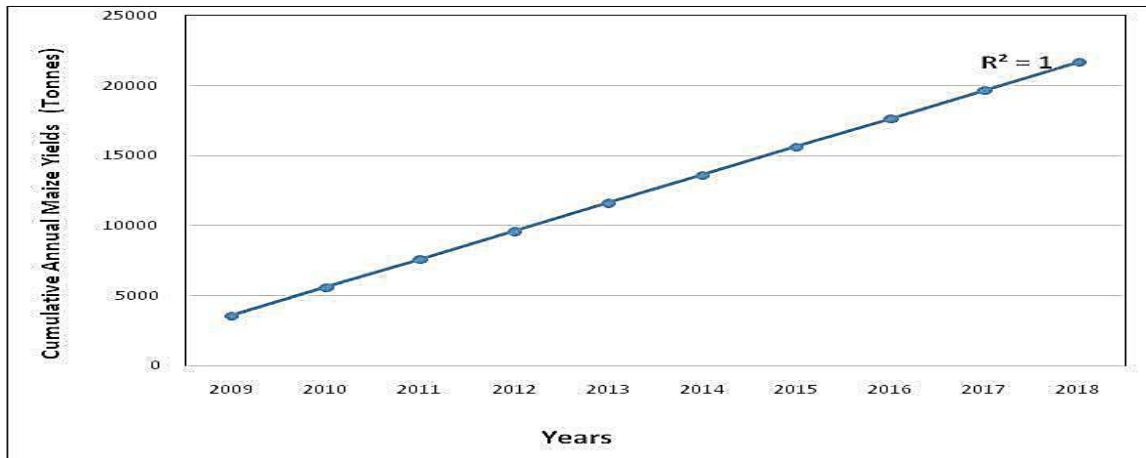


Figure 3.3: Cumulative Annual Maize Trend (2009 – 2018)

Source: Field Data, 2019

3.8 Data Analysis

The data from the questionnaires was cleaned, coded, and entered into a computer to be analyzed. The rainfall data was analyzed using trend analysis for objective (i). The data was divided into months to allow for seasonal variation analysis. Annual and seasonal rainfall variability, estimation of the commencement and cessation of seasonal rainfall, and peak months for the MAM and OND seasons were all evaluated using the rainfall data, which was also used by Ekwe *et al.* (2014). The annual and seasonal rainfall trends were also analyzed using running means. Running means is often used to illustrate climatic trends by temporally smoothing data. It is calculated by finding a number of successive means, each mean incorporating the same number of observations. Each

successive mean will drop first value of the mean interval and add the next value in the dataset to the next mean interval. It tends to damp out extreme values and highlights the movement of data with time. To obtain annual and seasonal rainfall anomalies, the researcher employed the means, standard deviation, coefficient of variation, and variability indices. A common measure of the dispersion of data points around the mean is the coefficient of variation. Mzezewa *et al.* (2010) also used the coefficient of variation for seasonal rainfall. Anomaly is defined as a divergence from the long-term mean of annual or seasonal rainfalls (Juma, 2015). Rainfall data series with coefficients of variance more than 30% suggest a great deal of variation in rainfall amounts and patterns (Araya & Stroosnijder, 2011; Thornton *et al.*, 2014).

The maize yield data for the MAM and OND seasons were analyzed for trends for objective (ii). Individual maize yield data for the MAM and OND seasons were shown to vary about their long-term mean value using the coefficient of variation and variability index. T-test statistics were used to determine the statistical significance of the variability and change from the mean. A T-test is a statistical test that shows deviations of sample means from the population mean (Madukwe, 2015). The use of a t-test was necessitated by the fact that the sample population (rainfall data) was drawn from a variety of environments (seasons) (Shaw & Wheeler, 1985).

The Pearson's correlation coefficient was used to determine the correlation between annual and seasonal rainfall variability and maize yields in order to achieve objective (ii). When Pearson's r is close to 1, it indicates that two variables have a strong relationship and that changes in one variable are significantly associated with changes in the other. When Pearson's r is near to 0, it suggests that the relationship between two variables is

weak and that changes in one variable are unrelated to changes in the other. A positive Pearson's r means that as the value of one variable rises, the value of the other rises as well, and vice versa. A p -value of less than or equal to 0.01 is statistically significant, indicating strong evidence against the null hypothesis, and so the null hypothesis is rejected. The statistical significance of the variability and change from the mean was determined using T-test statistics.

For objective (iii), content analysis was used on the questionnaires to assess the existing adaptive strategies the farmers are using in response to seasonal rainfall variability in Kieni East. Leedy and Omrod (2013) confirm that content analysis is a meticulous methodological evaluation of the content of a specific form of material with an intention to identify a preconceived notion. This entailed categorizing both coded and uncoded data and sorting information based on relevance and trustworthiness. SPSS software version 20 and Microsoft Excel 2010 were used to code and analyze the farmers' responses to the questionnaire. A SWOT analysis was performed on the maize farming environment in Kieni East sub-County to assess the strengths, weaknesses, opportunities, and threats associated with the farming area. The summarized data was represented using tables, pie charts, percentages, means, frequencies, standard deviation, and bar graphs.

Table 3.2: Data Analysis Matrix

Objective	Variable	Statistical Techniques
To determine the inter and intra seasonal rainfall variability in Kieni East sub-county between 1988 and 2018	Rainfall trends	Descriptive statistics: Trend analysis, Running means Mean, mode, variability index, standard deviation, coefficient of variation
To analyze the effects of seasonal rainfall variability on smallholder maize farming in Kieni East sub-County between 2009 and 2018	Maize yields Rainfall variability	Descriptive statistics: Trend analysis Running means, variability index Inferential statistics; Pearson's correlation
To assess the existing adaptive strategies to the effects of seasonal rainfall variability by smallholder maize farmers in Kieni East sub-County	Adaptive strategies	Descriptive statistics: Measures of central tendency and dispersion Content analysis SWOT analysis

3.9 Ethical Consideration

The researcher received an introductory letter from Kenyatta University, which was used to apply for a research permit from the National Council of Science, Technology, and Innovation (NACOSTI), as shown in Appendix VIII, as well as permission from the Nyeri County agricultural offices, as shown in Appendix (IX), and the Nyeri County Commissioner's office, as shown in Appendix (X). As a result of these considerations, the researcher was able to acquire entry to the field. The researcher then went to the study area to meet with farmers, Nyeri County Ministry of Agriculture officers, local administration officials, Agricultural Extension Officers in the four wards, and officials from the Nyeri County Kenya Meteorological Department Station. The key informants

were informed in advance about the purpose of the study. 223 small-holder maize farmers participated in the study and filled out questionnaires. Honesty and objectivity were maintained throughout the data collection, analysis, interpretation, and presentation. The information obtained from respondents was kept in strict confidence.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the study's findings are presented and discussed. The discussion is separated into three parts based on the findings of specific objectives. The first section discusses annual and seasonal rainfall trends, as well as variability and aspects of rainfall. The second section covers annual and seasonal maize yield trends, variability in annual and seasonal maize yields, seasonal and annual rainfall trend analysis against maize yields, and the correlation between rainfall trends and maize yields. The SWOT analysis of the study area is discussed in the third section.

4.2 Rainfall Trends

4.2.1. Annual Rainfall Trend

A trend is a substantial change in a random variable over time that may be detected using statistical parametric and non-parametric approaches (Longobardi & Villani, 2009). Figure 4.1 demonstrates that annual rainfall quantities in Kieni East sub-County, Nyeri County, have decreased from 1988 to 2018, as evidenced by a negative gradient (-0.991) in the trend line. The wettest years were 1997 (1308.5mm), 2003 (908.4mm), 2010 (856mm), and 2015 (1021mm), which happened to coincide with El Nino-related high rainfall episodes in Kenya at the time. Dips, on the other hand, were seen in 1991 (582mm), 1993 (579.5mm), 2000 (519.6mm), 2008 (698.75mm), and 2016 (584.9mm), all of which coincided with drought spells in Kenya caused by La Nina. The average annual rainfall from 1988 to 2018 was 780.07 mm, with a standard deviation of 156.38

mm and a 20 % correlation of variation. Annual rainfall amounts in Nyeri County's Kieni East sub-County have fluctuated at random, as seen by the oscillations. Rain-fed maize growing could be risky due to the considerable variability of rainfall. If farming activities aren't timed properly, crops could suffer from moisture stress, leading to a decrease in yields. The study's findings are consistent with those of Shisanya *et al.* (2011) and Omwoyo *et al.* (2015), who found that high rainfall variability has harmed ASALs in Kenya, as well as Limantol *et al.* (2016) and Mutunga *et al.* (2017), who documented farmers' views of an overall decline in rainfall.

Furthermore, Kenya has seen variability of rainfall over the last decade, as a result of El Nino and La Nina events (Parry *et al.*, 2013). In a study conducted in Swaziland by Mamba *et al.* (2015), rainfall was identified to be the most important element in farming. Farmers face a significant problem due to its variability. It makes rainfall exceedingly unpredictable, which causes farmers to be perplexed. Seasonal rainfall has exhibited significant inter-annual changes throughout East Africa and the Mount Kenya region, notably during the short rains (Camberlin, 2010). Low rainfall persists, putting people's livelihoods at jeopardy. As a result, farmers in the Kieni East sub-County have learned to farm in methods that partially compensate for such changes, such as early planting, replanting due to 'false' start of seasons, and water harvesting, among other things, in order to reduce their risk.

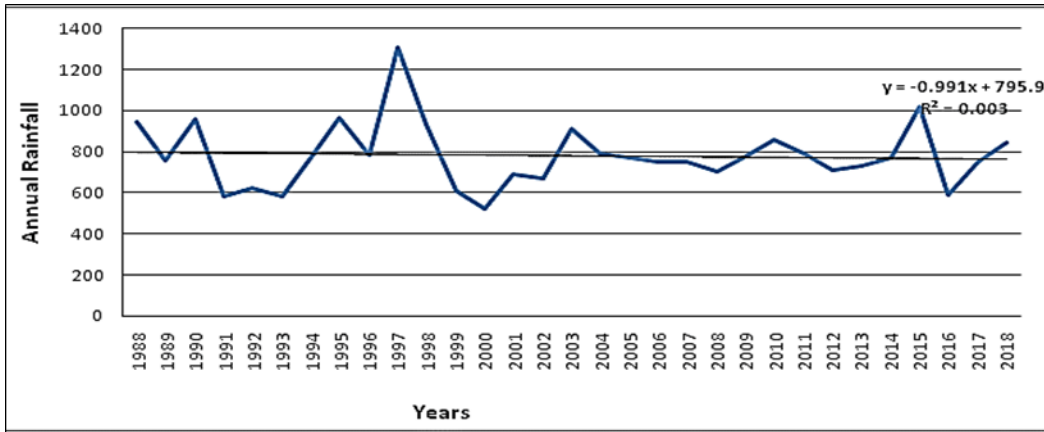


Figure 4.1: Annual Rainfall Trend (1988 – 2018)

Source: Field Data, 2019

Running means were also calculated at 5-year intervals by the researcher. Sinha *et al.* (2015) used the running means, also known as the moving average, to investigate the patterns and oscillations in Indian summer monsoon rainfall over the last two millennia. The use of running means aided in the smoothing of the curve for random data, as seen in Figure 4.1, which depicts the annual rainfall trend from 1988 to 2018. According to the data in Figure 4.2, there was an increase in average annual rainfall from 1996 to 2001, which coincided with El Nino-related high rainfall events in Kenya during that time.

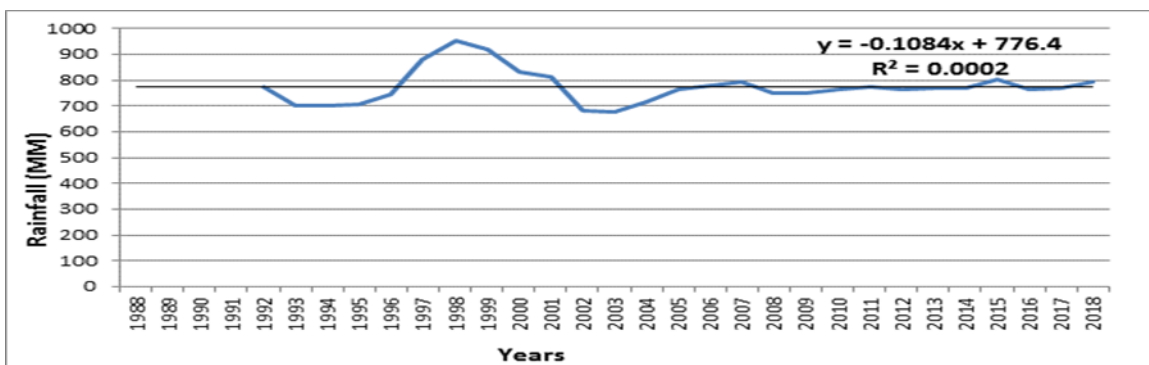


Figure 4.2: Five Years Running Means for Annual Rainfall (1988 – 2018)

Source: Field Data, 2019

4.2.2 Seasonal Rainfall Trends (Long Rains) (MAM)

The findings in Figure 4.3 revealed that rainfall amounts in Kieni East sub-County in Nyeri County decreased during the long rains season (MAM), as evidenced by a negative gradient (-0.5162) in the trend line. Peak rainfall values of 361mm were recorded in 1997, 2003 (439mm), 2006 (368.5mm), 2015 (336mm), and 2018 (427.8mm), corresponding with El Nino-related high rainfall periods in Kenya since 1988 of 1997/98, 2002/2003, 2008/2009, and 2013/2014. Dips, on the other hand, were seen in 2000 (130.3mm), 2012 (162mm), and 2016 (127.4mm) due to low rainfall amounts during the season. Since 1988, Kenya has experienced droughts associated to La Nina in the years 1991/1992, 1995/1995, 1999/2000, 2004/2005, 2008/2009, and 2010/2012.

In the period from 1988 to 2018, the average quantity of rainfall during the long rains was 260.86 mm, with a standard deviation of 84.49 mm and a 32% correlation of variation. The oscillations demonstrated that rainfall levels in Nyeri County's Kieni East sub-County changed randomly during long rains, with the trend showing decreasing rainfall volumes. According to Nicholson, (2017) long rains are consistently less predictable at the seasonal scale in East Africa, with fewer linkages to predictable large-scale coupled Sea Surface Temperatures (SST) processes. Despite the fact that the Madden-Julian Oscillation, the Quasi-biennial Oscillation, and SSTs in the northwest Indian Ocean have recently been proven to generate a significant part of inter-annular variability, for example, the long rains of 2013 were delayed by two weeks in Kieni East, and approximately 70% of the rainfall was received in April alone (MoALF, 2016). These changes are in line with remarks made elsewhere, such as at the consultative

stakeholder workshop on the development of a National Climate Change Response action plan (NCCR) (GoK, 2012). This backs Cooper and Coe's (2011) claim that East African farmers have always experienced considerable rainfall variability, both within and between seasons, and that their farming practices have never been static.

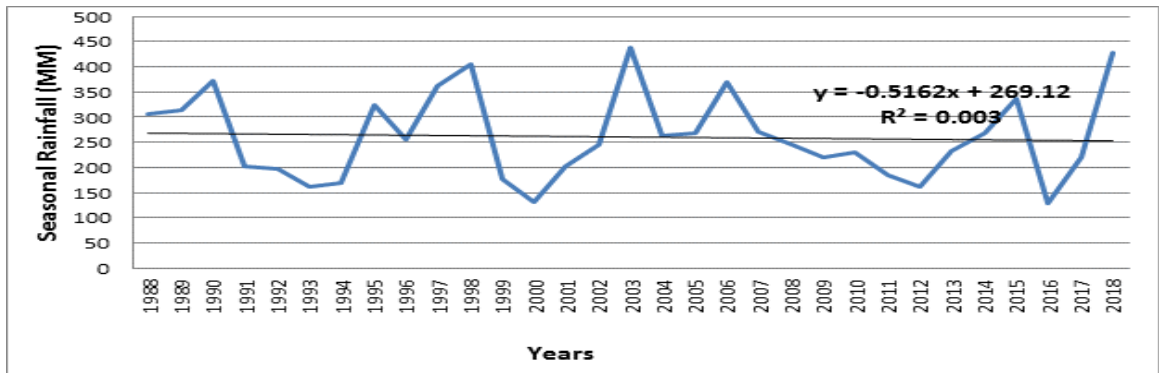


Figure 4.3: Rainfall Trend during Long Rains (1988 – 2018)

Source: Field Data, 2019

Similarly, over the study period, the researcher generated a running average for the seasonal rainfall amount for the long rains. Other researchers, such as Trauth *et al.* (2009), used running means to analyze patterns, rhythms, and occurrences in Plio-Pleistocene African climate. Figure 4.4 shows fluctuations in the amount of long rains, with two peaks identified in two periods, 1996–2001 and 2004–2009. The fluctuations in the pattern of rainfall amount is clear evidence that the usage of running means aids in the creation of a smoother curve when dealing with highly random data as is the case in the erratic rainfall pattern shown in Figure 4.4 for the long rains.

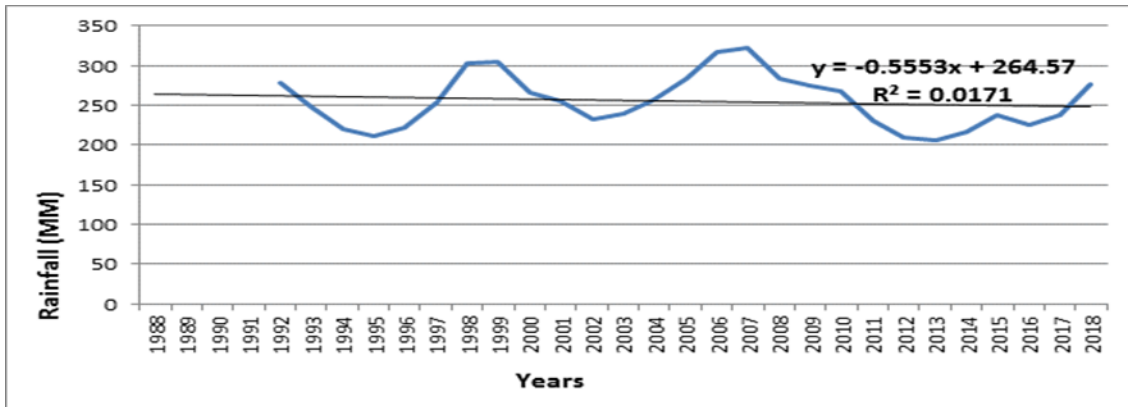


Figure 4.4: Five Years Running Means for Amount of Long Rains (1988 – 2018)

Source: Field Data, 2019

4.2.3 Trend of Seasonal Rainfall during the Short Rains

The trend line in Figure 4.5 shows that rainfall levels increased during the short rains (OND), as demonstrated by a positive gradient (1.1293). The wettest years were 1997 (728.8mm), 2003 (345.3mm), 2006 (458.75mm), 2009 (401mm), and 2015 (401mm) (531.5 mm).

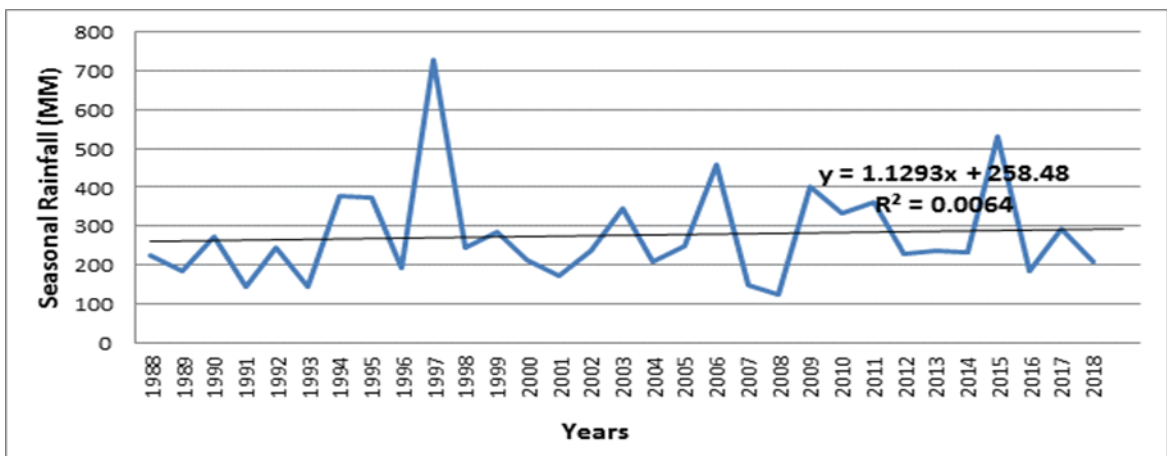


Figure 4.5: Rainfall Trend during Short Rains (OND) (1988 – 2018)

Source: Field Data, 2019

The 1997 OND rainfall positive anomaly is ascribed to the El Nino rains that defined the OND season in Eastern Africa in 1997/98 according to Amissah *et al.* (2002). Dips, on the other hand, were recorded in 1991 (144.5mm), 1993 (144mm), 1996 (192mm), 2001 (172.4mm), 2004 (207mm), 2008 (122.5mm), 2012 (230mm), 2014 (231mm), and 2016 (183mm). The short rains had a mean of 261.68 mm and a standard deviation of 129.09 mm, with a 46% correlation of variation. The short rains variations varied from -154.05mm in 2008 to 452.25mm in 1997, indicating that there has been some variability. Though rainfall amounts in Kieni East sub-County, Nyeri County, have been increasing, there has been random variability during the short rains. As a result, OND rainfall in the sub-County is more suitable for maize farming. These findings are backed up by Mzezewa *et al.* (2010), who discovered that in Eco tope-South Africa, 80% of annual rainfall occurs between October and March. Rainfall patterns, on the other hand, have grown variable and unpredictable, with some seasons extending into January and February, resulting in higher total rainfall for the season (CDKN, 2014).

The researcher generated the running means for the rainfall for the short rains over the period (1988–2018) in an attempt to smooth out the uneven and extremely random pattern in Figure 4.5. Jacob and Van den Hurk (2012) employed running means in a study on climate change scenarios at the global and local scales. The curve revealed a cyclic pattern with a peak in the period 1996–2001, according to the results shown in Figure 4.6.

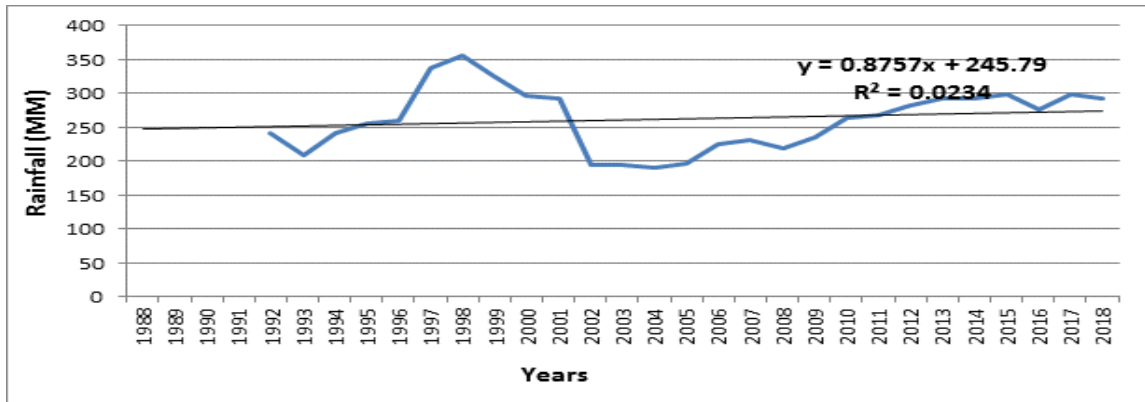


Figure 4.6: Five Years Running Means for Amount of Short Rains (1988 – 2018)

Source: Field Data, 2019

4.3 Rainfall Variability

The annual rainfall variability ranged from – 260.47 mm in 2000 to 528 mm in 1997, according to Table 4.1. During the long rains, rainfall variability ranged from – 133.46 mm in 2016 to 178.14 mm in 2003. Short rains variations ranged from -154.05 mm in 2008 to 452.25 mm in 1997, according to the study. These findings are consistent with those of Nicholson and Kim (1997), who found that ENSO has little impact on the long rainfall season (MAM), but has a considerable impact on the short rains (OND). The findings also back up the claim that "rainfall varies from year to year and season to season" in East Africa, a phenomenon that continues to present a challenge to agricultural production (Shisanya, 1996; Seleshi & Zanke, 2004).

Table 4.1: Seasonal and Annual Rainfall Variability Index

Year	Annual rainfall amount mean=780.0 7	Annual rainfall variations	Seasonal rainfall amount - long rain mean=260.8 6	Seasonal rainfall variation -long rain	Seasonal rainfall amount - short rain mean=276.5 5	Seasonal rainfall variation-short rain mean=276.5 5
1988	945.10	165.03	306.00	45.14	222.50	-54.05
1989	757.70	-22.37	312.70	51.84	183.20	-93.35
1990	958.00	177.93	371.00	110.14	274.50	-2.05
1991	582.00	-198.07	202.00	-58.86	144.50	-132.05
1992	623.70	-156.37	197.50	-63.36	243.50	-33.05
1993	579.50	-200.57	160.50	-100.36	144.00	-132.55
1994	771.80	-8.27	168.00	-92.86	378.50	101.95
1995	966.20	186.13	324.90	64.04	375.30	98.75
1996	781.10	1.03	255.80	-5.06	192.00	-84.55
1997	1308.50	528.43	361.00	100.14	728.80	452.25
1998	932.50	152.43	405.50	144.64	246.30	-30.25
1999	607.90	-172.17	177.80	-83.06	284.30	7.75
2000	519.60	-260.47	130.30	-130.56	210.80	-65.75
2001	689.00	-91.07	201.70	-59.16	172.40	-104.15
2002	670.50	-109.57	246.05	-14.81	237.60	-38.95
2003	908.35	128.28	439.00	178.14	345.30	68.75
2004	789.40	9.33	263.80	2.94	207.00	-69.55
2005	771.65	-8.42	267.05	6.19	247.25	-29.30
2006	750.50	-29.57	368.50	107.64	458.75	182.20
2007	750.00	-30.07	269.75	8.89	146.00	-130.55
2008	698.75	-81.32	246.25	-14.61	122.50	-154.05
2009	772.50	-7.57	220.75	-40.11	401.00	124.45
2010	856.00	75.93	230.50	-30.36	334.50	57.95
2011	787.00	6.93	185.50	-75.36	363.50	86.95
2012	709.25	-70.82	162.00	-98.86	230.00	-46.55
2013	730.50	-49.57	233.50	-27.36	235.00	-41.55
2014	768.00	-12.07	269.00	8.14	231.00	-45.55
2015	1021.00	240.93	336.00	75.14	531.50	254.95
2016	584.90	-195.17	127.40	-133.46	183.00	-93.55
2017	747.00	-33.07	219.00	-41.86	292.00	15.45
2018	844.30	64.23	427.80	166.94	206.50	-70.05
Mean	780.07		260.86		276.55	
Std. Dev.	156.38		84.49		126.09	
Correlation	0.20		0.32		0.46	

4.4 Maize Yield in Kieni East sub-County

4.4.1 Trend of Annual Maize Yield in Tons

The findings in Figure 4.7 reveal that yearly maize yields in tons in Kieni East sub-County have decreased, as indicated by a negative gradient (-231.9). The peak years for maize yields were 2010 and 2015, with 5861.52 tons and 4984.83 tons, respectively. On the other side, there were declines in 2016 and 2012, when 482.58 tons and 963.00 tons of maize were produced, respectively. According to several studies, variations in mean annual precipitation have a negative impact on maize production (Oseni & Masarirambi, 2011). These results are similar to those of Jokastah *et al.* (2013), who discovered that most smallholder farmers in Kenya's semi-arid and sub-humid regions have seen a decrease in crop production due to low rainfall, or erratic rainfall patterns, as well as other factors such as hailstones, floods, and longer-than-normal rainfall.

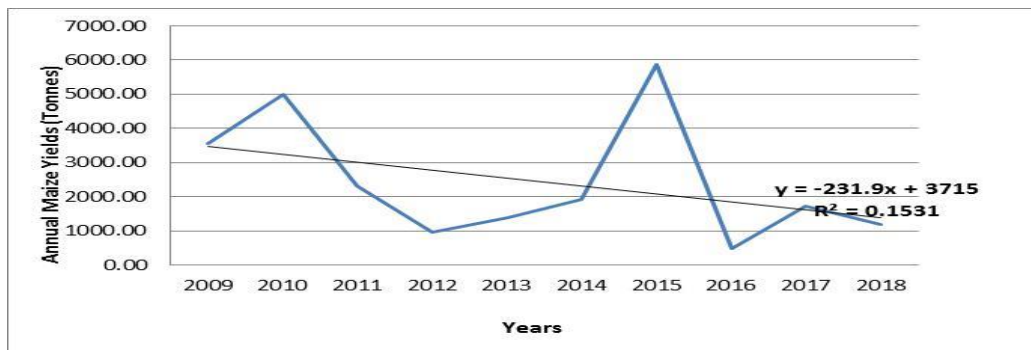


Figure 4.7: Annual Maize Yields Trend in Tons (2009 – 2018)

Source: Field Data, 2019

4.4.2 Seasonal Maize Yields Trend in Tons during Long Rains Season

The findings in Figure 4.8 show that during the long rains, maize yields in tons in the Kieni East sub-County decreased, as indicated by a negative gradient (-69.19). Maize yields of 2148.48 tons and 2059.83 tons were the highest in 2015 and 2010, respectively. On the other hand, there were declines in 2016 and 2012, when 256.5 tons and 513.0 tons of maize were produced, respectively. According to Nicholson (2017), long rains are regularly perceived as less predictable at seasonal scale, with weaker linkages to predictable large-scale SST processes although a substantial component of the inter-annual variability is driven by the Quasi-biennial Oscillation, and SSTs in the northwest Indian Ocean. According to Tarun *et al.* (2013), anytime the maize crop is subjected to moisture stress at any stage of its development, a considerable loss in maize yield is expected. Shumetie *et al.* (2017) evaluated the impacts of climate variability on smallholder farmers' crop revenue and discovered that rainfall fluctuations during the cropping season have a significant and negative impact on farmers' crop income.

Farmers in the Kieni East sub-County may limit the area under cultivation due to the idea that OND is the main season. Due to reduced maize growing during MAM, overall annual maize yields are lower than they would be otherwise. Farmers should be informed about the need of maximizing the two rainy seasons in maize farming, and should likely plant short-cycle maize varieties during the long rains season.

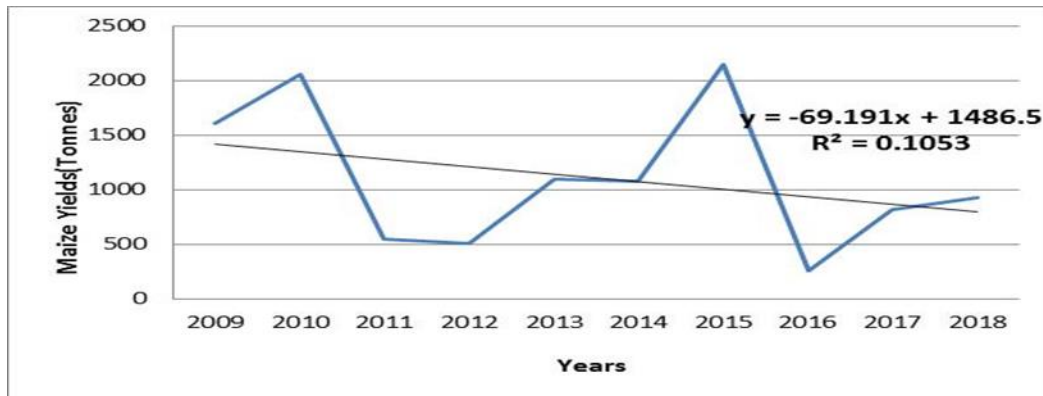


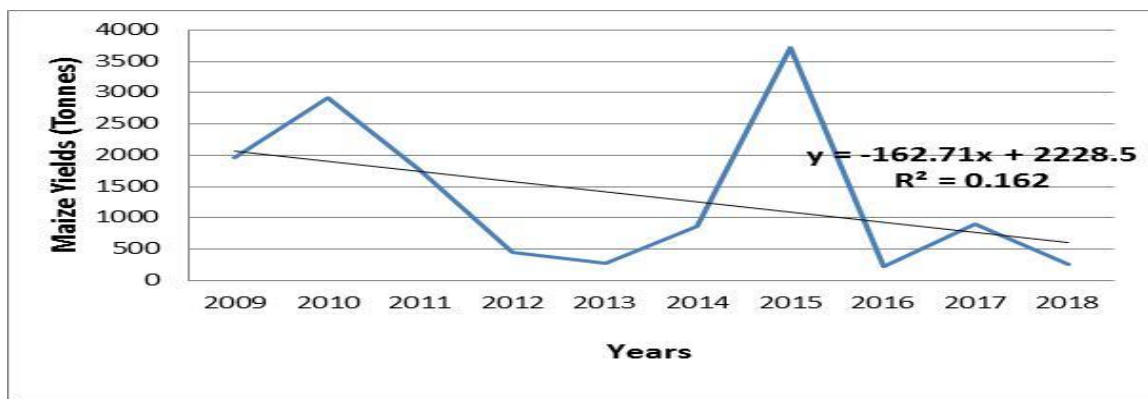
Figure 4.8: Maize Yields Trend in Tons during long rains season (2009 – 2018)

Source: Field Data, 2019

4.4.3 Seasonal Maize yields Trend in Tons during the Short Rains Season

Figure 4.9 shows that during the short rains, maize yields in tons in the Kieni East sub-County have decreased, as evidenced by a negative gradient (-162.71). The highest maize yields were reported in 2015 and 2010, with 3713.04 tons and 2925.00 tons, respectively. On the other side, there were declines in 2016 and 2013, when 226.08 tons and 274.5 tons of maize were produced, respectively. A study in Uganda that used ARCH model estimates discovered that a variation in rainfall from the long-term mean had a significant impact on crop yield, while exponential increases in rainfall had a negative impact (Mwaura & Okoboi, 2014). Maize yields, however, were higher during the short rains (OND) than they were during the long rains (MAM). According to Amissah-Arthur *et al.* (2002), OND is the most common growing season in the country's central and lower eastern regions, where annual crops like as maize, sorghum, green grams, and finger millet thrive.

Increased rainfall intensities during the main rainy growing season, however according to Yengo *et al.* (2010), could increase the rate of erosion and loss of nutrients from arable soils, reducing soil fertility and negatively reducing crop yield. A significant increase in total seasonal precipitation is not required, according to Geerts and Raes (2012) but that maize output aided by rain. In the development of crop phenology, rainfall distribution is critical. Farmers must be trained on soil conservation measures, as well as water collecting, to decrease soil nutrient loss following severe rains. Water can be conserved



and used during the dry season, when crops are most in need, to help increase maize yields.

Figure 4.9: Maize Yield Trend during the Short Rains (2009- 2018)

Source: Field Data, 2019

4.5 Maize Yield Variability

4.5.1 Annual Maize Yield Variations from the Long Term Mean

The findings in Table 4.2 reveal that there is evidence of annual maize yield variability, as evidenced by variations ranging from -1956.94 in 2016 to 3422.00 in 2015. The variance in seasonal and annual rainfall is primarily to blame for the drop in maize yield

trend in Kieni East sub-County. High rainfall variability has an effect on maize yield variability in Benue state, Nigeria, according to Adame and Ujoh's (2013) research.

Table 4.2: Annual Maize Yield Variability Index

Year	Annual Maize yield in Tons	Annual yield variation Mean=2439.52
2009	3569.58	1130.06
2010	4984.83	2545.31
2011	2321.01	-118.51
2012	963.00	-1476.52
2013	1376.10	-1063.42
2014	1931.76	-507.76
2015	5861.52	3422.00
2016	482.58	-1956.94
2017	1723.05	-716.47
2018	1181.79	-1257.73

4.5.2 Maize Yield Variations from the Long Term Mean during the Long Rains Season

Source: Field Data, 2019

The results in Table 4.3 show that maize yield variability exists, as seen by variances ranging from -849.46 in 2016 to 1042.52 in 2015.

Table 4.3: Maize Yield Variability Index during Long Rains Season

Year	Seasonal Maize yield in tons (long rains season)	Seasonal yield variation (long rains season mean=1105.96)
2009	1610.28	504.32
2010	2059.83	953.87
2011	549.81	-556.15
2012	513.00	-592.96
2013	1101.60	-4.36
2014	1074.24	-31.72
2015	2148.48	1042.52
2016	256.50	-849.46
2017	815.04	-290.92
2018	930.78	-175.18

4.5.3 Maize Yield Variations from the Long Term Mean during the long Rains Season

Source: Field Data, 2019

The results in Table 4.4 show that maize yield variability exists during the short rains, as seen by variations ranging from -1107.49 in 2016 to 2379.47 in 2015.

Table 4.4: Maize Yield Variability Index during the Short Rains Season

Year	Seasonal Maize yield in tons (short rains season)	Seasonal yield variation (short rain season mean=1333.37)
2009	1959.30	625.73
2010	2925.00	1591.43
2011	1771.20	437.63
2012	450.00	-883.57
2013	274.50	-1059.07
2014	857.52	-476.05
2015	3713.04	2379.47
2016	226.08	-1107.49
2017	908.01	-425.56
2018	251.01	-1082.56

Source: Field Data, 2019

4.6 Comparative Trend Analysis

4.6.1 Annual Rainfall and Maize Yield Data

Annual rainfall and maize yield patterns, as shown in Figure 4.10, illustrate that variations in rainfall generate variations in maize yields. Figure 4.10 below demonstrates a decline in the trend lines with negative gradients of -33.709 and -231.9, respectively, for rainfall and maize yields. The peak years for annual rainfall were 2010 and 2015, and the peak years for maize yield were also 2010 and 2015. The yearly rainfall decreased in 2011, 2012, 2016, and 2018, while the maize yield decreased in the same years. These results are consistent with those of Ali *et al.* (2017), who discovered that rainfall variability had a significant impact on maize yield. Blanc (2011) and Bhandari (2013) found that precipitation increase leads to increased maize yield. Sowunmi and Akimola (2010) also found that maize can be cultivated in many places of Nigeria with enough water. Water scarcity, however, causes yield loss throughout critical stages of maize development (grain filling and anthesis) (Basir *et al.*, 2018). This is why plant kinds that

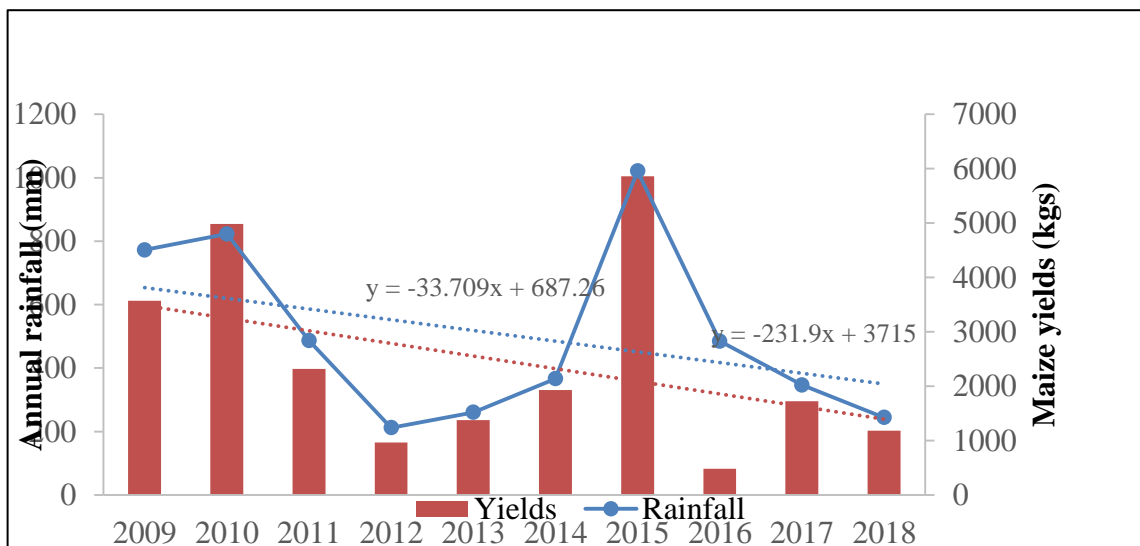
correlate to the length of the growing sub-County's season are so important. One of the main reasons why smallholder farmers in Africa are struggling is because of declining yields and droughts. ASALS do not appear to be adopting improved farming practices as observed by Nyandiko *et al.* (2012).

Figure 4.10: Annual rainfall and maize yields trends between 2009 and 2018

Source: Field Data, 2019

4.6.2 Seasonal Rainfall and Maize Yields during the Long Rains Season

Variation in rainfall amounts induced variations in maize yield, according to the findings



in Figure 4.11 on rainfall and maize yield trends during the long rains. Figure 4.11 depicting a decrease in the trend lines with negative gradients of -21.412 and -69.192 for rainfall and maize yields, respectively, demonstrate this clearly. The peak years for long rains were 2010 and 2015, which coincided with the peak years for maize yield. Both trends, however, experienced a downturn in 2011, 2012, 2013, 2016, and 2018.

According to a joint study released in February 2018 by the Kenya Food Security Steering Group (KFSSG) and Nyeri County Steering Group, the county's maize yields were 61,531,000 bags in 2015, 13,028,000 bags in 2016, 18,114,000 bags in 2017, and 12,866,000 bags in 2018, indicating variability. This is in accordance with Sage *et al.* (2015), who predicted that higher rainfall variability would affect maize yields.

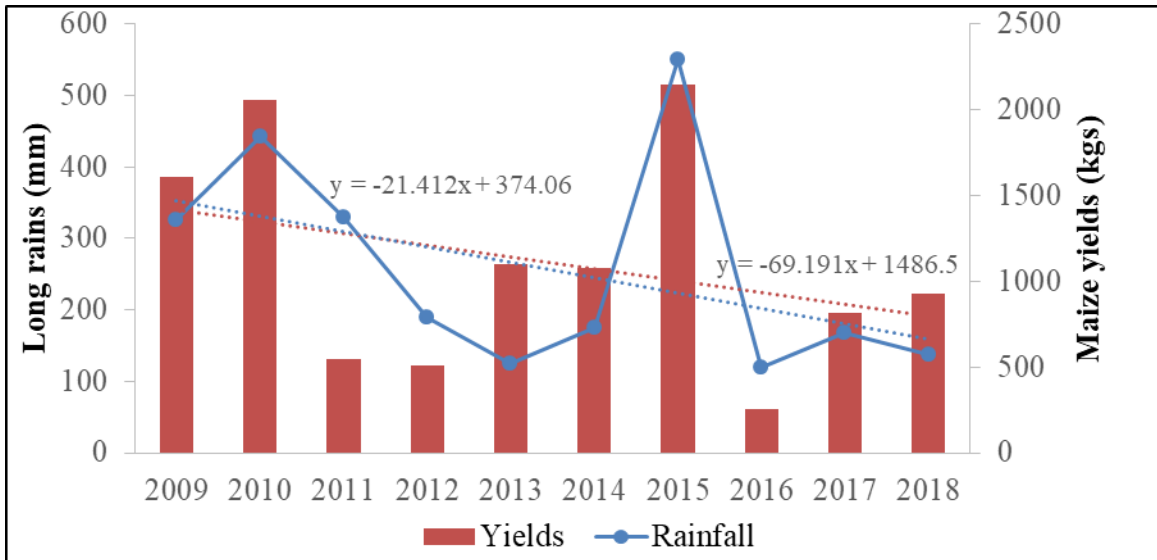


Figure 4.11: Seasonal rainfall and maize yields trends during Long Rains (2009–2018)

Source: Field Data, 2019

4.6.3 Seasonal Rainfall and Maize Yields Data during the Short Rain Season

During the short rains, variations in rainfall caused variations in maize yield, as seen in Figure 4.12. Figure 4.12 clearly show a decrease in the trend lines for rainfall and maize yields, with negative gradients of -10.384 and -162.71, respectively. Similarly, these curves peaked in the same years, 2010, and 2015 and dips in 2011, 2012, and 2016.

Water levels above those required by the crop have a detrimental impact on yields. According to Rowhani *et al.* (2011), a rise in inter-seasonal precipitation affects maize yield. Higher rainfall intensities can also lead to increased soil erosion and nutrient losses from arable soils, affecting crop productivity. This can explain the lower yields in 2013 and 2018 despite the increase in rainfall amounts.

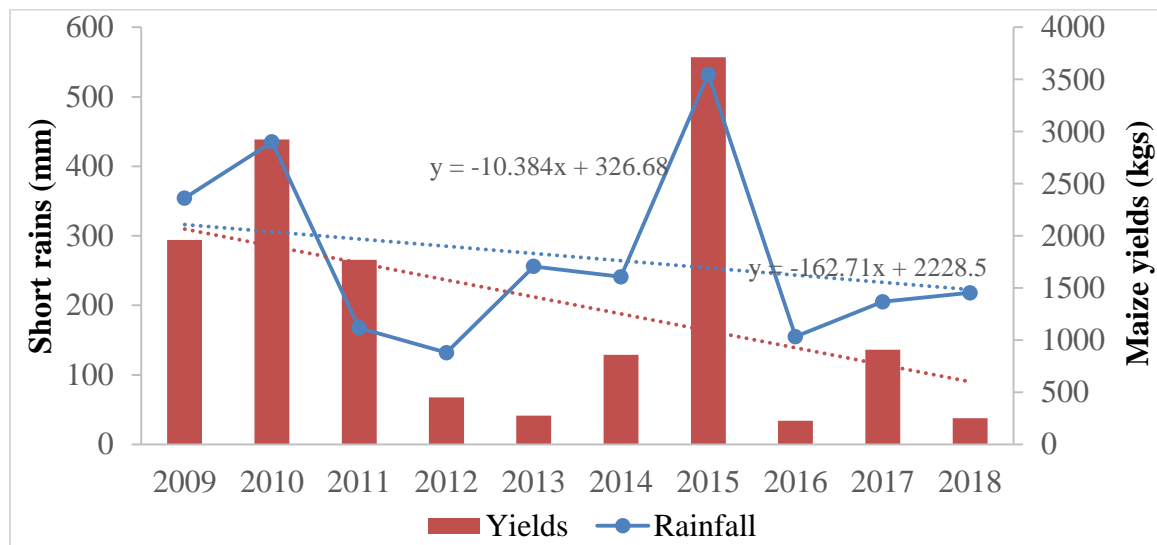


Figure 4.12: Seasonal rainfall and maize yield trends during Short Rains Season (2009–2018)

Source: Field Data, 2019

4.7 Analysis of Rainfall Characteristics

4.7.1 Long-term monthly rainfall

Sawa *et al.* (2011) define onset as the time when an area receives enough rain to support agricultural growth, whereas cessation refers to the conclusion of the effective rainy season. It does not refer to the last day of rain, but rather to the point at which rain cannot be assured or effective any longer. These terms were adopted and used as the definitions in this research for the research area. The researcher plotted a long-term seasonal rainfall

trend in Kieni East sub-County in Nyeri County in order to show the rain seasons. It is obvious from Figure 4.13 that there are two rain seasons; long rains in the months of March, April, and May (MAM) and short rains in the months of October, November, and December (OND). The onset month for the long rains is March, as shown in the figure, the peak April while May is the cessation. As for the short rains, the onset is October, peak November while the cessation is December. Additionally, the dry season is clearly shown as January and February.

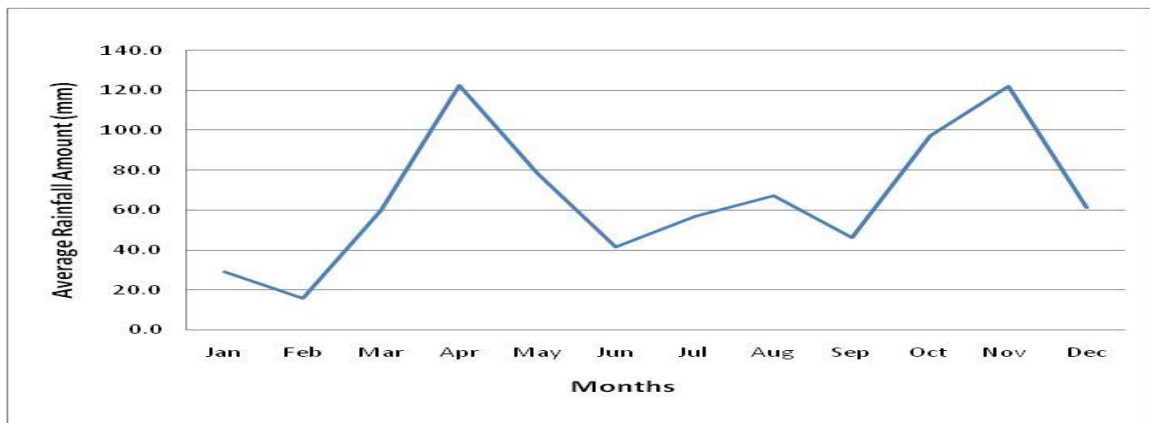


Figure 4.13: Long-Term monthly rainfall (1988-2018)

Source: Field Data, 2019

4.7.2 Analysis of Rainfall Characteristics during the Long Rain Season

The findings in Table 4.5 show the peak, onset and cessation months for long rains in Kieni East Sub-County in Nyeri County.

Table 4.5: Summary of Rainfall Characteristics during the Long Rain Season

Year	Peak Month	Onset Month	Cessation Month
1988	April	March	May
1989	April	March	May
1990	April	March	May
1991	May	March	June
1992	April	April	July
1993	April	April	July
1994	May	March	July
1995	April	March	June
1996	May	March	June
1997	April	March	May
1998	April	March	May
1999	March	March	May
2000	April	April	May
2001	April	April	May
2002	April	March	May
2003	April	March	May
2004	April	April	May
2005	April	April	July
2006	April	March	June
2007	May	April	June
2008	April	March	May
2009	April	March	June
2010	March	March	June
2011	May	March	May
2012	April	April	June
2013	April	March	June
2014	April	March	May
2015	April	March	June
2016	May	March	June
2017	April	April	May
2018	March	March	May

Source: Field Data, 2019

Early warning of the start and end of rains is a common request from user needs assessments in semi-arid East Africa (Owusu *et al.*, 2017), since it will help farmers better manage potential threats to their planting and harvesting activities. The long rains in Nyeri County's Kieni East sub-County began in March and lasted till April. Figure

4.14 shows that March was recorded 21 times as the month when the rains started (67.7%), while April was recorded 9 times (32.3%). When farmers are informed of the onset date, they plan when to prepare their field and get the necessary inputs. False rainy season onset leads to replanting and raise maize cultivation costs. As a result, the start of seasons must be coordinated to minimize the risk of crop failure. The start of the rainy season is critical for agriculture.

Camberlin and Okoola (2003) made an important discovery that a 20-day delay in the main rainy season in Kenya resulted in a 25-30% reduction in maize output. According to Barron *et al.* (2003), an uneven seasonal distribution of rainfall, such as the one depicted by MAM, might expose crops to a variety of mild to severe intra-seasonal dry spells, lowering yields. A delayed onset means a shorter growing season for the crops, resulting in lower yields (Mugalavai *et al.*, 2008). Araya and Stoosnijder (2011) found that short growth periods were one of the factors in Ethiopia leading to crop failure. Smallholder maize farmers must plant prior to or at the start of the MAM season, as failing to do so may result in a large quantity of rainfall being missed, affecting maize yield. The cultivation of early maturing maize seeds, as well as drought mitigation methods such as rainwater harvesting, are therefore significant in the Kieni East sub-County.

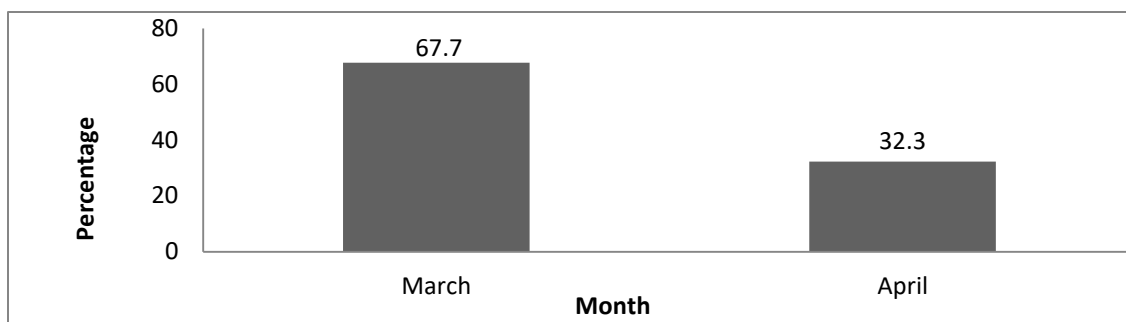


Figure 4.14: Onset Month for the Long Rains Season

Source: Field Data, 2019

The peak month during the long rains season in Nyeri County's Kieni East sub-County varied from March to May. Figure 4.15 shows that the highest month for long rainfall varies between April (71.2%), May (19.4%), and March (9.4%).

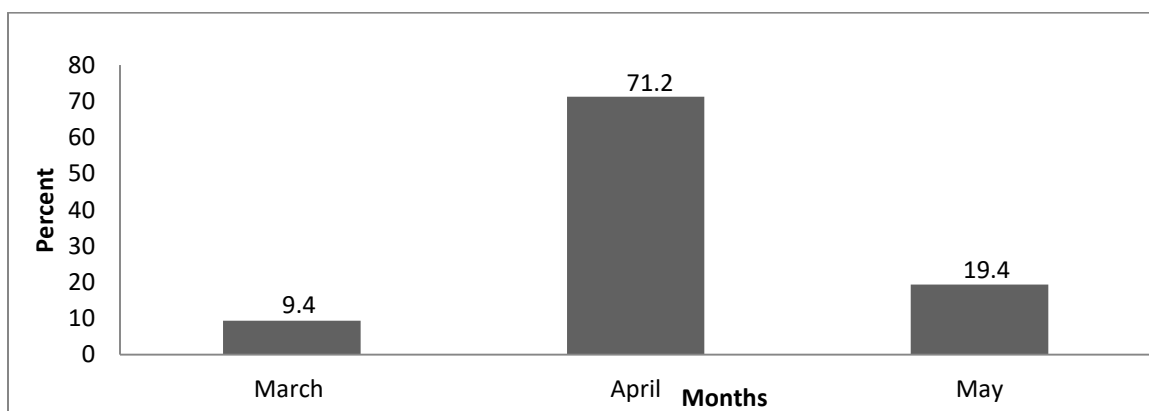


Figure 4.15: Peak Month for the Long Rains in Kieni East sub-County

Source: Field Data, 2019

The cessation month for the long rains season in Kieni East sub-County in Nyeri County varied from May to July. According to Figure 4.16, the cessation for the long rains varied from May (54.6%), June (32.5%) and July (12.9%). An early cessation implies a short

crop growing season leading to low crop yields. This concurs with the findings by Oruonye *et al.* (2014) that a reliable estimation of the onset and cessation dates of the rain crop could help maximize rainwater use by farmers.

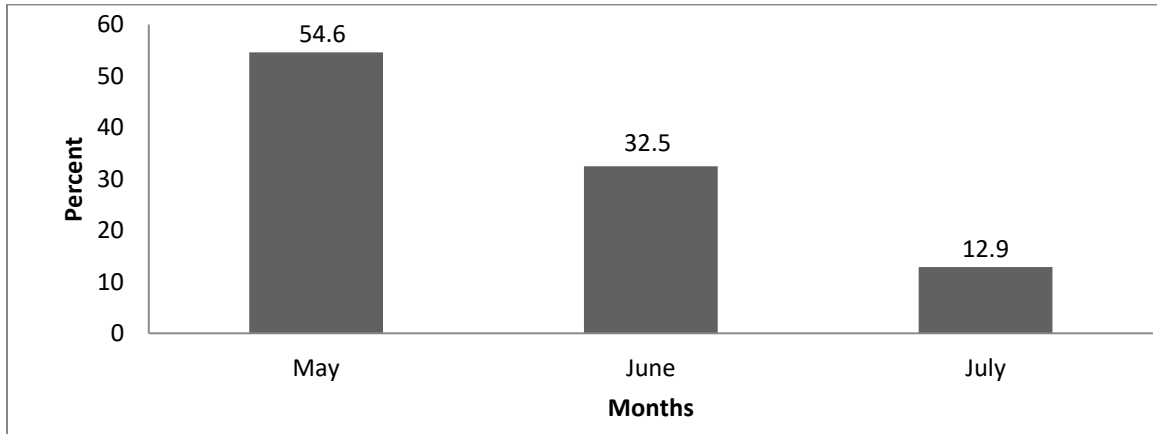


Figure 4.16: Cessation Month for the Long Rains in Kieni East sub-County

Source: Field Data, 2019

4.7.3 Analysis of Rainfall Characteristics during the Short Rain Season

Results in Table 4.6 show the peak, onset and cessation months for short rains season in Kieni East sub-County in Nyeri County.

Table 4.6: Summary of Rainfall Characteristics during the Short Rain Season

Year	Peak month of Rainfall	Onset month of rainfall	Cessation month of rainfall
1988	November	September	December
1989	October	October	December
1990	November	October	December
1991	August	October	December
1992	November	October	December
1993	November	October	December
1994	November	October	December
1995	November	October	January
1996	November	October	December
1997	November	October	January
1998	November	October	December
1999	November	October	December
2000	October	October	December
2001	November	October	December
2002	December	October	January
2003	December	October	January
2004	November	October	December
2005	October	October	December
2006	December	October	January
2007	October	October	December
2008	October	October	December
2009	November	October	February
2010	November	October	December
2011	November	October	December
2012	October	October	December
2013	October	October	December
2014	November	September	December
2015	November	October	January
2016	November	October	December
2017	November	October	December
2018	November	October	January

Source: Field Data, 2019

The short rains in Nyeri County's Kieni East sub-County began in September and lasted till October. According to Figure 4.17, September received 93.5% of the rains received at the start, whereas October received 6.5% of the onset rainfall. This results in a prolonged

crop growing season because rainfall peaks in November and ceases between December and February. Mugalavai *et al.* (2008) agreed, arguing that for short rains, early start translates into a prolonged growing season. This could explain why the OND season has higher yields, making it the primary agricultural growing season in the research location. Due to delayed onset of rains, shorter growing seasons impair soil preparation and expose crops to greater terminal moisture stress during grain filling, decreasing crop yields. Short rains in East Africa are commonly known to be more predictable, according to Nicholson (2017), due to shifts in the Indian Ocean Dipole and ENSO.

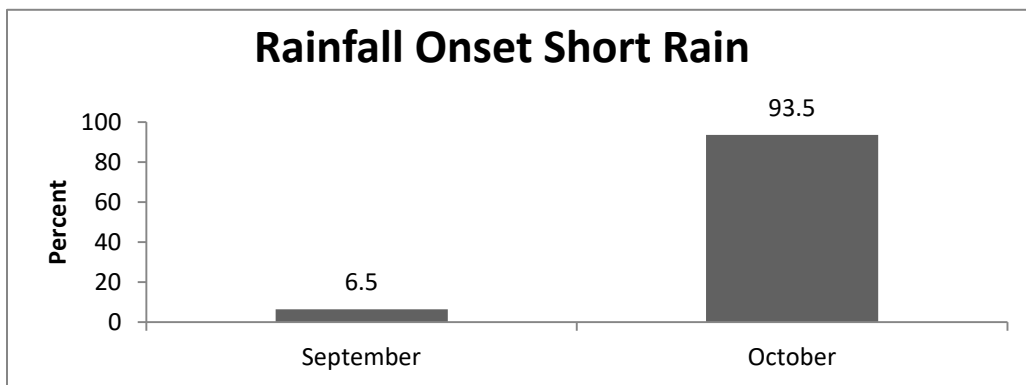


Figure 4.17: Onset Month for the Short Rains

Source: Field Data, 2019

The peak months for short rainfall in Nyeri County's Kieni East sub-County ranged from October to December. Figure 4.18 shows that November is the peak month recorded for the short rains (64.5%) times,, followed by October (22.6%), and December (12.9%).

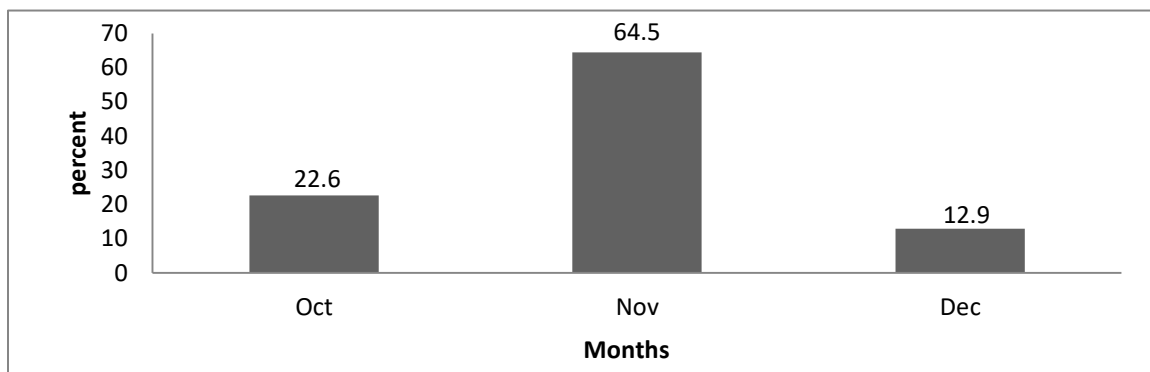


Figure 4.18: Peak Month for the Short Rains in Kieni East Sub-County

Source: Field Data, 2019

Figure 4.19 shows that the short rains cessation was recorded in December (71%), January (22.6%), and February (6.4%). Seasonal shift is a challenge in the sub-County, according to these findings, and farmers need to be informed and instructed in order to plant on time. Farmers must plant early if the maize crop is to maximize rainfall received in the early phases of the season, with rainfall peaking in November. Effective utilization of weather forecast information, such as commencement and cessation dates, can help the sub-County maximize maize yields by maximizing rainfall. Short growing seasons were found to be one of the causes of crop failure by Araya and Stroosnijer (2011). Farmers must plant early because the cessation begins in December. This allows farmers to maximize rainfall obtained in the early phases of the season. Planting dates must be well-timed for optimal maize yields. This prevents crops from succumbing to moisture stress during their vital early stages of development (Chivenge *et al.*, 2015). Medium and short-term maize varieties generate larger yields when planted early. As a result, short cycle maize varieties, rainwater gathering, and irrigation would be critical adaptation strategies in Kieni East sub-County.

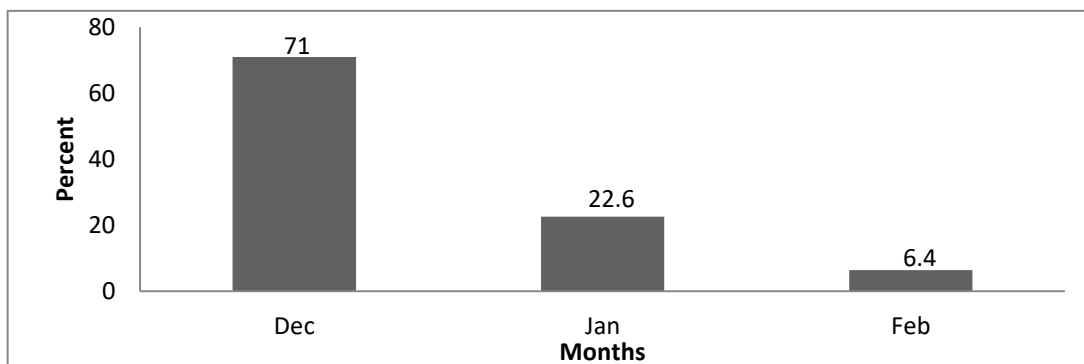


Figure 4.19: Cessation Month for the Short Rains in Kieni East Sub-County

Source: Field Data, 2019

4.8 Correlation between Rainfall Amount and Maize Production

4.8.1 Correlation between Annual Rainfall and Annual Maize Yield

The correlation between annual rainfall amount and yearly maize yield is shown in Table 4.7. The p-value of 0.004 is less than the threshold of 0.01. This means that there is a significant positive correlation between annual rainfall and yearly maize yield in Nyeri County's Kieni East sub-County at 1% levels of significance.

Table 4.7: Correlation between Annual Rainfall and Annual Maize Yield

		Annual Rainfall	Annual Maize Yield
Annual Rainfall	Pearson Correlation	1	0.821**
	p-Value		0.004
	N	10	10
Annual Maize Yield	Pearson Correlation	0.821**	1
	p-Value	0.004	
	N	10	10

** Correlation is significant at the 0.01 level (2-tailed).

Source: Field Data, 2019

4.8.2 Correlation between Seasonal Rainfall and Seasonal Maize Yields during the Long Rains

The correlation between rainfall and maize yield under long rains is seen in Table 4.8. The p-value of 0.009 is less than the threshold of 0.01. This means that there is a strong positive correlation between rainfall and maize yield during long rains in Nyeri County's Kieni East sub-County at 1% levels of significance.

Table 4.8: Correlation between Rainfall Amount and Maize Yield during Long Rains

		Long Rains	Maize Yield Annual
Long Rains	Pearson Correlation	1	0.634**
	p-Value		0.009
	N	10	10
Maize Yield	Pearson Correlation	0.634**	1
	p-Value	0.009	
	N	10	10

** Correlation is significant at the 0.01 level (2-tailed).

Source: Field Data, 2019

4.8.3 Correlation between Seasonal Rainfall and Seasonal Maize Yields during the Short Rains

The correlation between rainfall and maize yield during short rains is seen in Table 4.9. The p-value is less than 0.01 with a p-value of 0.000. This means that there is a strong positive correlation between rainfall and maize yield during short rains in Nyeri County's Kieni East sub-County at 1% levels of significance.

This is supported by a research conducted in the Laikipia East district (Huho *et al.*, 2012). Annual rainfall amounts increased between 1976 and 2005, but this did not result in greater agricultural production. This was ascribed to the disruption of farming activities

caused by changing rainfall patterns. Extreme climatic events and climate factors influencing crop output owing to shifting and erratic climate conditions like fluctuating rainfall and unpredictable floods have a negative impact on maize harvests, especially in the ASALs, according to Adamgbe and Ujoh (2013). The study concludes that if maize is correctly evaluated in terms of how it adapts to climate change, effective adaptive measures are likely to be established. These findings support the findings of Eludoyin *et al.* (2017), who found that heavy rainfall, too early rainfall, late rainfall, and protracted dryness after an initial rainfall, are common weather-related reasons of low crop yields.

Table 4.9: Correlation between Rainfall Amount and Maize Yield during Short Rains

		Short Rains	Maize Yield Annual
Short Rains	Pearson Correlation	1	0.918**
	p-Value		0.000
	N	10	10
Maize Yield	Pearson Correlation	0.918**	1
	p-Value	0.000	
	N	10	10

** Correlation is significant at the 0.01 level (2-tailed).

Source: Field Data, 2019

4.9 Farmers Adaptation Strategies to Rainfall Variability in Kieni East Sub-County

4.9.1 SWOT Analysis

The SWOT Matrix, a strategic planning approach, was used to assess the strengths, weaknesses/limitations, opportunities, and threats faced by smallholder maize farmers in Nyeri County's Kieni East sub-County. It entailed defining the study's objectives, as well as identifying internal and external factors that are favorable and unfavorable to achieving the objectives. Strengths and weaknesses, according to Humphrey (2004), are

internal characteristics over which you have some control, whereas opportunities and threats are external elements over which a single person, in this case the farmer, has no control. According to the SWOT matrix on Table 4:10, the SWOT analysis for this study analyzed several underlying aspects and findings established in the study affecting maize farmers in Nyeri County's Kieni East sub-County, which guided conclusions and formulation of research recommendations.

Table 10: SWOT Matrix

STRENGTHS	WEAKNESSES
Farmers were at the prime age.	Insufficient water harvesting strategies
Literacy of farmers.	Decline in farm sizes for maize cultivation
Availability of labor based on household size and Land ownership	Inadequate training on maize farming
Gender inclusivity	Inadequate capital
Additional income generating activities, water harvesting, use of manure and fertilizer	Inadequate weather data
A bi-modal rainfall pattern	Mostly women engaged in farming
OPPORTUNITIES	THREATS
Various sources of training for farmers	Poor seed qualities
Availability of maize seeds from agro-vets	Inadequate rainfall
Assistance by the County government	Pests and diseases
Varieties of water harvesting activities	Lack of information on modern and efficient adaptive strategies
Kenya Meteorological Station(Nyeri)	Farmers not planting according to the seasonal weather changes

Source: Field data, 2019

4.9.2 A SWOT analysis of existing adaptive strategies in Kieni East Sub County

The findings in Table 4.11 show that the population of Nyeri County's Kieni East sub-County is relatively young. The majority (46.1%) were between the ages of 41 and 60,

with (41%) between the ages of 21 and 40 following closely behind. Only 0.5% of the participants were under the age of 20, while 12.4% were beyond the age of 60. This supports a research by Momanyi *et al.* (2012), which indicated that the average age of a Kenyan farmer is 57. This indicates that the majority of the farmers in the study area are in that age range. The population is made up of people who are relatively young and have the energy to support farming activities, notably maize farming, as well as any adaptive measures that aid in cultivation. They're also a resource that, when managed correctly, can help reduce the limitations of small land size by adopting intensive agriculture. According to Mintewab *et al.* (2013), the quantity of experience required to appreciate various components of climate variability that affect agricultural methods is proportional to the age of the farmer. Farmers who are older are more likely to have seen the majority of climatic variability difficulties as well as the variability of its variables. As a result, they are more likely to perceive and adjust to rainfall fluctuations.

The survey found that both men and women work in maize cultivation, according to Table 4:11. This supports the findings of Ndegwa *et al.* (2010), who discovered that men and women both farm, with the main variation being the farming activities they engage in. The survey did find, however, that the majority (56.2%) of the household heads who participated in the survey were female. It's possible that this is due to the fact that women are more involved in agricultural operations than men (Odame *et al.* 2002). These findings further support Peacock *et al.* (2004) hypothesis that, as a result of quicker male out-migration, agriculture is increasingly becoming a female-dominated sector, with females bearing the brunt of maize cultivation. The existing labor force has therefore been strained, affecting maize yield in the Kieni East sub-County. Because maize

harvests are dwindling, several men relocate in search of alternative sources of income. In the position of household heads, however, there is a gender balance, as neither gender outnumbers the other by more than two-thirds. However, the relatively young population of Kieni East sub-County in Nyeri County, which is made up of more females, as shown in Table 4.11, suggests that the population of Kieni East sub-County in Nyeri County will grow rapidly over time, leading to further land fragmentation and a decline in maize yields. According to Table 4:11, the majority of homes (123 (56.6%) had between 4 and 6 family members, with 74 (34.2%) having between 1 and 3 individuals. Only 20 people (9.2%) had seven to nine family members. These were used to offer farm labor. In Kenya, labor is a crucial component of agricultural production, with most farmers, especially smallholders, employing traditional farming practices and cultivating the majority of their land by hand. Family members do the majority of the job, with the amount of work depending on family arrangements and the number of hours spent. In addition, seasonal labor demands vary, as do labor attributes such as education and health. Furthermore, agricultural experiences influence crop production through work capability and crop management methods quality (Blanc, 2011), all of which have an impact on maize yields.

Table 4.11: Demographic Characteristics of the Respondents

	Categories	Frequency	Percent
Gender	Male	95	43.8
	Female	122	56.2
	Total	217	100
Age (Years)	< 20	1	0.5
	21 – 40	89	41
	41 – 60	100	46.1
	> 60	27	12.4
	Total	217	100
Family Size (members)	1 -3	74	34.2
	4 – 6	123	56.6
	7 – 9	20	9.2
	Total	217	100

Source: Field data, 2019

Table 4.12 shows that the majority of respondents (45.2%) had completed primary school, 39.2% secondary school, 11.1% post-secondary education, and 4.6% had completed informal education. As a result, the level of education in Nyeri County's Kiieni East sub-County was evidently low. The majority of the respondents, on the other hand, had the fundamental literacy skills required to interpret farming processes. According to Glennerster *et al.* (2011), such low levels of education are due to high primary school dropout rates, particularly among girls. It has been determined that the domestic labor market in ASALs consistently fails to appeal to the educated, causing them to migrate. Educated farmers can use adaptive practices and make decisions that increase agricultural productivity, such as asking for finance and using title deeds as security, as well as crop diversity, irrigation, and planting at the right time. Farmers with greater education have better access to adaptation information and are more likely to adapt to climate change (Deressa *et al.*, 2009).

According to Table 4:12, respondents had supplementary income-generating activities such as business (52.6%), casuals (37.3%), and formally employed (10.1%) as a strategy to mitigate the effect of rainfall variability. According to study conducted by Bhatta *et al.* (2015), a large proportion of farm households in Bihar work as wage laborers on farm lands or in non-farm industries. Farmers need money to buy things like certified seeds and fertilizer for their farms. Kuyiah (2007) agrees, claiming that monetary constraints and limited land holdings are the two most significant impediments to achieving greater farm incomes and optimal agricultural productivity. Poverty, a lack of solid property rights, a lack of cash, farm size, a lack of technical experience, and off-farm jobs are all listed as hurdles to the adoption of climate variability adaptation measures by Gbetibouo (2009).

Table 4.12: Socio-economic Characteristics of the Respondents

	Categories	Frequency	Percent
Education Level	Informal	10	4.6
	Primary	98	45.2
	Secondary	85	39.2
	Post-Secondary	24	11.1
	Total	217	100
Income generating activities	Formal	22	10.1
	Business	114	52.6
	Casual	81	37.3
	Total	217	100

Source: Field data, 2019

According to the findings in Table 4.13, the majority of respondents have very small land sizes, with 52.1% having between 0 – 2 acres, 41.5% 3 – 5 acres, and just 6.4% having more than 5 acres. Due to the small land sizes in Kieni East sub-County, farmers must

invest as much as possible on the present land to boost productivity because there is limited room for expansion. According to Ogola *et al.* (2011), small land area indicates that intensive farming is the only option for increased production. Because the majority of maize farming is done on family property that is very small in size, as shown in Table 4.13, this supports optimization of the land resource compared to leased land. However, as the population grows, there will be greater sub-division of family land through inheritance, as well as a major reduction in area available for settlement.

This, in turn, will diminish the amount of land under maize cultivation, resulting in lower maize yields. Furthermore, if land area per household decreases due to population growth, small and fragmented plots may limit the utilization of some viable adaption strategies. Due to the limited land size in Kieni East sub-County, as well as the fact that most farmers rely on rain-fed agriculture, they are forced to optimize maize yields. Furthermore, the issue of land size suggests that cropping strategies must be intensified. Agricultural intensification, which leads to greater productivity, would aid in mitigation by making better use of agricultural inputs (Burney *et al.*, 2010).

Table 13: Farm Characteristics in Kieni East Sub- County

	Categories	Frequency	Percent
Farm Size (acres)	0 – 2	113	52.1
	3 – 5	90	41.5
	> 5	14	6.4
	Total	217	100
Land Ownership	Family Land	143	65.9
	Leased	21	9.7
	Bought	53	24.4
	Total	217	100

Source: Field data, 2019

According to Table 4:13, majority of the respondents, (65.9%) were cultivating maize on family land, while (24.4%) had purchased the farm, and (9.7%) were leasing the land. This means the farmers don't have to pay more for leasing, which would cut into their profit margins. Farmers who cultivate crops on leased property suffer greater losses as a result of rainfall variability, and they are less receptive to adaptation strategies because they are only on the land for a short time. For farm productivity, land and other productive resources must be available and accessible (Moock, 1973). Farmers who cultivate on family land, as opposed to those who lease property for a limited time, have a better chance of adopting permanent and long-term adaptation techniques to rainfall variability.

Small-holder maize farmers have two rainfall seasons, MAM and OND, according to the area's accessible rainfall data on long-term seasonal rainfall trends (Fig. 4.13), in which crop failure in one season can be compensated by replanting in the next season. According to studies, farmers in East African countries preferred to change field preparation or planting dates to avoid climate-related hazards (Kelvin *et al.*, 2016). One probable explanation for this is because such techniques need little commitment in terms of time and money to execute, requiring simply information and training, whereas many other techniques demand significant time and money commitments. Farmers also grow early maturing and drought-resistant maize types, which, when planted at the right time, can result in enhanced yields.

In Sub-Saharan Africa, it is a common adaptive strategy (Kristjanson *et al.*, 2012; Bryan *et al.*, 2013). Late planting reduces the chance of being caught off guard by late rainfall.

Early planting is done to allow for replanting in the event that the crops do not germinate. Farmers' observations of the rainy season over the last few years are used to change planting dates, which is especially crucial for rain-fed agriculture. Planting at the right time permits the plant to mature before the dry season begins. These findings corroborate those of Ogalleh *et al.* (2012), who discovered that fundamental adaptation strategies like planting date changes and mixed cropping are commonly adopted. According to studies from South Africa, Kenya, and Uganda, many farmers identify climate changes such as changes in the start and end of rainy seasons, increased rainfall unpredictability, decreased rainfall, and rising temperatures. (Osbahe *et al.*, 2011; Ogalleh *et al.*, 2012; Simelton *et al.*, 2013).

Despite these benefits, maize farming may be discouraged by inconsistent rainfall, low yields, and unpredictably high yield income. Expanding the number of extension staff who can advise farmers on appropriate rainfall variability adaptation measures will help farmers overcome rainfall variability. The Nyeri Meteorological Station's establishment will assist farmers in obtaining accurate weather forecasts and, as a result, planting on time based on the meteorological station's onset dates.

4.9.3 Sources of Maize Seeds

The study sought to find out where farmers in Nyeri County's Kieni East sub-County obtained the maize seeds for sowing. Figure 4.20 shows that the vast majority of respondents (98%) said they sourced maize seeds for planting from agro-vets, with only 2% saying they get it locally. This demonstrates that farmers understand that hybrid seeds are superior to locally available seeds, as the latter put them at more risk of negative

effects from rainfall variability. Early planting and the use of hybrid seeds, particularly early maturing hybrid seeds, are recommended to offset the detrimental effects of climate variability in maize cultivation may be required, according to Bancy (2000.) Despite increased certified seed production in Kenya over the previous decade, consumption has remained low due to poor distribution and high costs (GoK, 2009). In addition, the lack of control measures encourages seed market misbehavior and makes it more difficult to obtain high-quality seeds. Planting clean seeds helps to prevent undesired traits from transferring from one season to the next.

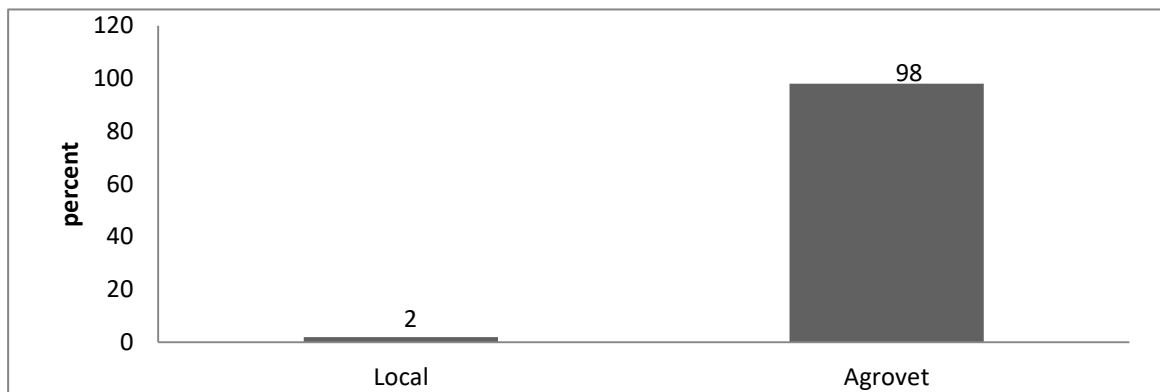


Figure 4.20: Source of Maize Seed in Kieni East Sub-County

Source: Field Data, 2019

The researcher was curious as to what factors farmers consider while deciding which maize variety to plant. The majority of farmers (82.9%) pick the maize variety to plant based on its early maturity, as shown in Figure 4.21. This was followed by 77% who wanted a high-yielding maize variety and 57.5% who wanted a drought-tolerant maize variety. However, the majority of families (73.3%) say disease resistance is not a significant factor to consider when planting maize varieties. This indicates that farmers are environmentally conscious and are cultivating crops that are suitable for their

surroundings. Farmers in Ovambo, Namibia, introduced new and early maturing varieties such as pearl millet in the 1980s, according to Newsham and Thomas (2011). Namibia's resilience to the effects of dry circumstances has improved as a result of this. Drought-tolerant or early maturing varieties are available to Kenyan farmers, particularly in the maize seed market (KEPHIS, 2015). It takes more than 150 days for the long season cultivar to mature. Maize is a C4 plant, and its optimum photosynthetic rate occurs between January and February, when the temperature is between 28⁰ and 35⁰ Celsius. During this time, the chances of experiencing dry spells lasting longer than 14 days are rather high. Water stress during anthesis and grain filling reduces yields significantly. In the future, farmers' maize seed selection must react to the sub-County's rainfall variation vagaries as a step toward increasing yields.

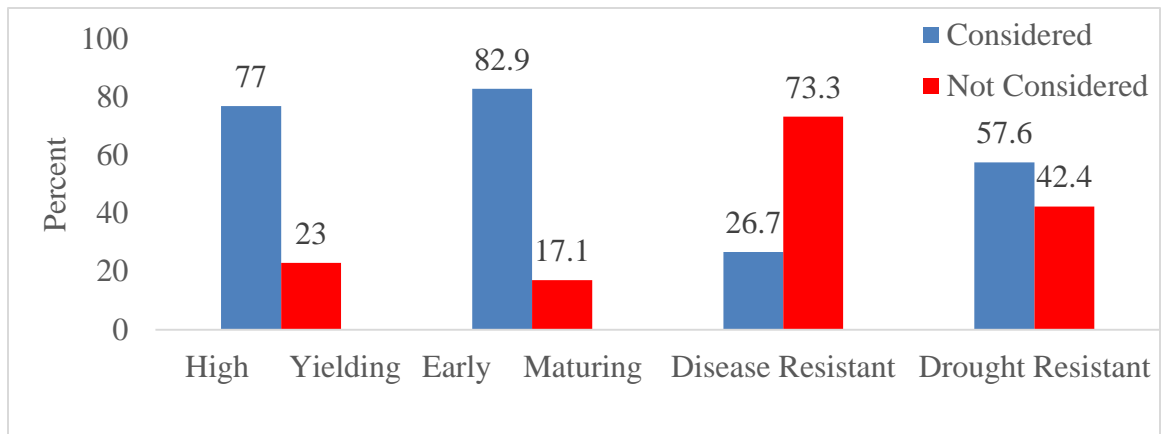


Figure 4.21: Factors Considered when Choosing Maize Varieties

Source: Field Data, 2019

4.9.4 Water Harvesting

Based on evidence demonstrating a decline in rainfall amounts over time, as well as rainfall variability, the study aimed to reveal measures of water harvesting by farmers in

Kieni East sub-County, Nyeri County. The majority of households do not harvest water, as seen in Figure 4.22. Value addition (30.5%) was more common than soil and water conservation (12.8%) according to the 2013 ASDSP household survey. This could be attributable to a lack of storage space (MoALF, 2016). Nyeri County, on the other hand, is among the counties with the highest adaption of strategies such as water harvesting, according to Syomiti (2015). Water tanks were found to be the most frequent water harvesting strategy (31.8%), followed by water pans (18.4%). Only 4.1% of farmers, on the other hand, have terraces, with a similar percentage having grass strips and only 1.4% having water wells. 92.2% of household heads, on the other hand, believe that the water gathering technologies in use are insufficient to support maize farming. Water harvesting structures are a group of topographical features that collect rainwater from a given surface area (Bernier *et al.*, 2015).

Using structures such as ridges, bunds, and dams, rainwater is channeled, stored, and used for irrigation at a later date (Ali, 2010). Harvested water can be used for additional irrigation during dry spells to maintain yield stability or for off-season cash crop planting to enhance household income in the study region. However, high investment costs and competence requirements prevent smallholder farmers in SSA from adopting the technology (Fox *et al.*, 2005). Climate-proof tactics, such as better seasonal weather forecasts (Hansen *et al.*, 2011), are critical for expanding rain-fed agriculture in the study area, but the environmental consequences of various water harvesting methods, such as drilling boreholes, must be examined.

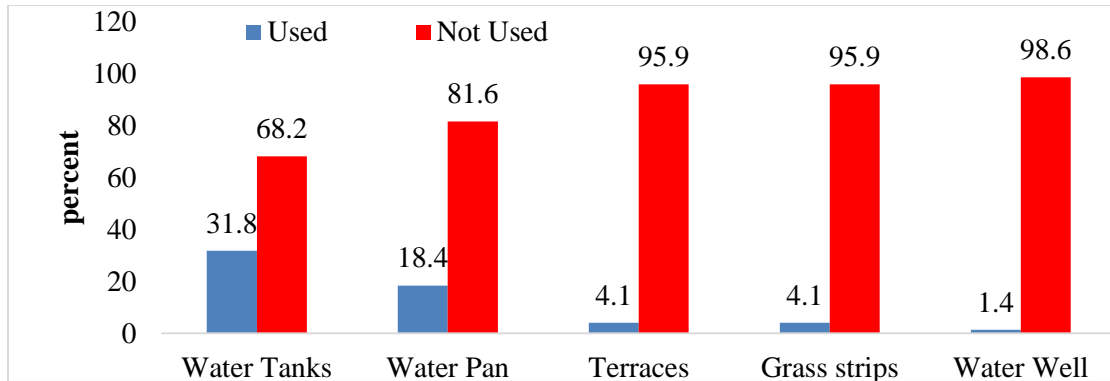


Figure 4.22: Water Harvesting Strategies in Kieni East sub-County

Source: Field Data, 2019

4.9.5 Use of Manure/Fertilizer in Maize Farming

The study intended to establish if the farmers used manure or fertilizer in their maize farming. According to the findings in Figure 4.23, the majority of respondents (92%) use manure/fertilizer in their maize cultivation, with only 8% reporting they do not. This indicates that farmers have invested in expanding maize cultivation and improving soil fertility in order to increase maize yields. Application of the right mineral fertilizer and animal manure can increase yields and improve soil fertility (Tittonel *et al.*, 2008). In Kenya, the average application rate is 52.5kg/ha, but in SSA, it could be as low as 10kg/ha for smallholder farmers (Tittonell *et al.*, 2008; FAO, 2015). Smallholder farmers use less artificial fertilizer due to high input costs and confusing labeling (GoK, 2009). Additionally, fertilizer purchases are done prior to planting, when farmers have already sold their previous season's crops, avoiding risky investments (Tittonel *et al.*, 2008). Animal manure is only used as a natural fertilizer by 24.3% of Kenyan farmers (GoK, 2009), and while this is higher in Kieni East sub-County in general, there is still a huge possibility to improve soil conditions.

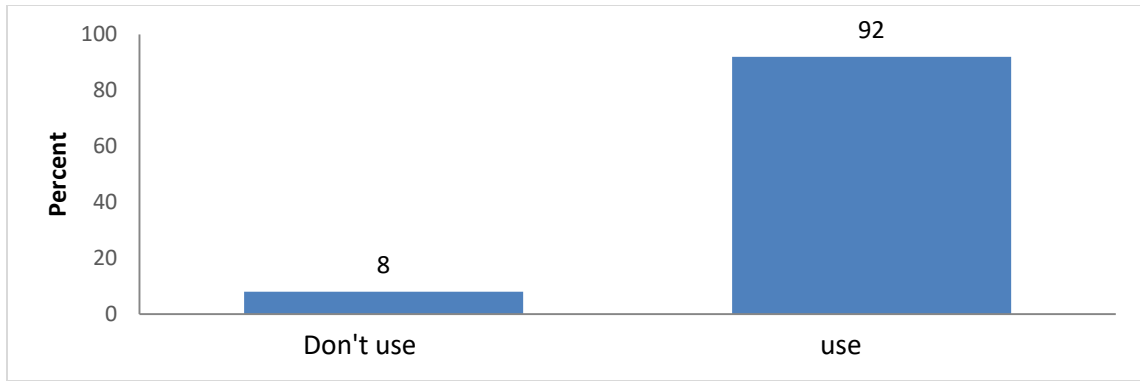


Figure 4.23: Use of Manure/Fertilizer in Kieni East Sub-County

Source: Field Data, 2019

The researcher was interested in learning where farmers in Nyeri County's Kieni East sub-County get their manure. The majority of households (81%) obtain manure for maize farming from on-farm livestock, according to the findings in Figure 4.24. This was followed by 77.9% of those who bought manure off-farm. Only 17% of maize farmers, on the other hand, were found to employ compost manure.

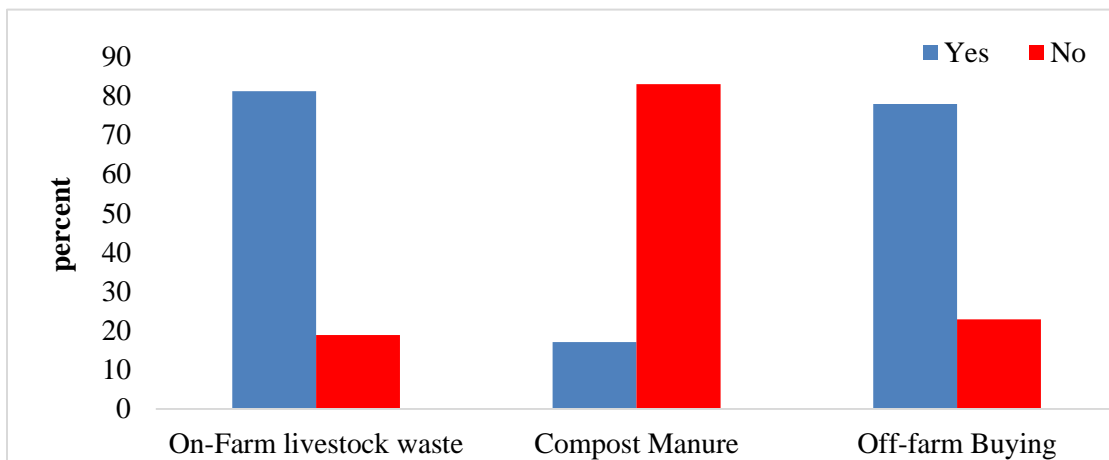


Figure 4.24: Source of Manure in Kieni East Sub-County

Source: Field Data, 2019

The study wanted to find out where farmers in Nyeri County's Kieni East sub-County get their fertilizer for maize farming. The majority of households (77.9%) get their fertilizer from agro-vets, according to the findings in Figure 4.25. Only a small percentage (34.6%) was found to have access to government-subsidized fertilizers and donations (3.2%). Due to the fact that just 20% of Kenya's land is agriculturally productive, farmers in Kenya cultivate sub-optimal land and use the same plot season after season, thus fertilizer use is crucial for sustained crop yield (Sheahan, 2011).

Farmers that utilize fertilizer on improved seeds have the maximum maize production, according to Okoboi *et al.* (2012). The limited use of fertilizers is one of the most significant barriers to raising maize yields. High input costs and a lack of financial services, according to Spielman *et al.* (2011), are among the most significant impediments to farmers adopting existing seed-fertilizer technology packages, which is a big concern in Africa (Tittone & Giller, 2013).

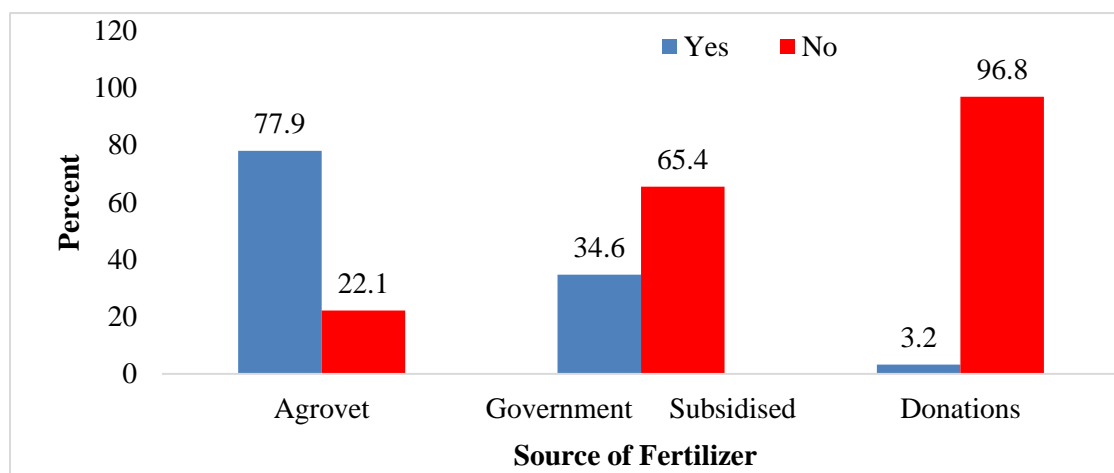


Figure 4.25: Source of Fertilizer in Kieni East Sub-County

Source: Field Data, 2019

4.9.6 Analysis of Opportunities and Threats

According to the findings in Figure 4.26, 31% of respondents had received training in maize farming practices, whereas 69% had not.

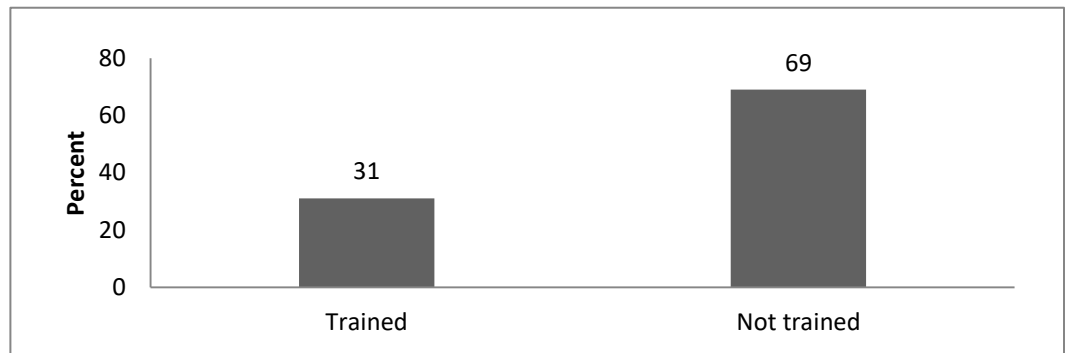


Figure 4.26: Training on Maize Farming

Source: Field Data, 2019

According to Table 4.14, the study found that there are numerous sources of maize farming instruction. The media (43.5%), government extension officers (29.6%), and private service providers (10.2%) were the sources of training for the respondents. The findings back up Muga's (2010) notion that all means of communication should be used to guarantee that farmers receive critical information on time so that they can prepare well. Increased extension officers are needed to educate farmers about the importance of seasonal weather updates and to keep them informed. Farmers will be able to make informed maize cultivation decisions, which will help to offset the effects of rainfall variability. Farmers are unable to acquire important information on scientific agricultural methods when extension officers are limited, resulting in low yields.

Table 4.14: Source of Training on Maize Farming

Source of Training	Frequency	Percent
Friends	18	16.7
Government extension officers	32	29.6
Private service provider	11	10.2
Media	47	43.5
Total	108	100.0

Source: Field data, 2019

The study sought to know if the household heads needed more maize farming training. According to Figure 4.27, the majority of respondents (86%) stated they'd prefer more maize farming information, including information on different maize varieties, their growth cycles, when to plant for maximum yields, spacing during planting, and fertilizer requirements, among other things. This desire could be linked to the region's extension agricultural authorities' failure to adequately teach farmers about the beginning and cessation of rains, as well as proper maize growing procedures in general. Farmers will be able to make more educated decisions about when to plant and harvest for maximum yields as a result of this information. Farmers' training should be expanded, particularly on the need of early planting, so that they can make use of available rains at various stages of crop growth, such as flowering and maturity.

Access to extension services is one of the most commonly mentioned adaptation criterion (Below *et al.*, 2012; Bryan *et al.*, 2013). Several studies in the SSA region have also demonstrated the value of regular training in improving farmer knowledge (Adolwa *et al.*, 2010). Agricultural extension is a type of informal adult education that is relevant to agriculture. It's employed in agricultural development, community resource development,

group promotion, and cooperative development, among other things (Oakley & Garforth, 1985). A major barrier to adaptation in SSA has been revealed to be a lack of knowledge (Ofuoku, 2013). As a result, agricultural extension is anticipated to be positively connected with rainfall variability adaption approaches. The Nyeri Meteorological Department must train extension officers in the use and interpretation of forecast information, particularly on the start and end of rainy seasons, so that the information may be communicated to farmers. Farmers may be able to increase maize yields by adjusting to the rainfall seasons. Farmers who successfully connected with climate data can better plan their livelihood activities, such as what to cultivate, when to plant, when to intensify, when to diversify, and so on (Hansen, 2012; Carr *et al.*, 2015).

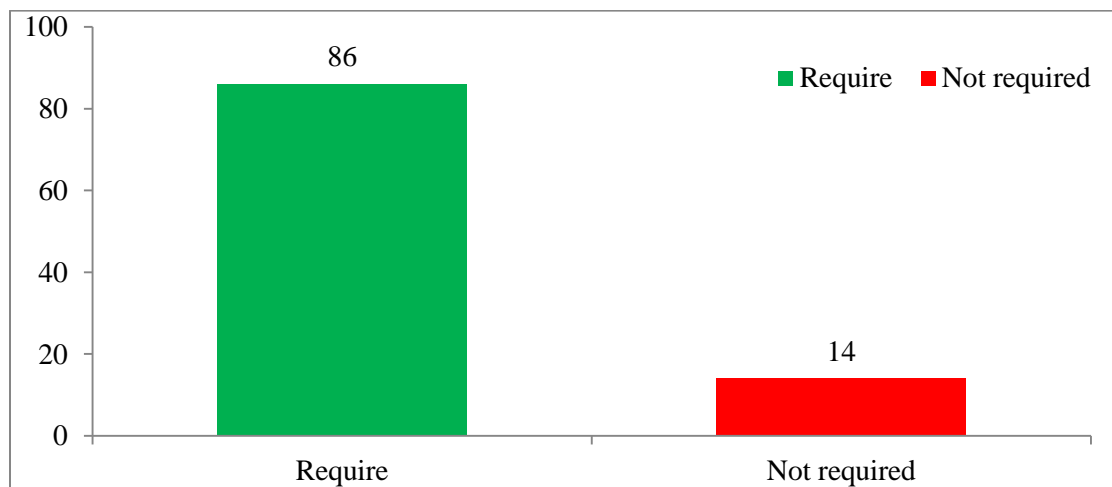


Figure 4.27: Need for Additional Training

Source: Field Data, 2019

Pests (31.3%) are the most common challenge impacting farmers in Kieni East sub-County, followed very closely by insufficient rainfall (31.1%), diseases (20.4%), and a lack of capital (17.2%), according to the statistics in Table 4.15. Rain, heavy dews, warm temperatures, and dry conditions have all been blamed for the increase in pests and

diseases (Abang *et al.*, 2014). The presence of pests could be attributed to the area's warm climate, which provides an ideal environment for them to thrive. Pest and disease infestations in plants have been shown to result in yield losses of more than 50% of significant crops. Plant diseases were also expected to reduce the output of important food and cash crops by 20% globally (Gautam *et al.*, 2013). Millipedes caused a loss in agricultural land in Gakawa, NaroMoru, and Kiamathaga in the lower sections of Kieni East in 2014, according to NDMA (2014). Diseases and pests increase production costs while lowering maize quality and yield.

Table 4.15: Challenges facing Maize Farming in Kieni East Sub-County

Challenges	Frequency	Percent
Pests	166	31.3
Diseases	108	20.4
Inadequate rainfall	165	31.1
Lack of capital	91	17.2
Total	530	100.0

Source: Field data, 2019

The study sought to identify the climate hazards that maize farmers in Nyeri County's Kieni East sub-county face. According to Table 4.16, the study discovered that drought is the most common climatic threat (45.1%), followed by frost (44.4%), and floods (10.5%). This high percentage of residents who have experienced severe drought effects indicates that they are well aware of their vulnerability. The fact that the majority of farmers rely on rain-fed crops adds to the severity of the drought. Severe rainfall, changes in rainfall timing, frequent droughts, temperature fluctuations, landslides, crop pests, floods, winds,

thunderstorms, and hailstorms are among the impressions presented in literature (Mutunga *et al.*, 2017; Fadina & Barjolle, 2018; Williams *et al.*, 2018).

By simply being aware of their vulnerability to the effects of climate change according to Hansen (2002), this can help farmers to reduce their susceptibility to climate variability. Nsabimana and Masabo (2005) discovered that knowledge is essential for technology adoption and use. Increasing the number of extension officers who visit farmers to advise them on the best ways to adjust to rainfall variability can solve these concerns. The Nyeri Meteorological Station's presence will aid in the delivery of seasonal weather forecasts to farmers, allowing them to organize their planting schedules around the station's onset dates.

Table 4.16: Climate Hazards affecting Maize Farming in Kieni East sub-County

Climate Hazards	Frequency	Percent
Frost	140	44.4
Drought	142	45.1
Floods	33	10.5
Total	315	100.0

Source: Field data, 2019

In Nyeri County's Kieni East sub-County, the researcher attempted to determine the role of the county administration in aiding farmers in overcoming climate hazards. According to Table 4.17, the county government's principal engagement was in the construction of dams (43.4%), the distribution of fertilizer and seeds to farmers (37.9%), and the digging of boreholes (18.6%). Despite the fact that they are currently insufficient and dry up during the dry season, the Ministry of Agriculture is aggressively sponsoring the

construction of dams and pans in semi-arid areas, including Kieni East sub-County, in an attempt to offset the effect of rainfall variability. Orindi and Ochieng (2005) proposed seed fairs as a drought-recovery strategy in semi-arid South-East Kenya. Seeds, rather than food handouts, are a better adaptation technique to drought repercussions, according to the study.

Table 4.17: Role of Nyeri County Government on Maize Farming

Functions	Frequency	Percent
Supplying fertilizers and seeds to farmers	55	37.9
Sinking bore-holes	27	18.6
Dam construction	63	43.4
Total	145	100.0

Source: Field data, 2019

The researcher was interested in learning how farmers in Nyeri County's Kieni East sub-County handle climate hazards. Table 4.18 shows that the majority of farmers (37%) plant early maturity maize varieties, 32.7% plant drought resistant seeds, 22.2% engage in alternative farming activities, and 8% engage in other economic activities, suggesting that a range of strategies are used. These provide as a buffer in the event of severe weather, especially when the rains fail. Several studies have found that different asset bases might lead to different adaptation mechanisms among households in the same neighborhood (Jain *et al.*, 2015). Maintaining a variety of practices, according to Hoang *et al.* (2014), is a critical strategy for helping farmers to endure climate variations. This is because some of these approaches have been used to reduce risk and ensure at least some productivity during bad years for thousands of years. Irrigation is sometimes viewed as

an expensive investment that cannot be made entirely by farm households alone (Bryan *et al.*, 2011). Climate-resistant strategies, such as improved cultivars and efficient rain-water management (Hansen *et al.*, 2011), are critical for improving rain-fed agriculture. As a first step toward future climate change adaptation, it would be prudent to focus the development of livelihoods that would allow farmers to manage better with current rainfall variability based on these findings. Planting at the right time permits the plant to mature before the dry season begins.

Table 4.18: Smallholder Farmers Response to Climate Hazards

Response	Frequency	Percent
Engage in alternative farming activities	72	22.2
Planting drought -tolerant seeds	106	32.7
Planting early maturing varieties	120	37.0
Engaging in other economic activities	26	8.0
Total	324	100.0

Source: Field data, 2019

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The findings, conclusions, and recommendations of the study are summarized in this chapter. In Kieni East sub-County, Nyeri County, Kenya, the study aimed to assess the effects of seasonal and temporal rainfall variability on maize yields as well as smallholder farmers' adaptive strategies.

5.2 Summary of Study Findings

The first objective of the study demonstrated that rainfall amounts decreased during long rains in Kieni East sub-County, as evidenced by a negative gradient (-0.5162) in the trend line, with peaks in 2003 and 2018 and dips in 2016 and 2000. Long rains were seen to begin in March, peak in April, and end in May in most of the years. With peaks in 1997 and 2015 and dips in 2008 and 1993, the trend line indicates a positive gradient (1.1293), indicating an increase in rainfall amounts during the short rains. The short rains began in September, October, peaked in November, and ended in December, according to the findings. The first null hypothesis indicated that there was no significant inter- and intra-seasonal rainfall variability in the Kieni East sub-County between 1988 and 2018. Annual rainfall was less by 260.47mm from the long-term mean in 2000 to 528mm in 1997, according to the study's findings, with a standard deviation of 156.38mm and a 20% correlation of variation. The rainfall was less by 133.46mm in 2016 from the long-term mean to 178.14mm in 2003, with a standard deviation of 84.49mm and a 32% correlation

of variation. The study discovered that short rains was less by 154.05mm from the long-term mean in 2008 to 425.25mm in 1997, with a standard deviation of 126.09mm and a 46% correlation of variation. As a result, the null hypothesis was rejected, and the alternative hypothesis, "there is significant inter- and intra-seasonal rainfall variability in Kieni East sub-County between 1988 and 2018," was accepted. As a result, the study concludes that there is significant inter- and intra-seasonal temporal rainfall variability in Kieni East sub-County for both the short and long rains seasons over the last 30 years, from 1988 to 2018.

As for the second objective, the study found out that there had been a decline in the annual maize yields in tons as indicated by a negative gradient (-231.9) in Kieni East sub-County, with the peak years being 2015 and 2010, and the dips being 2016 and 2012. During the long rains, maize yields declined along a negative gradient (-69.19), with peak years in 2015 and 2010 and dips in 2016 and 2012. The short rains resulted in a negative gradient (-162.71) in maize yields, with peaks in 2015 and 2010 and dips in 2016 and 2012. Both the annual rainfall and maize yield trends were dropping compared to previous years. Surprisingly, the amount of rainfall and maize yields peaked in the same years, 2010 and 2015, and also during the short rains. This is true evidence that seasonal rainfall variability has an effect on maize yields by smallholder farmers in the Kieni East sub-County. 'There is no significant link between seasonal temporal rainfall variability and smallholder farmers' maize yields in Kieni East sub-County between 2009 and 2018,' according to the second hypothesis. The maize yield was shown to be correlated with rainfall quantity: $r(10) = p\text{-value} = 0.004$ with rainfall amount during annual rains, $r(10) = 0.634$, $p\text{-value} = 0.009$ with rainfall amount during long rains, and $r(10) = 0.918$, $p\text{-value} = 0.000$ with rainfall amount during short rains.

value = 0.000 with rainfall amount during short rains. The researcher rejected the null hypothesis and accepted the alternative hypothesis that 'There is no significant relationship between seasonal temporal rainfall variability and smallholder farmers' maize yields and accepted the alternative hypothesis that 'There is a significant relationship between seasonal temporal rainfall variability and smallholder farmers' maize yields between the years 2010 and 2018.

In Kieni East sub-County, Nyeri County, the third objective focused on smallholder farmers' adaptive strategies in response to seasonal rainfall variability on maize yields. Farmers employ a variety of methods according to the research, including obtaining improved seed kinds, seeking training on effective maize farming, harvesting water, and applying manure and fertilizers. The agro-vets provided the majority of the fertilizers, while on-farm livestock waste provided the manure. Farmers have been found to respond to rainfall variability by planting early maturing, drought-tolerant maize varieties, as well as engaging in alternative farming and economic activities. However, extension services and meteorological data were insufficient.

5.3 Conclusions

Between 1988 and 2018, the study's main goal was to examine the effects of seasonal rainfall variability on maize yields and smallholder farmers' adaptation techniques in Kenya's Kieni East sub-County, Nyeri County.

Annual rainfall amounts had dropped throughout the previous period, with an average annual rainfall of 780.07mm, a standard deviation of 158.97mm, and annual rainfall variability ranging from -260.47mm in the year 2000 to 528mm in 1997, according to the

study. During the long rains, the study's findings demonstrated a drop in rainfall amounts. From 1988 to 2018, the average rainfall amount during the long rains was 260.86mm, with a standard deviation of 85.89mm. With fluctuations ranging from -133.46mm in 2016 to 178.14mm in 2003, the trend line suggested a decline in rainfall. The study's findings revealed that rainfall amount increased during the short rains, with an average of 261.68mm and a standard deviation of 102.26mm. The variability of the short rains was observed to range from -154.05mm in 2008 to 452.25mm in 1997, indicating that there was random variability during the short rains, according to the study.

The correlation study found a substantial, positive, and strong link between annual rainfall and maize yield ($r=0.821$, $p=0.004$). The correlation study also demonstrated a substantial, positive, and strong association ($r=0.634$, $p=0.009$) between long rains and maize yields, as well as a substantial, positive, and strong link ($r=0.918$, $p=0.000$) between short rains and maize yields. Furthermore, the findings of the study indicate that there has been a shift in the timing of rainfall commencement and cessation. The long rainy season began in March and lasted until April. The month of cessation ranged from May to July. For the short rains, the onset month fluctuated from September to October, while the cessation month fluctuated from December to February.

For objective (iii), rainfall variability, insufficient water harvesting strategies, decline in farm sizes for maize farming due to population increase, inadequate weather data, inadequate maize farming training, insufficient capital for buying farm inputs, pests and diseases were among the problems faced by smallholder maize farmers in Kieni East sub-County. The study also discovered that smallholder maize farmers in the research area have particular seasonal rainfall variability adapting techniques. These include, but are

not limited to, using a range of maize seeds, water harvesting, soil conservation and management strategies, and seeking maize farming training from a variety of sources. However, as maize yields have not increased, the adaptive measures used do not appear to be effective. As a result, the findings of this study highlight the need of using consistent and long-term adaptive approaches for rain-fed maize farming in Kenya's Nyeri County.

5.4 Recommendations

The following recommendations are offered to maize farmers, stakeholders, policymakers, and researchers in Kieni East sub-County based on the study's findings.

The study recommends that the Kenya Meteorological Department (Nyeri) engage with agricultural extension officers to offer farmers with early and credible forecasts on the commencement and cessation of seasonal rains in order to boost maize yields in the research area. Farmers should plant prior to or at the start of the MAM season, since failure to do so may result in a large quantity of rainfall being missed, affecting maize output. Farmers should capitalize on maize cultivation during the OND season because rainfall begins in September and lasts until February, making it the primary crop growing season. The MAM season can then be used to plant short-cycle maize varieties to boost annual yields, as well as other crops with short growing cycles, such as beans, to protect them from the effects of rainfall variability.

Policymakers and other stakeholders could use the research findings to establish policies that focus on rainfall variability and its effect on smallholder maize farming in order to

improve maize yields, based on the association between annual and seasonal rainfall and maize yields in the study area.

Farmers must be taught on soil conservation and management practices to prevent soil nutrient loss during periods of substantial seasonal rainfall especially during the short rains season, as well as more effective and long-lasting water collection technologies for usage for the dry season during both the MAM and OND seasons.

5.4.1 Recommendation for Further Study

More research is needed to determine the most effective and long-term adaptive techniques for lowering smallholder maize farmers' sensitivity to rainfall variability and improving maize yields in the study area.

More research is needed to evaluate the effects of additional climatic characteristics on maize farming in the study area, such as temperature, warmth, light, and air, as well as non-climatic elements.

REFERENCE

- Abang, A. F., Kouame, C. M., Abang, M., Hanna, R. and Fotso, A. K. (2014). “Assessing vegetable farmer knowledge of diseases and insect pests of vegetable and management practices under tropical conditions”. *International Journal of Vegetable Science*, Vol. 20 No. 3, pp. 240-253, doi: 10.1080/19315260.2013.800625.
- Adamgbe, E. M., & Ujoh, F. (2013). Effect of variability in rainfall characteristics on maize yield in Gboko, Nigeria.
- Adolwa, I. S., Esilaba, A. O., Okoth, P., Mulwa, M. R. (2010). Factors influencing uptake of integrated soil fertility management knowledge among smallholder farmers in Western Kenya. 12th KARI Biennial Scientific Conference: *Transforming agriculture for improved livelihoods through agricultural product value chains*. KARI headquarters. Pp. 1146-1152.
- Harris, T., & Consulting, T. H. (2014). *Africa agriculture status report 2014: Climate change and smallholder agriculture in Sub-Saharan Africa* (No. BOOK). Alliance for a Green Revolution in Africa (AGRA).
- Ali, M. H. (2010). *Fundamentals of Irrigation and On-farm Water Management: Volume 1*. Springer New York, New York, NY. 489-498.
- Ali, S., Liu, Y., Ishaq, M., Shah, T., Ilyas, A., & Din, I. U. (2017). Climate change and its impact on the yield of major food crops: Evidence from Pakistan. *Foods*, 6(6), 39.
- Amissah-Arthur, A., Jagtap, S., and Rosenzweig, C. (2002). Spatio-temporal effects of El-Nino events on rainfall and maize in Kenya. *International Journal of Climatology*, 22 (15), 1849-1860.
- Araya, A., and Stroosnijder, L. (2011). Assessing drought risk and irrigation needs in Northern Ethiopia. *Agricultural and Forest Meteorology*, 15, 425-436.
- Atheru, Z. K. K. (1999). Fundamental of forecast verification. In first climate prediction capacity building training workshop for the GHA, Vol. 1, 111-116.
- Bishaw, B., Neufeldt, H., Mowo, J., Abdelkadir, A., Muriuki, J., Dalle, G., ... & Mbow, C. (2013). Farmers’ strategies for adapting to and mitigating climate variability and change through agroforestry in Ethiopia and Kenya.
- Bancy M. M. (2000). “The influence of climate change on maize production in the semi-humid areas of Kenya”. *Journal of Arid Environments* 46, no. 4:333-334.

- Barasa, B. M. O., Oteng'i, S. B. B., & Wakhungu, J. W. (2015). Farmer awareness of climate variability in Kakamega county, Kenya. *The International Journal of Science and Technoledge*, 3(7), 43.
- Barron, J. (2004). *Dry spell mitigation to upgrade semi-arid rainfed agriculture: Water harvesting and soil nutrient management for smallholder maize cultivation in Machakos, Kenya* (Doctoral dissertation, Institutionen för systemekologi).
- Barron, J., Rockstrom, J., Gichuki, F., and Hatibu, N. (2003). Dry spell analysis and maize yields for two semi-arid locations in East Africa. *Agricultural and Forest Meteorology*, 117, 23-27.
- Basir, A., Aziz, A., Khan, M. A., Khan, I., Adnan, M., Fahad, S., ... & Rahman, A. (2018). 20. Phenology and growth traits response of maize (*Zea mays* L.) genotypes to semi-arid conditions. *Pure and Applied Biology (PAB)*, 7(1), 169-173.
- Below, T., Artner, A., Siebert, R., Sieber, S. (2010). *Micro-level practices to adapt to climate change for African small-scale farmers*. International Food Policy Research Institute. IFPRI Discussion Paper 00953. International Food Policy Research Institute (IFPRI). Washington DC, USA.
- Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables?. *Global environmental change*, 22(1), 223-235..
- Below, T. B., Schmid, J. C., & Sieber, S. (2015). Farmers' knowledge and perception of climatic risks and options for climate change adaptation: a case study from two Tanzanian villages. *Regional environmental change*, 15(7), 1169-1180.
- Bernier, Q., Meinzen-Dick, R. S., Kristjanson, P. M., Haglund, E., Kovarik, C., Bryan, E., ... & Silvestri, S. (2015). Gender and institutional aspects of climate-smart agricultural practices: evidence from Kenya. *CCAFS Working Paper*.
- Bhandari, G. (2013). Effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura district of Far Western development region, Nepal. *International journal of plant, animal and environmental sciences*, 3(1), 247-256.
- Bhatta, G. D., Aggarwal, P. K., Shrivastava, A. (2015). Livelihood diversification and climate change adaptation in Indo-Gangetic plains: implication of rainfall regimes. *J. Agric. Environ*, 16, 77-94.
- Bilham, J. (2011). Climate change impacts upon yields in Kenya: learning from the past. *Earth and E-nvironment*, 6, 1-45..

- Blanc, E. (2011). *The impact of climate change on crop production in Sub-Saharan Africa*. (Doctoral dissertation). University of Otago, Dunedin.
- Boberg, F., Berg, P., Thejll, P., Gutowski, W. J., and Christensen, J. H. (2010). Improved confidence in climate change projections of precipitation further evaluated using daily statistics from ENSEMBLES models. *Climate dynamics*, 35 (7-8): 1509-1520.
- Bruin, K. (2011). *An Economic Analysis of Adaptation to Climate Change under Uncertainty*. Unpublished Doctoral Dissertation, University of Wageningen, the Netherlands.
- Bryan, E., Ringler, C., Okoba, B., Koo, J., Roncoli, C., Herrero, M. and Silvestri, S. (2011). *Adapting Agriculture to Climate Change. Household and Community Strategies and Determinants*. January 28, 2011. Accessed from ipcc-wg2.gov/nj-lite-download2.php?id/.
- Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., Hererro, M. (2013). "Adapting agriculture to climate change in Kenya: Household strategies and determinants". *Journal of Environmental Management* 114, pp 26-35, doi: 10.1016/j.jenvman.2012.10.036.
- Burney, J. A., Davis, S. J., Lobell, D. B. (2010). Greenhouse gas mitigation by agricultural intensification. *Proceedings of the National Academy of Sciences* 107, 12052-1257.
- Camberlin, P. (2010). More variable tropical climates have a slower demographic growth. *Climate Research* 41, 157-167.
- Camberlin, P., Moron, V., Okoola, R., Philippon, N., Gitau, W. (2009). Components of rainy seasons' variability in equatorial East Africa: onset, cessation, rainfall frequency and intensity. *Theoretical and Applied Climatology* 98, 237-249. DOI:10.1007/s00704-009-0113-1.
- Camberlin, P., Okoola, R. E. (2003). The onset and cessation of the 'long rains' in Eastern Africa and their inter-annual variability. *Theoretical and Applied Climatology*. 75:43-54.
- Carr, E. R., Abrahams, D., Arielle, T., Suarez, P., Koelle, B. (2015). Vulnerability assessments, identity and spatial scale challenges in disaster-risk reduction. *Jamba. J. Disaster Risk Stud.* 7 (1), 1-17.
- CDKN. (2014). Nationally Appropriate Mitigation Action (NAMA) to accelerate geothermal power: Lessons from Kenya.

- Cheserek, B. C., Elbehri, A., and Bore, J. (2015). A nalysis of links between climate variables and tea production in the recent past in Kenya. *Donnish Journal of Research in Environmental Studies*, 2(2), 005-017.
- Chivenge, P., Mabhaudhi, T., Modi, A. T., & Mafongoya, P. (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-Saharan Africa. *International journal of environmental research and public health*, 12(6), 5685-5711.
- Claessens, L., Antle, J.M., Stoorvogel, J. J., Valdivia , R. O., Thornton, P. K., Hererro, M. (2012). A method for evaluating climate change adaptation strategies for small-scale farmers using survey, experimental and modeled data. *Agricultural Systems* 111, 85-95.
- St Clair, S. B., & Lynch, J. P. (2010). The opening of Pandora’s Box: climate change impacts on soil fertility and crop nutrition in developing countries. *Plant and Soil*, 335(1), 101-115.
- Connolly-Boutin, L. and Smit, B. (2015).” Climate change, food security and livelihoods in Sub-Saharan Africa.” *Regional Environmental Change*, Vol. 16. No. 2, pp. 385-399, doi: 10.1007/s10113-015-0761-x.
- Conway, D., Schipper, E. L. F. (2011). Adaptation to Climate Change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change* 21, 227-237.
- Cooper, P. J. M., and Coe, R. (2011). Assessing and addressing climate induced risk in Sub-Saharan rain-fed agriculture. *Experimental Agriculture*, 47 (02), 179-184.
- Cooper, P. J. M., Dimes, J., Rao, K. P. C., Shapiro, B., Shiferaw, B., Twomlow, S. (2008). Coping better with current climate variability in the rain-fed farming systems of Sub-Saharan Africa: An essential first step in adapting to future climate change. *Agriculture, Ecosystems & Environment* 126,24-35.
- Coumou , D., Rahmstorf, S. (2012). Adecade of weather extremes. *Nature Climate Change* 2, 491-496.
- Creswell, J. W., and Plano Clark, V. L. (2011). *Choosing a mixed methods design. Designing and conducting mixed methods research*, 2:53-106.
- Demeke, A. B., Keil, A., & Zeller, M. (2011). Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia. *Climatic change*, 108(1), 185-206.

- Deressa, T. T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M. (2009). Determinants of farmer's choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19 (22)248-255.
- Di Falco, S. (2014). Adaptation to climate change in Sub-Saharan agriculture: assessing the evidence and rethinking the drivers. *Eur. Rev. Agri.Econ*, 41 (3), 404-430.
- Di Falco, S., & Veronesi, M. (2013). How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia. *Land Economics*, 89(4), 743-766.
- Dube, T., Moyo, P., Ncube, M., & Nyathi, D. (2016). The impact of climate change on agro-ecological based livelihoods in Africa: A review. *Dube T, Moyo P, Mporfu M, Nyathi D (2016), The impact of climate change on agro-ecological based livelihoods in Africa: A review, Journal of Sustainable Development*, 9(1), 256-267.
- Dunning, C. M., E. C. L. Black., R. P. Allan. (2016). The onset and cessation of seasonal rainfall over Africa. *J. Geophys. Res: Atmospheres*, 121 (19) (2016), pp. 11, 405-11,424, 10.1002/2016JD025428.
- Eakin, H. C., Lemos, M. C., Nelson, D. R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. *Global Environmental Change* 27, 1-8.
- Ekwe, M. C., Joshua, J. K., Igwe, J. E., & Osinowo, A. (2014). Mathematical study of monthly and annual rainfall trends in Nasarawa State, Nigeria. *IOSR Journal of Mathematics (IOSR-JM)*, 10(1), 56-62.
- Eludoyin, A. O., Nevo, A. O., Abuloye, P. A., Eludoyin, O. M., Awotoye, O. O. (2017). Climate events and impact on cropping activities of small-scale farmers in a part of South-west Nigeria. *Weather Clim. Soc.* 2017; 9 (2): 235-253. [Google Scholar].
- Environmental Systems Research Institute (ESRI). (2011). ArcGIS Desktop: Release 10.
- Erenstein, O., Kassie, G. T., Langyintuo, A., and Mwangi, W. (2011). *Characterization of Maize Producing Households in Drought Prone Regions of Eastern Mexico.*
- Fadina, A. M. R., & Barjolle, D. (2018). Farmers' adaptation strategies to climate change and their implications in the Zou Department of South Benin. *Environments*, 5(1), 15.
- Falaki, A. A., Akangpe, J. A and Ayinde O. E. (2013). Analysis of Climate Change and Rural Farmers' Perception in Northern Central Nigeria. *Journal of Human Ecology*. 43(2):133-140 (2013).

- Faostat, F. (2015). Agriculture organization of the United Nations, 2011. *FAO*, Retrieved from <http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/S>. Acceso, 20.
- FAOSTAT. (2010). FAOSTAT Agricultural Data. www.faostat.fao.org/.
- Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16, 253-303.
- Food and Agriculture Organization (FAO). (2015). *Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade*. Food and Agriculture Organization of the United Nations (FAO), Rome.
- Food and Agriculture Organization (FAO). (2015). Crop water information. Rome: FAO.
- Food and Agriculture Organization. FAOSTAT: Retrieved on July 01, (2013), from faostat.fao.org/.
- Fox, P., Rockstrom, J., Barron, J. (2005). *Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya*. *Agricultural systems* 83, 231-250.
- Funk, C., Eilerts, G., Davenport, F., and Michaelson, J. (2010). *Climate Trend Analysis of Kenya- August 2010*.
- Funk, C., M. D. Dettinger, J. C., Michaelsen, J. P., Verdin, M. E., Brown, M., Barlow, and A, Hoell. (2008). Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proc. Natl. Acad. Sci*, 105, 1-6.
- Gallopin, G. C. (2006). Linkages between vulnerability, resilience and adaptive capacity. *Global Environmental Change* 16, 293-303.
- Gardner, T. A., Ferreira, J., Barlow, J., Lees, A. C., Parry, L., Vieira, I. C. G., ... & Zuanon, J. (2013). A social and ecological assessment of tropical land uses at multiple scales: the Sustainable Amazon Network. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 368(1619), 20120166.
- Gautam, H. R., Bhardwaj, M. L. and Rohitashw, K. (2013).” Climate change and its impact on plant diseases”. *Current science*, Vol. 105. No. 12.
- Gay, L.R. (2009). *Educational Research: competencies for analysis and application*. Second Edition, Columbus: Charles E. Merrill publishing Company.
- Gbetibouo, G. A. (2009). *Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa* (Vol. 849). Intl Food Policy Res Inst.

- Geerts, S., and Raes, D. (2012). Relative Transpiration as a Decision Tool in Crop Management: A.
- Glennerster, R., Kremer, M., Mbiti, I. and Takavarasha, K. (2011). *Access and Quality in the Kenyan Education System: A Review of the Progress, challenges and Potential Solutions*. <http://www.povertyactionlab.org/publication/access-and-quality-Kenyan-education-system>. Accessed Thursday, 5th July, 2012.
- Glotter, M., and Elliot, J. (2017). Simulating US agriculture in a modern Dust Bowl drought . *Nature Plants*, 3, 16193. <https://doi.org/10.1038/nplants.2016.193>.
- GoK, Ministry Of State for Special Programmes. (2009). *National Policy for Disaster Management Report, Nairobi*.
- Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willet, K., Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Philos. Trans. R. Soc. B: Biol. Sci.* 365, 2973-2989.
- Government of Kenya. (2012). Consultative workshop on the development of a National Climate Response Strategy Action Plan.
- Government of the Republic of Kenya (GoK). (2009). *Agricultural Sector Development Strategy (ASDS). 2009-2020*. Nairobi, Kenya.
- Government of the Republic of Kenya (GoK). (2013). *Vision2030: National Climate Change action plan 2013-2017*. Nanyuki, Kenya.
- Hansen, J. (2012). Making climate information work for agricultural development. *World Politics Review*, 21.
- Hansen, J. W., Mason, S. J., Sun, L., Tall, A. (2011). Review of seasonal climate forecasting for agriculture in Sub-Saharan Africa. *Experimental Agriculture* 47, 205.
- HarvestChoice. (2010). Rainfall Variability and Crop Yield Potential. International Food Policy Research Institute, Washington, DC., and University of Minnesota, St. Paul, MN. Retrieved on July 29, 2015, from <http://harvestchoice.org/labs/rainfall-variability-and-crop-yield-potential>.
- Herrero, M., Ringler, C., van de Steeg, J., Thornton, P., Zhu, T., Bryan, E., Omolo, A., Koo, J., Notenbaert, A. (2010). *Climate Variability and Climate Change and Their Impacts on Kenya's Agricultural Sector*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

- Herrero, M., Thornton, P. K., Bernues, A., Baltenweck, L., Vervoort, J., van de Steeg, J., Makokha, S., van Wijk, M. T., Karanja, S., Rufino, M. C., Staal, S.J. (2014). Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models. *Global Environmental Change* 24, 165-182.
- Hickey, G. M., Pelletier, B., Brownhill, L., Kamau, G. M., Maina, I. N. (2012). Preface: Challenges and Opportunities for enhancing food security in Kenya. *Food Security* 4, 333-340.
- Hoang, M. H., S. Namirembe, M., Van Noojdimjk, D. Catacutan, I., Oborn, A. S., Perez-Teran, H. Q, Nguyen and M. K. Dumans-Johansen. (2014). Farmer Portfolios, Strategic Diversity Management and Climate Adaptation: Implications for Policy in Vietnam and Kenya. *Climate and Development*, 6:3, 216-225.
- Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annu. Rev. Ecol. Syst.*, 4:1-23.
- Huho, J. M., & Kosonei, R. C. (2013). The opportunities and challenges for mitigating climate change through drought adaptive strategies: The case of Laikipia County, Kenya. *Academic Research International*, 4(3), 453.
- Huho, J. M and Mugalavai, E. M. (2010). The effects of drought on food security in Kenya. *International Journal on Climate Change Impact and Response*. Vol. 2, No. 2.
- Huho, J. M., Ngaira, J. K., Ogindo, H. O., and Masayi, N. (2012). The changing rainfall pattern and the associated impacts on subsistence agriculture in Laikipia East District, Kenya. *Journal of Geography and Regional planning*, Vol. 5(7) pp. 198-206, April, 2012.
- Humphrey, A. (2004). SWOT analysis method and examples, with free SWOT template. <http://www.businessballs.com/swotanalysisfreetemplate.htm>. Accessed on 12th August 2013.
- Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M., & Silvestri, S. (2011). *Agricultural management for climate change adaptation, greenhouse gas mitigation, and agricultural productivity: Insights from Kenya* (No. 1098). International Food Policy Research Institute (IFPRI).
- Igoden, C., Ohoji, P. and Ekpare, J. (1990). Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. *Agricultural Administration and Extension* 29 (2), 149-156.

- IPCC. (2007). In S. Solomon, D., Qin, M., Manning, Z., Chen, M., Marquis, K.B., Averyt, M. Tignor and H. L. Miller (Eds.). *Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (p.996). Cambridge: Cambridge University Press.
- IPCC. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. [Field, C. B., V. Barros, T. F. Stocker, D. QIN, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. K. Plattner, S. K. Allen, M. Tignor and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp582.
- IPCC. (2014). *Climate Change (2014): Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the IPCC Fifth Assessment Report*. Cambridge University Press, Cambridge.
- Jacob, D., and Van den Hurk, B. (2012). Climate change scenarios at the global and local scales. In *Climate change adaptation in the water sector* (pp. 45-56). Routledge.
- Jaetzold, R., Schmidt, H., Hornet Z, B. and Shisanya, C. A. (2007). *Farm Management Handbook of Kenya Vol 2 (2nd Edition)*. Central Ministry of Agriculture and GTZ, Nairobi.
- Jain, M., Naeem. S., Orlove, B., Modi, V., and DeFries, R. S. (2015). Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. *Global Environmental Change*, 31, 98-109.
- Jokastah, W. K., Leahl Filho, W. and Harris, D. (2013). Smallholder farmers' perception of the Impacts of Climate Change and Variability on Rain-fed Agricultural Practices in Semi-arid and Sub-humid regions of Kenya. *Journal of Environment and Earth Sciences*. Vol.3. No. 7, 2013.
- Jokastah, W. K., Leahl Filho, W. and Harris, D. (2013). Smallholder farmers' perception of the Impacts of Climate Change and Variability on Rain-fed Agricultural Practices in Semi-arid and Sub-humid regions of Kenya. *Journal of Environment and Earth Sciences*. Vol.3. No. 7, 2013.
- Juma (2015). Projected Rainfall and Temperature Changes in Bungoma County, Western Kenya Based on PRECIS modelling system. *Environmental Science and Management* 9(5):625-640.
- Kabubo- Mariara, Jane and Fredrick K. Karanja. (2007). "The economic impact of climate change on Kenyan crop agriculture. A Ricardian approach." *Global and planetary change* 57, no 3:319-330.

- Kamau, M., Olwande, J., and Githuku, J. (2011). Consumption and Expenditures on Key Food Commodities in Urban Households: The Case of Nairobi. Tegemeo Working Paper 41. Nairobi; Tegemeo Institute, Egerton University.
- Kang'ethe, E. (2011). Situation Analysis: Improving Food Safety in the Maize Value Chain in Kenya. College of Agriculture and Veterinary Science, University of Nairobi.
- Karienyee, J. M., Nduru, G. M., Huho, J. M., and Opiyo, F. E. (2012). Influence of Rainfall Variability on Tomato Production among Small Scale Farmers in Kieni East Sub County, Kenya. *Journal of Arts and Humanities*, 8(2), 07-19.
- Kelvin, M., Leigh, W., Jennifer, T., Anton, E., Juan, G., Mwongera, C., & Peter, L. (2016). Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. *Journal of Climate Risk Management*, 16:234-245. journal homepage:www.elsevier.com/locate/crm.
- KEPHIS (Kenya Plant Health Inspectorate Services). (2015). *National Crop Variety List-Kenya*. Available at:<http://www.kephis.org/images/VarietyList/updatejuly2015.pdf>; accessed on November 17 2015.
- Keya Rani Das, A. H. M. Rahmatullah Imon. A Brief Review of Tests for Normality. *American Journal of Theoretical and Applied Statistics*. Vol. 5, No. 1, (2016), pp. 5-12. Doi: 10.11648/j.ajtas.20160501.12.
- Khanal, A. R., Mishra, A. K. (2017). Enhancing food security: Food crop portfolio choice in response to climatic risk in India. *Global Food Security*, 12, 22-30.
- Kiprono Richard. (2009). The Effects of Climate Variability on Tea Production and Adaptation Strategies in Kericho County.
- Khuram, R. & Rasul, G. (2011). Rainfall variability and maize production over the Potohar plateau of Pakistan. *Pakistan Journal of Meteorology* 8, 15, 63-70.
- Kiprono Richard. (2009). The Effects of Climate Variability on Tea Production and Adaptation Strategies in Kericho County.
- KNBS. (2010). Population and Housing Census, Nairobi: Kenya Central Bureau of Statistics.
- Kombo, D. K. and Tromp, I. A. (2009). Proposal and thesis writing, Nairobi, Kenya.
- Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Forch, W., Thornton, P. K., Coe, R. (2012). Are food insecure

smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security* 4, 381-397.

Kumar, R., Sharmar, D. H., Kansal, S., and Thakur, K. (2012). Vegetable Production under Changing Climate Scenario, Nauni, India.

Kuyiah, J. W. (2007). Economic analysis of smallholder agricultural production under conditions of risk: the case of Vihiga and Kilifi Districts in Kenya. MSC Thesis, Egerton University, Kenya.

Lal, B.R. Sing, D.L. Mwaseba, D. Kraybill, D.O. Hansen, L.O.(2015), Sustainable intensification to advance food security and enhance climate resilience in Africa, Springer, London.

Le Dang, H., Li, E., Bruwer, J., Nuberg, I. (2013). Farmers' perceptions of climate variability and barriers to adaptation: lessons learned from an exploratory study in Vietnam. *Mitigation and Adaptation Strategies for Global Change*, 19, 531-548.

Leedy, P., and Ormrod, J. (2013). *Practical research: Planning and design* (10th ed.). Boston: Pearson.

Limantol, A. M., Keith, B. F., Azabre, B. A. and Lennartz, B. (2016). "Farmer's perception and adaption practice to climate variability and change: a case study of the vea catchment in Ghana." *Springerplus*, Vol. 5. No. 1, pp 830, doi: 10.1186/s40064-016-2433-9.

Livingstone, G., Schonberger, S., and Delaney, S. (2011). Sub-Saharan Africa: The state of smallholders in agriculture. In *Conference on New Directions for Smallholder Agriculture 24-25 January, Rome IFAD HQ (pp. 1-31)*.

Lobell, D. B, Schlenker, W., and Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333, 616-620. <http://dx.doi.org/10.1126/science.120453>.

Lobell, D. B., Hammer, G. L., McLean, G., Messina, C., Roberts, M. J., and Schlenker, W. (2013). The critical role of extreme heat for maize production in the United States. *Nature Climate Change*, 3(5), 497-501. <https://doi.org/10.1038/nclimate1832>.

Longobardi, A. and Villani, P. (2009). "Trend analysis of annual and seasonal rainfall time series in the Mediterranean area". *International Journal of Climatology*, doi: 10.1002/joc.2001.

Macauley, H., and Ramadjita, T. (2015). Cereal crops: Rice, maize, millet, sorghum, wheat. In U.N. E. C. F. (Ed.), *Feeding Africa*, AbdouDiouf International Conference Center, p.36.

- Madukwe, M. C. (2015). Application of t-test in agricultural extension research. In: Madukwe, M.C., editor. *A guide to Research in Agricultural Extension. AESON; Nigeria. Third ed.* 2015. pp. 203-217. [Google Scholar].
- Magehema, A. O., Chang, L. B., and Mkoma, S. L. (2014). Implication of rainfall variability on maize production in Morogoro, 4(5). <http://doi.org/10.6088/ijes.2014040404547>.
- Maina, J., Wandiga, S., Gyampoh, B., and Charles, G. K. K. (2019). Analysis of Average Annual Rainfall and Average Maximum Annual Temperature for a Period of 30 years to Establish Trends in Kieni, Central Kenya. *Climatol Weather Forecasting*, 7, 249.
- Makenzi, P., Ketiemi, P., Omondi, P., Maranga, E. and Wekesa, C. (2013). Trend Analysis of Climate Change and its Impacts on Crop productivity in the Lower Tana River Basin, Kenya. *Octa Journal of Environmental Research*. Vol. 1 (4):237-248.
- Malek, K., Adam, J. C., Stockle, C. O., and Peters, R. T. (2018). Climate change reduces water availability for agriculture by decreasing non-evaporative irrigation losses. *J. Hydrol.* 561, 444-460
- Mamba, S. F., Salam, A. and Peter, G. (2015). "Farmers' perception of climate change: A case study in Swaziland". *Journal of Food Security*, Vol. 3, No. 2, pp. 47-61.
- Mateche, D. (2011). *Environmental Security Programme*, Institute of Securities Studies. Nairobi.
- Mayer, H. O. (2008). *Interview und schriftliche Befragung*. Odelbourg Verlag, Munchen
- Mazdiyasi, O., & AghaKouchak, A. (2015). Substantial increase in concurrent droughts and heatwaves in the United States. *Proceedings of the National Academy of Sciences*, 112(37), 11484-11489.
- Mazdiyasi, O., and AghaKouchak, A. (2015). Substantial increase in concurrent droughts and heatwaves in the United States. *Proceedings of the National Academy of Sciences*, 112(37), 11484-11489.
- Mbwesa, J. K. (2006). *Introduction to Management Research*. Nairobi: Jomo Kenyatta Foundation.
- Mertz, O., Mbow, C., Reenberg, A., Genesio, L., Lambin, E. F., D'haen, S., Sandholt, I. (2011). Adaptation strategies and climate vulnerability in the Susano-Sahelian region of West Africa. *Atmospheric Science Letters*, 12(1), 104-108.

- Micah, B. and Absalom, M. (2014). Factors Influencing the Choice of Climate Change Adaptation Strategies by Households: A case of Mpolonjeni Area Development Programme (ADP) in Swaziland. *Journal of Agricultural Studies*, ISSN 2166-0379 2014, Vol.2, No. 1.
- Micheni, A. N., Kihanda, F. M., Warren, G. P., & Probert, M. E. (2004). Testing the APSIM Model with Experimental Data from the Long-term Manure Experiment at Machang's (Embu), Kenya. In *ACIAR PROCEEDINGS* (pp. 110-117). ACIAR; 1998.
- Bezabih, M., Beyene, A. D., Gebreegziabher, Z., & Borga, L. (2013). *Social Capital, climate change and soil conservation investment: panel data evidence from the Highlands of Ethiopia* (Vol. 135). London: Grantham Research Institute on Climate Change and the Environment.
- MoALF. (2016). *Climate Risk Profile for Nyeri. Kenya County Climate Risk Profile Series. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF)*, Nairobi, Kenya.
- Mohajan, H. K. (2014). Food and nutrition scenario of Kenya. *American Journal of Food and Nutrition*, 2(2), 28-38.
- Momanyi, S., Mutai, N, and Bii, J. (2012). Attracting young people to farming. Agfax. Reporting science in Africa.
- Moock, P. (1973). Managerial ability in small-farm production: an analysis of maize yields in the Vihiga Division of Kenya. PhD Thesis (published) Columbia University, USA.
- Morton, J. F. (2007). *The Impact of Climate Change in Small holder and Subsistence Agriculture* [<http://www.phas.org>] site visited on 20/06/2011.
- Muchuru, Shepherd, and Godwell Nhamo. (2019). "Sustaining African Water Resources under Climate Change: Emerging Adaptation Measures from UNFCCC National Communications." *African Journal of Science, Technology, Innovation and Development* 0(0): 1-16. <https://doi.org/10.1080/20421338.2018.1550934>.
- Muga, M. (2010). Climate Change: A Major Challenge and Revelation for EA Nationals. *A journal on resource, reflection and discourse for sustainable development*. 32: 201-207.
- Mugalavai, E. M, Kipkorir E.C., Raes D, Rao M. S. (2008). Analysis of rainfall onset, cessation and length of growing season for Western Kenya. *AgricforMeteorol* 148:1123-1135.

- Mugenda, O. and Mugenda, A. (2003). *Research Methods (revised edition)*. Acts press. Nairobi, Kenya.
- Muller, C. (2011). Agriculture: Harvesting from uncertainties. *Nature climate change*, 1(5), 253-254.
- Muller, C., Cramer, W., Hare, W. L., Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences* 108, 4313-4315.
- Mutimba, S. (2010). *Climate change vulnerability and adaptation preparedness in Kenya*. Nairobi: Heinrich Boll Foundation.
- Mutunga, E. J., Ndung'u, C. and Muendo, P. (2017). "Smallholder farmers' perceptions and adaptations to climate change and variability in Kitui County, Kenya. *Journal of Earth Science and Climatic Change*, Vol 8, No. 3, doi: 10.4172/2157-7617.1000389.
- Mwaura, F. M., and Geoffrey, O. (2014). Climate Variability and Crop Production in Uganda. *Journal of Sustainable Development*, 7(2), 159-172. <http://dx.doi.org/10.5539/jsd.v7n2p159>.
- Mzezewa J. Misi T, Rensburg L. D. (2010). Characteristics of rainfall at a semi-arid ecotope in the Limpopo Province(South Africa)and its implications for sustainable crop production. *Water SA* 36(1): 19-26.
- Nassiuma, D. K. (2000) *Survey Sampling: Theory and Methods*. Nairobi: University of Nairobi, Kenya.
- Nathan, M. (2014). Food production variability and modeling in East Africa. Retrieved in June 1, 2015 from, <http://www.agriskmanagementforum.org/content/food-production-variability-and-modeling-east-africa>.
- National Drought Management Authority Nyeri County. (2014). Drought early warning bulletin for July 2016.
- Ndegwa, W., Rao, K. P. C., Hgugi, R. K., & Kwena, K. (2010). *Improving farmer adaptive capacity by integrating local and indigenous knowledge in climate forecasting and adaptive response*. Adaptation Insights, 4. Retrieved from http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Climate_Change_and_Adaptation_in_Africa/Documents/Adaptation-Insights-Kenya-local-climate-forecasting.pdf.

- Neumann, L. (2000). *Social research methods, quantitative and qualitative approach*. Allyn and Bacon. Boston.
- Newsham, A. J., and Thomas, D. S. G. (2011). Knowing, farming and climate change adaptation in North-Central Namibia. *Global Environmental Change*, 21 (2), 760-770.
- Newton, A. C., Johnson, S. N., & Gregory, P. J. (2011). Implications of climate change for diseases, crop yields and food security. *Euphytica*, 179(1), 3-18.
- Niang, I., Ruppel, O. C., Abdrado, M., Essel, A., Lennard, C., Padgham, J. *et al.* (2014) "Africa" in *Climate Change 2014: Impacts, adaptations, and vulnerability*. In: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp 1199-1265). Cambridge/New York: Cambridge University Press.
- Nichols, K. K., Nichols, J. J., & Mitchell, G. L. (2004). The reliability and validity of McMonnies dry eye index. *Cornea*, 23(4), 365-371.
- Nicholson, S. E. (2017). Climate and climate variability of rainfall over Eastern Africa. *Rev. Geophys*: 55 (3) (2017), pp, 590-635, 10.1002/2016RG000544.
- Nsabimana, J. D. and Masabo, F. (2005). Factors influencing adoption of agricultural technologies in Kiruhura district of Rwanda. *African Crop Science Conference Proceedings*, Vol. 7. Pp. 759-760.
- Nyandiko, N. O. Wakhungu, J. Oteng'I S. B. B. (2012). The predicting crop yields and livestock production in the arid and semi-arid lower Eastern Kenya. PhD draft thesis. Masinde Muliro University of Science and Technology, Kakamega, Kenya: 166-182.
- Oakley, P., Garforth, C. (1985). *Guide to Extension Training*. Food and Agriculture Organization (FAO). Rome, Italy. Available at :<http://www.fao.org/docrep/t0060e/T0060E00.HTM#Contents>; accessed on :02 November 2015.
- Ochieng, J., Kirimi, L., Mathenge, M. (2016). Effects of climate variability and change on agricultural production: the case of small scale farmers in Kenya. *NJAS Wageningen. J. Life Sci.* 2016; Vol. 77, pp.71-78, doi:10.1016/j.njas.2016.03.005.
- Odame, H. H., Hafkin, N., Wesseler, G. and Boto, I. (2002). *Gender and Agriculture in the Information Society*. International Service for National Agricultural Research Briefing Paper no. 55. The Hague, Netherlands: ISNAR.
- Odame, H. H., Hafkin, N., Wesseler, G., & Boto, I. (2002). *Gender and agriculture in the information society* (No. 2126-2021-1352)..

- Ofuoku, A. U. (2013). Rural farmers' perception of climate change in central agricultural zone of Delta State, Nigeria. *Indonesian Journal of Agricultural Science*. 12 (2), 63-69.
- Ogalleh, S., Vogl, C., Eitzinger, J., Hauser, M. (2012). Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. *Sustainability* 4, 3302-3325.
- Ogola, O., Milton, W., Ayieko, A., Orawa O., Kimani, W. (2011). Analysis of fertilizer use in potato production in Nakuru district, Kenya. *Africa Journal of Agriculture* vol. 6 (16): 3672-3677.
- Ojwang, G. O., Agatsiva, J., & Situma, C. (2010). *Analysis of climate change and variability risks in the smallholder sector*. FAO.
- Okoboi, G., Muwanga, J., & Mwebaze, T. (2012). Use of improved inputs and its effect on maize yield and profit in Uganda. *African Journal of Food, Agriculture, Nutrition and Development*, 12(7).
- Omwoyo, N. N., Wakhungu, J. and Otengi, S. (2015). Effects of climate variability on maize yields in the arid and semi-arid lands of lower Eastern Kenya. *Agriculture and Food Security* 49 (8):1-13.
- Oremo, F. O. (2011). *Perceptions and adaptation measures of small scale farmers to climate change in Kitui county, Kenya*. University of Nairobi.
- Orindi, V. A., and Ochieng, A. (2005). Seed Fairs as a Drought Recovery Strategy in Kenya. *Institute of Development Studies*, 36 (4), 87-102.
- Makokha, G., & Obiero, K. (2021). Seasonal Rainfall Variability Effects on Smallholder Farmers' Maize Yields in Kieni East Sub-County, Nyeri County, Kenya. *Journal of Arts and Humanities*, 10(10), 12-29.
- Oruonye, E. D. (2014). An assessment of the level of awareness of climate change and variability among rural farmers in Taraba State, Nigeria. *International Journal of Sustainable Agricultural Research* 1(3):70-84.
- Osbahr, H., Dorward, P., Stern, R., Cooper, S. (2011). Supporting agricultural innovation in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture* 47, 293-316.
- Oseni, T. O., and Masarirambi, M. T. (2011). Effect of climate change on maize (*Zea mays*) production and food security in Swaziland. *American-Eurasian J. Agric. & Environ. Sci.* 11(3), 385-391. Retrieved from [http://www.idosi.org/aejaes/jaes11\(3\)11/12.pdf](http://www.idosi.org/aejaes/jaes11(3)11/12.pdf).

- Owusu, A., Tesfamariam Tekeste, Y., Ambani, M., Zebiak, S. E., & Thomson, M. C. (2017). Climate Services for Resilient Development (CSRSD) Technical Exchange in Eastern Africa Workshop Report.
- Peacock, C., Jowett, A., Dorward, A., Poulton, C., & Urey, I. (2004). Reaching the poor: a call to action Investment in smallholder agriculture in sub-Saharan Africa.
- Philippon, N., P. Camberlin., V, Moron., J. Boyard-Micheau. (2015). Anomalously wet and dry rainy seasons in equatorial East Africa and associated differences in intra-seasonal characteristics. *Clim. Dyn.* 45 (7) (2015), pp. 2101-2121.
- Phirri, G. K., Egeru, A. and Ekwamu, A. (2016). "Climate change and agriculture nexus in Sub-Saharan Africa: the agonizing reality for smallholders". *International Journal of Current Pharmaceutical Review and Research*, Vol. 8, No. 2.
- Republic of Kenya (2010): Economic Survey .Nairobi: Government printer.
- Rockstrom, J. (2001). Green water security for the food makers of tomorrow windows of opportunity in drought-prone savannas. *Water science and Technology* 43 (4) 71-78. Proceedings of the East Africa Integrated River Basin Management Conference Sokoine University of Agriculture Morogoro, Tanzania.
- Rosell, S. (2011). Regional perspective on rainfall change and variability in the central highlands of Ethiopia, 1978-2007. *Applied Geography* 31, 329-338.
- Rowhani, P., Lobell, D. B., Linderman, M., & Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, 151 (4), 449-460.
- Rurinda, J., Mapfumo, P., van Wijk, M. T., Mtambanengwe, F., Rufino, M.C., Chikowo, R., Giller, K.E. (2014). Comparative assessment of maize, finger millet and sorghum for household food security in the face of increasing climatic risk: *European Journal of Agronomy* 55, 29-41.
- Sacks, W. J., Derying, D., Foley, J. A., and Ramankutty, N. (2010). Crop planting dates: An analysis of global patterns. *Global Ecology and Biogeography*, 19(5), 607-620. <http://doi.org/10.1111/j.1466-8238.2010.00551.x>.
- Sage, T. I., Bagha, S., Lundsgaard-Nielson, V., Branch, H. A., Sultmanis, S., Sage, R. F. (2015). The effect of high temperature stress on male and female reproduction in plants. *Field Crop Res.* 182, 30-42, <http://ds.doi.org/10.1016/j.fer.2015.06.011>.
- Salami, A., Kamara, A. B., & Brixiova, Z. (2010). *Smallholder Agriculture in East Africa: Trends, Constraints and opportunities*. Working Paper No. 105.

- Sanchez-Cortes M. S., Chevero, E. L. (2011). Indigenous perception of changes in climate variability and its relationship with agriculture in a Zoque community of Chiapas, Mexico. *Clim Change*, 107:363-389.
- Sawa, B. A and Adebayo, A. A. (2011). The Impact of Climate Change on Precipitation Effectiveness Indices in Northern Nigeria: *Research Journal of Environmental and Earth Sciences* 3(5): 481-486, Maxwell Scientific Organization.
- Schoonenboom, J., Johnson, R .B. (2017). How to construct a mixed methods research design. *KolnerZeitschrift Fur Soziologie Und Sozialpsychologie*. 2017;69 (Suppl 2):107-131. [PMC free article] [PubMed] [Google Scholar].
- Schroeder, C., Onyango, T. K. O., Nar, R. B., Jick, N., Parzies, H., and Gemenet, D. (2013). Potentials of hybrid maize varieties for smallholder farmers in Kenya: a review based on Swot analysis. *African Journal of Food, Agriculture, Nutrition and Development*, 13(2), 1-25.
- Seleshi, Y. and Zanke, U. (2004). Recent changes in rainfall and rainy days in Ethiopia. *International journal of climatology*, 24:973-983.
- Shapiro, S. S., and Wilk, M. B. (1965). "An analysis of variance test for normality (complete samples)". *Biometrika* 52 (3/4): 591-611.<http://sci2s.ugr.es/keel/pdf/algorithm/articulo/shapiro1965.pdf>.
- Shaw, G. and Wheeler, D. (1985). *Statistical techniques in geographical analysis*. New York: John Wiley and Sons.
- Shaw, R.E and Meyer. W.S (2015), Improved Empirical Representation of Plant Responses to Waterlogging for Simulating Crop Yield. *Agronomy Journal*. Volume 107, Issue 5.
- Sheahan, M.B (2011). *Analysis of Fertilizer Profitability and Use In Kenya*. MSC Thesis, Michigan State University.
- Sheng, D., N. A, L., Shuang-En, Y., Ming-Hui, W., and Dong-Li, S. (2014). Effects of controlled irrigation and drainage on growth, grain yield and water use in paddy rice. *European Journal of Agronomy*, 53, 1-9.
- Shisanya, C. A. (1996). *Chances and risks of maize and beans growing in the semi-arid areas of South-East Kenya during expected deficient, normal and above normal rainfall of the short rainy seasons*. Geograph. Ges..
- Shisanya, C. A., Recha, C., & Anyamba, A. (2011). Rainfall variability and its impact on normalized difference vegetation index in arid and semi-arid lands of Kenya. *International Journal of Geosciences*, 2(01), 36.

- Shumetie, A., Alemayehu Yismaw, M. (2017). Effect of climate variability on crop income and indigenous adaptation strategies of households. *International Journal of Climate Change Strategies and Management*. 10(4), 580-595. [Web of Science]. [Google Scholar].
- Simelton, E., Quinn, C. H., Batisani, N., Dougill, A.J., Dyer, J.C., Fraser, E. D.G., Mkwambisi, D., Sallu, S., Stringer, L. C. (2013). Is rainfall really changing? Farmer's perceptions, meteorological data, and policy implications. *Climate and Development* 5, 123-138.
- Sinha, A., Kathayat, G., Cheng, H., Breitenbach, S. F., Berkelhammer, M., Mudelsee, M., & Edwards, R. L. (2015). Trends and oscillations in the Indian summer monsoon rainfall over the last two millennia. *Nature communications*, 6(1), 1-8.
- Smale, M., Derek, B., and Jayne, T. (2011). Maize revolutions in Sub-Saharan Africa (No. Policy Research Working Paper 5659). Washington, DC.
- Sombroek, W. G., Braun, H. M. H., & Van der Pouw, B. J. A. (1982). *Exploratory soil map and agro-climatic zone map of Kenya, 1980. Scale 1: 1,000,000*. Kenya Soil Survey.
- Sowunmi, F. A., & Akintola, J. O. (2010). Effect of Climate Change Variability in Maize production in Nigeria. *Research Journal of Environmental and Earth Sciences*, 2 (1), 19-30.
- Spielman, D. J., Kelemwork, D., & Alemu, D. (2011). *Seed, fertilizer, and agricultural extension in Ethiopia. Ethiopian strategy support program (ESSP II)* (No. 20, pp. 4-8). Working Paper.
- Syomiti, M., Maranga, E., Obwoyere, G., Getachew, G., Dana, H., Beatrice, M., et al. (2015). The adaptive and coping strategies of pastoralists to climate change in Baringo, Laikipia and Nyeri Counties of Kenya. *Livestock Res. Rural Dev.* 27:248.
- Tarun, A., Gopal, K., Chakravarty, N. V. K., R. K., Deshmukh, P. S., & Joshi, H. C. (2013). Biomass and biomass water use efficiency in oilseed crop (*BrassicaJuncea* L.) under semi-arid microenvironments: *Biomass and Bioenergy*, 51, 154-162.
- Thakural, L. N., Kumar, S., Jain, S. K., Ahmad, T. (2018). The impact of climate change on rainfall variability: a study in central Himalayas. In: Singh, V. P., Yadav, S., Yadava, R. N., editors. *Climate Change Impacts*. Springer Singapore; 2018. Pp. 181-192. [Google Scholar].
- Thornton, P. K., Jones, Alagarswamy, G., Andresen, J., Herrero, M. (2010). Adaptation to climate change: Agricultural system and household impacts in East Africa. *Agricultural Systems* 103, 73-82.

- Thornton, P. K., Jones, P. G., Ericksen, P. J., Challinor, A. J. (2011). Agriculture and food systems in Sub-Saharan Africa in a 4° C + world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, 117-136.
- Tittonel, P., Corbeels, M., van Wijk, M. T., Vanlauwe, B., Giller, K.E. (2008). Combining Organic and Mineral Fertilizers for Integrated Soil Fertility Management in Smallholder Farming Systems of Kenya: Explorations Using the Crop-Soil Model FIELD. *Agronomy Journal* 100, 1511-1526.
- Tittonel, P., Giller, K. E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research* 143, 76-90.
- Tongruksawattana, S. (2013). *Adaptation to climate change under poverty, food security and gender perspective of rural maize-legume farmers in Kenya* (No. 309-2016-5203).
- Trauth, M. H., Larrasoana, J. C., & Mudelsee, M. (2009). Trends, rhythms and events in Plio-Pleistocene African climate. *Quaternary Science Reviews*, 28(5-6), 399-411.
- Troy, T. J., Kipgen, C., and Pal, I. (2015). The impact of climate extremes and irrigation on US crop yields. *Environmental Research Letters*, 10(5), 054013. <https://doi.org/10.1088/1748-9326/10/5/054013>.
- UNDP. (2010). Gender Climate Change and Community Based Adaptation. UNDP, New York.
- UNEP. (2011). Towards a Green Economy: Pathway to Sustainable Development and Poverty Eradication, United Nations Environment Programme. www.unep.org/green_economy.
- Urban, D., Roberts, M. J., Schlenker, W., & Lobell, D. B. (2012). Projected temperature changes indicate significant increase in inter-annual variability of U.S maize yields. *Climate Change*, 112, 525-533. <http://dx.doi.org/10.1126/science.1239402>.
- USAID. (2010). Staple Foods Value Chain Analysis Country Report-Kenya. January, 2010.
- Vermeulen, S. J., Challinor, A. J., Thornton, P. K., Campbell, B. M., Eriyagama, N., Vervoort, J. M., Kinyangi, J., Jarvis, A., Laderach, P., Ramirez-Villegas, J. (2013). Addressing uncertainty in adaptation planning for agriculture. *Proceedings of the National Academy of Sciences* 110, 8357-8362.

- Vyas, S., Nigam, R., Patel, N. K., and Panigrahy, S. (2013). Extracting Regional Pattern of Wheat Sowing Dates Using Multispectral and High Temporal Observations from Indian Geostationary Satellite. *Journal of the Indian Society of Remote Sensing*, 41 (4), 855-864. <http://doi.org/10.1007/s12524-013-0266-3>.
- Wagesho, Negash. (2016). "Analysis of Rainfall Variability and Farmers' Perception towards it in Agrarian Community of Southern Ethiopia". *Journal of Environment and Earth Science* 6(4):99-107.
- Waha, K., Muller, C., Bondeau, A., Dietrich, J. P., Kurukulasuriya, P., Heinke, J., Lotze-Campen, H. (2013). Adaptation to climate change through the choice of cropping system and sowing date in Sub-saharan Africa. *Global Environmental Change* 23, 130-143.
- Wamicha, W. N. (1993). Soil Erosion Hazards in Kieni Division, Kenya.
- Wang, E., Martre, P., Zhao, Z., Ewert, F., Maiorano, A., Rotter, R. P., Asseng, S. (2017). The uncertainty of crop yield projections is reduced by improved temperature response functions. *Nature Plants*, 3 (8), 17102.
- Williams, A. P., Funk, C. (2011). A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dynamics* 37, 2417-2435.
- Wood, S. A., Jina, A. S., Jain, M., Kristjanson, P., De Fries, R. S. (2014). Smallholder farmer cropping decisions related to climate variability across multiple regions. *Global Environmental Change*, 25, 163-172.
- World Bank. (2010). The Economics of Climate Change. A Synthesis Report. *Final Constitution Draft*. EACC.
- World Meteorological Organization (WMO), (2013): The state of greenhouse gases in the atmosphere based on global observations through 2012. WMO Greenhouse Gas Bulletin, No. 9, 4 pp.
- World Meteorological Organization (WMO). (2017). Frequently asked questions: What is climate? <http://www.wmo.int/pages/prog/wcp/ccl/faqs.php> assessed on Retrieved from. [Google Scholar].
- Wuebbles, D. J., Fahey, D. W., Hibbard, K. A., Dokken, D. J., Stewart, B. C., and Maycock, T. K. (2017). *Climate science special report: Fourth national climate assessment, Vol.1*. Washington, DC: U.S. Global Change Research Program.
- Yengoh, G. T. (2012). *Determinants of yield differences in small-scale food crop farming systems in Cameroon*, 1-17.

- Yengoh, G. T., Armah, F. A., Onumah, E. E., Odoi, J. O. (2010). Trends in agriculturally relevant rainfall characteristics for smallscale agriculture in Northern Ghana. *Journal of Agricultural Science*, 2, 1-16.
- Zhao, D., Glaz, B., and Comstock, J. C. (2013). Sugarcane leaf photosynthesis and growth characters during development of water deficit stress. *Crop Sci.* 53, 1066–1075.
- Zhong, L., Liu, L., & Liu, Y. (2010). Natural disaster risk assessment of grain production in Dongting Lake Area, China. *Agriculture and Agricultural Science Procedia*, 1, 24-32.
- Zipper, S. C., Qiu, J., and Kucharik, C. J. (2016). Drought effects on US maize and soybean production: Spatiotemporal patterns and historical changes. *Environmental Research Letters*, 11(9), 094021.<https://doi.org/10.1088/1748-9326/11/9/094021>.
- Ziska, L. H., Blumenthal, D. M., Runion, G. B., Hunt, E. R., and Diaz-Soltero, H. (2011). Invasive species and climate change: an agro-nomic perspective. *Climatic Change*, 105 (1-2), 13-42.

cessation for both the short and the long rains seasons.					
c. The local weather stations have been providing weather data to the smallholder maize farmers					
d. Rainfall variability in my view has influenced maize yields for both the short and the long rains seasons					
e. In my opinion other factors and not rainfall variability have influenced maize yields annually					

c. If NO, give two main activities in your farm, _____; _____

10. What have you noted on the rainfall pattern in your area in the last 5 years?

Heavy rainfall (.....)

Light rainfall (.....)

Unevenly distributed rainfall (.....)

Evenly distributed rainfall (.....)

Timely onset of rainfall (.....)

Delayed onset of rainfall (.....)

Early subsiding rainfall (.....)

Any other- specify (.....)

Section 4: Adaptive strategies by farmers

11. What is the source of your maize seed? Local seed (.....) Agro-vet (.....)

12. What factors do you consider in choosing the maize variety to plant?

High yielding (.....)

Early maturing (.....)

Disease resistant (.....)

Drought resistant (.....)

13. a) Have you been using manure / fertilizer in your maize farming?

YES (.....) NO. (.....)

b) What is the source of manure in your farm?

On-farm livestock waste (.....)

Compost manure (.....)

Off-farm buying (.....)

c) What is the source of fertilizer for your maize farming?

Agro-vet (.....)

Government subsidized fertilizer (.....)

Donation (.....)

14. a) Please indicate the water harvesting structures/ measures found on your farm

Terraces (.....)

Water pan (.....)

Water well (.....)

Grass strips (.....)
Water tanks (.....)
Others-specify_____

b) Which of the above water harvesting measures support maize farming in your farm?_____

c) How do you rate the water harvesting measure in (b) above for maize crop farming?

Sufficient (.....)
Insufficient (.....)

15. a) Have you received any training on maize farming? YES (.....) NO. (.....)

b) If YES, what was the source of training?

Friends (.....)
Government extension officers (.....)
Private Service providers (.....)
Media (.....)
Others-specify _____

16. Do you require additional training on maize farming? Yes (.....) or NO (.....)

17. What challenges have you faced in maize farming?

Pests (.....)
Diseases (.....)
Inadequate rainfall (.....)
Lack of capital (.....)
Others specify_____

18. Which of these climate hazards affects farmers frequently in your locality?

Frost (.....)
Drought (.....)
Floods (.....)

19. How has the county government assisted farmers in the face of the above hazard?

Supplying every maturing seeds to farmers (.....)
Sinking bore-holes (.....)
Digging dams (.....)
Other-specify_____

20. What has been the response of the farmers to the hazards in (18), above?

Engage in alternative farming activities (.....)
Planting drought resistant seeds (.....)
Planting early maturing varieties (.....)
Engaging in other economic activities like trading (.....)
Others- specify_____

21. Give your suggestions for the improvement of maize yield in your area_____

Section 3: Adaptive strategies by Farmers.

11. How has the county government assisted farmers in the face of the above hazard?

12. Give an average % of farmers who use the following in your area,

- a. Manure only (.....)
- b. Fertilizer only (.....)
- c. Both manure and fertilizer (.....)
- d. Nothing (.....)

13. a) What is the main source of manure for maize farming?

b) What is the main source of fertilizer for maize farming?

14. a) Please indicate the water harvesting structures/ measures found on the farms in your area,

b) Which of the above water harvesting measures support maize farming in your area?

c) How do you rate the water harvesting measures in (b) above for maize crop production?

Sufficient (.....)

Insufficient (.....)

15. What is the main source of farmers training on maize farming in your area?

16. Do the farmers in your area require additional training on maize farming?

17. What challenges do farmers in your area face in maize farming?

18. Give your suggestions for the improvement of maize yield in your area_____

Appendix III: Research questionnaire for the personnel (KMD), Nyeri County

My name is Lilly Njeri Kabata, a student at Kenyatta University. I am carrying out a research on seasonal rainfall variability effects on maize yields on small holder farmers and their adaptive strategies in Kieni East Sub-County. The information you provide shall solely be used for academic purposes and will be treated with total confidentiality.

Please fill in the blank or tick in the relevant box. Your honesty and cooperation will be highly appreciated.

Section 1: respondent profile

1. Respondent name _____
2. Gender Male (.....) Female (.....)
3. Age group below 20 years (.....) 20 to 40 years (.....) Above 40 (.....)
4. Place of residence _____
5. Highest level of education attained: informal education (.....)
 Primary level (.....)
 Secondary level (.....)
 Post-secondary level (.....)

Section 2: Rainfall Variability

6. Are you aware of temporal seasonal rainfall variability in Nyeri County?
 Yes (.....) NO (.....)
7. a) In your view, have you observed any seasonal variability in rainfall for the last 30 years in the county? Yes (.....) NO (.....)
- b) If yes, what are the manifestations of seasonal rainfall variability in the county?

8. How frequently have you observed these manifestations? _____
9. Is the weather station responsible for providing weather related information such as extreme climatic conditions like erratic rainfall, pro-longed drought and floods to small holder maize farmers in the county? _____
10. Are the small holders maize farmers in the county aware of the weather station and the role it plays in the county? _____
11. In your view, are the small holder maize farmers therefore informed of any projected extreme climatic condition?
12. Give your views on how the dissemination of information from the weather stations in the county can assist the small holder farmers in improving maize production.

Appendix IV: Local Administration Interview Schedule

My name is Lilly Njeri Kabata, a student at Kenyatta University. I am carrying out a research on seasonal rainfall variability effects in maize yields and the adaptive strategies by smallholder maize farmers in Kieni East Sub-county. The information you provide shall solely be used for academic purposes and will be treated with confidentiality.

Please fill in the blank spaces or tick in the relevant box. Your honesty and cooperation will be highly appreciated.

- 1) What is your name?.....
- 2) What is the name of your location?.....
- 3) What is your occupation?.....
- 4) How long have you served in the current job?.....
- 5) What data records from the list below does your office keep?
 - a) Climate yes () no ()
 - b) Crop harvest yes () no ()
 - c) Population yes () no ()
- 6) In your opinion from the data collected above, how has the trend been over the last 30 years?
- 7) In your view, how has the rainfall trends influenced maize yields for the last 30 years in Kieni East sub-county?
- 8) What measures have you put forth to adapt to seasonal rainfall variability if any in your area?
- 9) In your view are there any constraints to the adaptive strategies if any?
- 10) Are there any institutions assisting smallholder maize farmers in educating them about rainfall variability?


Appendix V: Loruku farm Monthly rainfall (mm)

Mon YRS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL R/FALL
2018	0	11.5	205.5	82.3	140	91.5	56.5	30	20.5	68	108	30.5	844.3
2017	2.5	10.5	5	67	147	9	29	94	91	131.5	140	20.5	747
2016	67	5	14	22.9	90.5	26	63.5	64	49	44	121	18	584.9
2015	0	0.5	101	140.5	94.5	69.5	41	32	10.5	115.5	285.5	130.5	102.1
2014	0	10	74.5	104	90.5	38	51	79.5	88	94	100	37	768
2013	17.5	3.5	84	107	42.5	40	46	91	64	104	55.5	75.5	730.5
2012	0	2	1.5	124.5	36	71.5	130.5	65.25	51	103.5	96	30.5	709.25
2011	4	0	22.5	70.5	92.5	47	38.5	105	43.5	118.5	165	80	787
2010	3.7	16	64.5	109	57	26	28.5	98.5	85	115.5	180.5	38.5	856
2009	26.5	7.5	12.5	127	81.25	11.75	8.5	67	29.5	102.5	151.5	147	772.5
2008	64.25	9	73.25	128	45	28.5	69	48	74.5	90.25	36.75	32.25	698.75
2007	46.5	15	16.5	114.5	138.75	62	56.25	85	69.5	84.75	25.5	35.75	750
2006	15.5	7.5	91.5	171.25	105.75	21.5	4.5	134	49.5	92	163.25	203.5	750.5
2005	28.8	12.3	2.8	134	130.25	33.25	85	68.5	29.25	65.75	45.25	36.25	771.65
2004	64.3	53.8	47.5	126.3	90	49	93.5	38.5	19.5	79	103.5	24.5	789.4
2003	15.8	8.5	80.5	228	130.5	21	32	39.5	7.25	124	94	127.3	908.35
2002	12.6	0	61.8	136.5	47.75	34.25	76.75	35.25	28	66.9	61.1	109.6	670.5
2001	94.9	0	2.8	122.7	76.2	13.4	63.8	123.6	19.2	56.1	85.8	30.5	689
2000	21	2.5	11	70.5	48.8	47	72.5	13	22.5	102.5	84.5	23.8	519.6
1999	9.5	3	108.8	51.5	17.5	4.8	57	60	14	102.3	106.5	75.5	607.9
1998	140.5	80.5	93.5	180	132	39	83	54.3	15.3	86.3	120.5	39.5	932.5
1997	7	0	84.5	239.5	37	43.7	80.5	74	13.5	290.5	338.5	99.8	1308.5
1996	1.5	0	77	87.5	91.3	108.3	70.5	189.5	33.5	40.5	106.5	45	781.1
1995	0	49	67.4	149	108.5	30.5	45	38	103.5	108.5	144.3	122.5	966.2
1994	8.5	37	37	63.5	67.5	94	27.5	38	26	159	190	29.5	771.8
1993	155	45.5	8	118	34.5	32	28	0	14.5	23	95	26	579.5
1992	19.6	47.7	31.8	133.7	32	24.5	12.5	40.4	38	85.9	128.6	29	623.7
1991	0	4	92	78.5	31.5	96.5	12	97	46	69.5	49	26	582
1990	23	29.5	139.5	152	79.5	0	100.5	63.5	96	93	93.5	88	958
1989	47.5	24.4	89.0	131.7	92	0	100	27.7	61.8	79.2	73.1	30.9	757.7
1988	16	0	59	226.5	20.5	80.5	101.6	96	122.5	22	147	53.5	945.1

Appendix VI: Kieni-east Sub-County maize yields data

YEAR	ACHIEVED AREA (HA)		ACHIEVED PRODUCTION (TONS)	
	LONG RAINS	SHORT RAINS	LONG RAINS	SHORT RAINS
2009	1510	3275	1610.28	1959.30
2010	1907	3250	2059.83	2925.00
2011	3394	3280	549.81	1771.20
2012	2850	2500	513.00	450
2013	2800	3050	1101.60	274.50
2014	2984	3176	1074.24	857.52
2015	2984	3210	2148.48	3713.04
2016	2850	2900	256.50	226.08
2017	2264	2523	815.04	908.01
2018	2800	1800	930.78	251.01

Appendix VII: NACOSTI permit

 REPUBLIC OF KENYA	 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Ref No: 303399	Date of Issue: 10/October/2019
RESEARCH LICENSE	
	
<p>This is to Certify that Ms.. Lilly Kabata of Kenyatta University, has been licensed to conduct research in Nyeri on the topic: Seasonal Rainfall Variability Effects on Maize Yields and the Adaptive Strategies by Small Holder Farmers in Nyeri County, Kenya for the period ending : 10/October/2020.</p>	
License No: NACOSTI/P/19/1805	
303399 Applicant Identification Number	 Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
	Verification QR Code 
<p>NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.</p>	

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

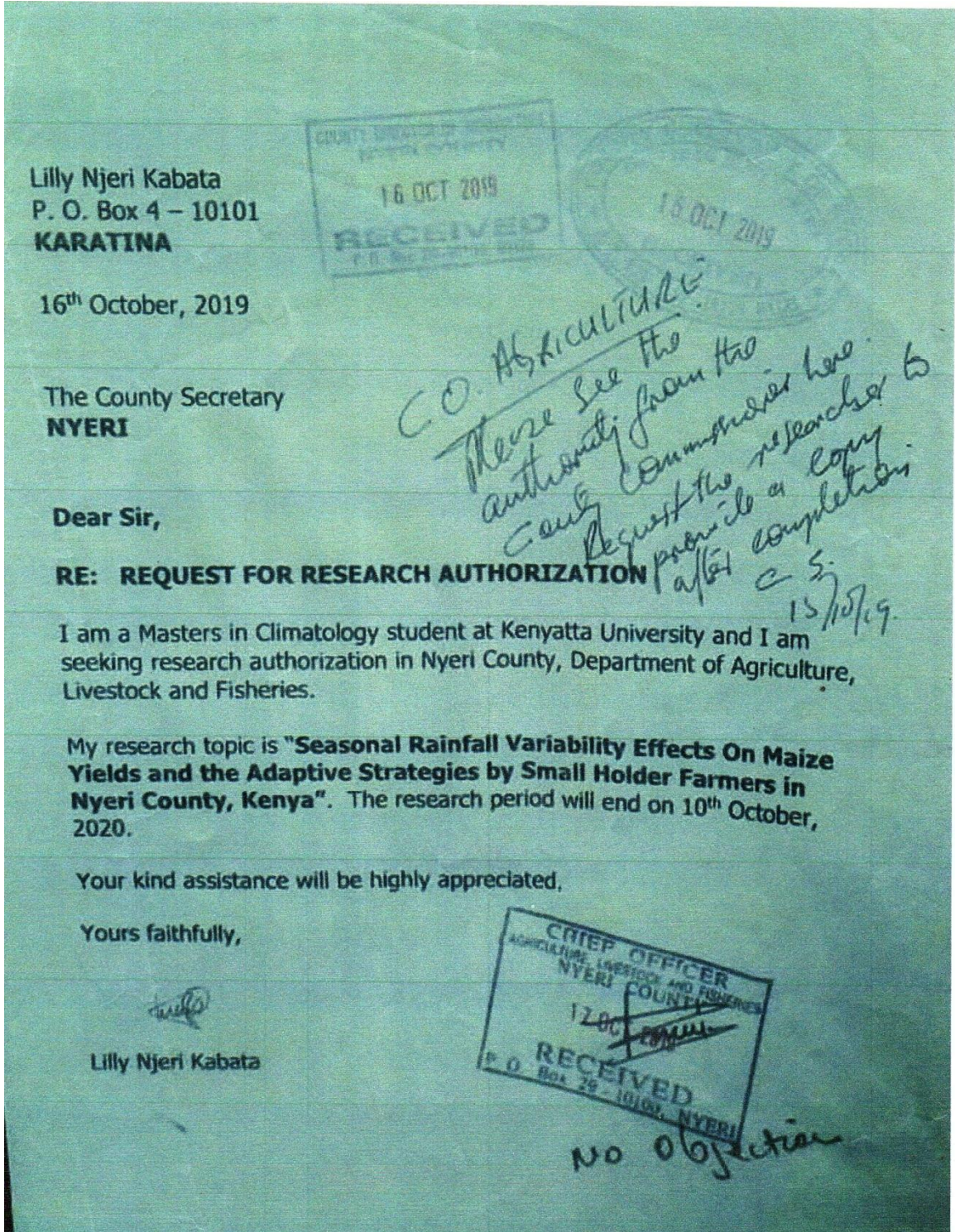
The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies
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Website: www.nacosti.go.ke

Appendix VIII: Nyeri County Agricultural Office Permit



Appendix IX: Nyeri County Commissioner's office Permit



THE PRESIDENCY

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT

E-mail: nyericountycommissioner@yahoo.com
Telephone: 061 2030619/20
Fax: 061 2032089
When replying please quote

NYERI COUNTY COMMISSIONER
P.O. BOX 33-10100
NYERI

Ref. No. NYC/ADM 1/57.VOL.VII/ (80)

Date: 16th October, 2019

Lilly Njeri Kabata
P.O BOX 4 - 10101
KARATINA

RE: RESEARCH AUTHORIZATION

Reference is made to your letter dated 15th October, 2019 on the above subject.

Approval is hereby granted to carry out research on "*Seasonal Rainfall Variability Effects on Maize Yields and the Adaptive Strategies by Smallholder Farmers in Nyeri County, Kenya.*"

The period of study ends on 10th October, 2020

A handwritten signature in blue ink, appearing to read 'F. Mwangi', written over a large, stylized blue flourish.

F. Mwangi
For: County Commissioner
NYERI COUNTY