EFFECT OF RAINFALL VARIABILITY ON SELECTED FOOD CROPS PRODUCTION IN NYANDO SUB COUNTY, KISUMU COUNTY KENYA

BY

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DECLARATION

Declaration by student

I hereby declare that this Thesis is my original work and that it has never been presented for award of any degree in any other University.

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DEDICATION

I dedicate this thesis to my parents Caren Akoth and Washington Odundo, my siblings Pecila Atieno, Mary Achieng, Leah Odundo and Jane Awour, my lovely wife Diana Mercy, son Tyce Nassi and Chief Principal Joyce Omondi. They all motivated and encouraged me that "*Education is the only way you can jump queue*"

ABSTRACT

Rainfall variability has led to detrimental influence on food crop production in different parts of the world. Many countries experience cases of reduced crop production thus lowering food security. Kenya being an agricultural country, has been affected by variation of rainfall leading to reduced food production. Nyando Sub-County has experienced incidences of rainfall variability which has affected crops that are rain-fed. Despite the fact that studies have been conducted on the effect of rainfall variability on food crop production, there was pending need to provide detailed information on how rain had affected maize, beans, and African nightshade. The data used in this study was for the past 10 years (2013 -2022) because it is within this period that the study area received fluctuating rainfall in terms of magnitude, duration and timing which affected production of maize, beans and African nightshade. The crops are the staples within the study area but their production was perceived to decline over the same period. Therefore, the purpose of the study was to assess the effect of rainfall variability on selected food crops production. The specific objectives of this study were: to examine the effect of duration of rainfall on maize, beans and African nightshade production; to establish the effect of magnitude of rainfall on maize, beans and African nightshade production; to assess the effect of timing of rainfall on maize, beans and African nightshade production in Nyando Sub County. A Quasi-longitudinal research design was adopted. The study was conducted in five wards in the sub-county namely; Ahero, Awasi, Kobura, East Kano and Kabonyo. A sample size of 384 household heads was selected using Fischer's formula from a target population of 24,866 households. The household heads' selection was done through simple random sampling for Questionnaire administration. Primary data collection methods were Observation, Photography, Key informant interview and Focus Group Discussions. Literature from KMD and Sub County and County Agricultural offices provided secondary data. Qualitative data was analyzed through themes. Quantitative data was analyzed using descriptive statistics such as means, percentages and standard deviation. Simple regression analysis was conducted to determine the effect of rainfall duration, magnitude and timing on yields of maize, beans and African nightshade. The regression model was found linear and significant; Rainfall duration and maize yield was [F (383) =25.63, $P < .001$, $R^2 = .65$], Beans yield [F (383) =20.42, $P < .001$, $R^2 = .47$], and African nightshade Yield [F (383) =19.41, $P < .001$, $R^2 = .38$]. This is because both beans and the African nightshade are cover crops which are susceptible to floods. Rainfall magnitude and maize yield showed [F (383) =11.45, $P < .001$, $R^2 =.44$], Beans yield [F (383) =16.08, $P < .001$, $R^2 = .37$], and African nightshade Yield [F (383) =8.73, P < .001, $R^2 = .34$]. This was so because the mean rainfall volume was not enough for maximum maize yield. The reduction in both beans and nightshade yields was possibly due to extreme fluctuations in rainfall volumes during short rains seasons. Rainfall timing and maize yield [F (383) =13.68, $P < .001$, $R^2 =.44$], beans yield [F (383) =21.24, $P < .001$, $R^2= .38$], and African Nightshade Yield [F (383) =14.45, $P < .059$, $R^2 =34$]. Poor timing affected maize yields in short rains timing. Similarly, the depreciation in both beans and African nightshade yields was possibly due to rainfall unpredictability which is common during short rains. However, correct rainfall timing resulted in the increase in the African nightshade yields. The findings were fundamental to the farmers as they advised on the importance of timing of rainfall enable them prepare adequately for onset of long and short rains to realize best crop yields. The findings showed that rainfall variability affected the production of the three crops hence the need to minimize absolute reliance on rain-fed farming, adopt smart farming and use hybrid seeds that mature faster. Meteorological data interpretations should be availed to farmers for timely planting.

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LIST OF ACRONYMS AND ABBREVIATIONS

FAO	Food and Agricultural Organization
GOK	Government of Kenya
IPCC	Intergovernmental Panel on Climate Change
KMD	Kenya Meteorological Department
MAM	March - April – May
MOA	Ministry of Agriculture
NACOSTI	National Commission for Science Technology and Innovation
OND	October- November- December
UNFCCC	United Nations Framework Convention on Climate Change
SD	Standard Deviation
WMO	World Meteorological Organization

WORKING DEFINITION OF TERMS

African Nightshade: A leafy vegetable that is commonly consumed by many households in different parts of Africa. It is commonly referred to as *Managu* in Kiswahili and *osuga* in Luo

Food Crop Production: Growing of crops that can be consumed and sold by households. Food crops play a significant role in sustaining most households in different parts of the world.

Global warming: The abnormal warming of the upper atmosphere due to the absorption of terrestrial heat from the earth's surface.

Rainfall variability: The change in the amount of rainfall concentration, millimeter per hour and the arrival of rainfall (Guntu et al 2020). The changes in rainfall patterns, trends and frequency can also be regarded as rainfall variability. This was established by analyzing rainfall data (duration, magnitude and timing) from the meteorological department.

Rainfall Duration: The distribution and the concentration of rainfall within a day (24hours). It encompasses the number of days in a week or the number of weeks in a month that experience rainfall.

Rainfall Magnitude: The average rainfall rate millimeter per (mm/h) or mm/min for specific rainfall duration and a classified frequency. This was established by looking at the surface run off after hours of rainfall.

Rainfall Timing: The onset and arrival of rainfall within a season. This was established by analyzing failed and successful food crops within the area.

Reliable Rainfall: The amount of rainfall that is timely and sufficient enough for the production of various food crops. This will be determined by reports from meteorological department.

Rain-fed crops: These are crops that rely wholly on rainfall to attain maximum maturity. This was established by looking at crops that were purely grown from rainfall as well as those under irrigation.

Rainfall predictability: Ability to tell and rightly predict the onset and arrival of rains.

Rainfall Trend: Certain pattern and occurrence in rainfall amounts either decreasing, increasing or remaining constant.

Staple food: Food that are commonly consumed by most households

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Rainfall variability is a major concern to most farmers globally due to its detrimental impacts on agricultural activities (Dinar, 2008). There have been many incidences of changes in rainfall amounts, seasonality, and trends. As reported by Nedumaran (2015), the yields by various crops depend on the reliability of rainfall that determines the soil water levels thus affecting the final yields. Globally, many countries have experienced changes in farming activities due to many cases of rainfall variability (Dinar, 2008). Major parameters of rainfall variability that concerns many geographers are the duration, timing, and magnitude of rainfall. Rainfall timing is defined as the onset and arrival of rainfall whereas duration means how rainfall is concentrated during the rainy season on the land. On the other hand, rainfall magnitude refers to the amount of rainfall received in millimeters per hour when it rains. (Shackleton et.al, 2009). These aspects of rainfall variability have affected crop production thus leading to food insecurity in different parts of the world. The data provided by United Nation Framework Convention on Climate Change (UNFCCC) shows that trends, seasonality and amounts of rainfall have changed in different parts of the world thus affecting crop production (2010). As much as these studies show the effect of on variability of rainfall on food crop production, there was still need to give detailed information on how rainfall trends, magnitude and intensity affects the production of maize, African nightshade and beans.

Moreover, the changing trends of rainfall in different years and seasons has become an area of concern to many scholars in Africa. According to Ogola et al (2007), change in mm/hour of rainfall between 2011 and 2015 in West Africa led to a significant reduction in the production of some vital food crops within the same period. For instance, In Nigeria there was a reduction in sorghum production between 2011 and 2014 from 970 metric tons to 880 metric tons respectively. This change in production of sorghum impacted negatively on the households' food security since this crop is widely consumed among the households. A report published by World Food Program (2016) showed that food crop production yield per hectare in South Africa is lower than the country's population growth. The reduced production of crops such as wheat and vegetables which are famous among South Africans is attributed to the change in concentration of rainfall (Leal et al, 2015). In their research, Williams & Kniveton (2011) also argued that the late arrival of rainfall affected the production of tobacco, wheat, and cotton from 213780, 213567 and 267903 tons to 198123, 201409 and 243712 tons respectively in Matabeleland South Province, Zimbabwe. This translated to 40% decline in production of these crops within that period. Satellite imagery taken in 2018 and 2019 confirmed that there was a decrease of planted areas by 70% within the province due to the late arrival of rainfall altering planting dates. Even though these researches examined the effect of rainfall trends on the production of tobacco, wheat and sorghum, they did not show how rainfall magnitude, duration and timing affects maize, beans and African nightshade yields. This gap is bridged by the current study.

Kenya as a developing nation has endured countless instances of climate change such as prolonged droughts, floods, heatwaves at the coast and ice recession seen at the top of Mount Kenya (Ondieki & Kitheka, 2019). According to Ogola et al (2007), the last two decades witnessed a massive decline in rainfall amounts in the areas that were perceived to experience high rainfall. This reduction of rainfall affected several crops, wheat being one of them. The change in rainfall magnitude in some parts of rift valley affected the production of valuable crops (Ogola et al, 2007). For instance, there was a reduction of total wheat produced in 2016 and 2017 from 215,900 to 156,900 tons. Seasonal rainfall changes between 2008 and 2010 had a serious impact on the production of Irish potato in Nyamira, Baringo, Nandi and Laikipia counties. Most farmers had to look for alternative crops that were drought resistant due to the changes in rainfall. Research by Ondieki & Kitheka (2019) showed that the production of cash crops like sugarcane have declined in Nyanza and western region. This reduction is attributed to the variation of rainfall such as magnitude and duration during the growing period of sugarcane. The prolonged drought affected the planting dates in 2017 led to a 51.1% decline in total sugarcane produced in Nyanza and western regions from 669,914 to 342,054 tons. Even though these studies also focused on the effect of rainfall variability on food crop production such as wheat and Irish potato, they did not show how rainfall variability affects crops such maize, beans and African nightshade. That gap was bridged by the current study.

Nyando Sub County for a long time was considered as the food basket to Kisumu County, especially in the production of food crops such as maize, beans and vegetables specifically the African nightshade (Ogola et al, 2007). There are other crops such as beans, cowpeas, tomatoes that were also grown in the area for a long time. These crops were fully dependent on rainfall for their survival as the area experienced high and reliable rainfall throughout the year in the past years. However, the changes in rainfall duration, magnitude and trends have made the food crop production difficult in Nyando Sub County. The rainfall data showed that there have been changes in magnitude, timing and duration of rainfall for the last 10 years (Ogola et al, 2007). For instance, in 2012 there was 100mm/hour of rainfall experienced within the area. The data also showed that long and short rains would arrive in time that is the month of March and September respectively (Owino, 2008). The rainfall data in 2013 further revealed that there were more hours of the rainy season hence greater duration. The rainfall data showed that magnitude of rainfall changed from 200mm/hour in 2013 to 50mm/hour in 2023. Furthermore, late arrivals of long and shorts rains were witnessed in 2020 as compared to timely rainfall onset in 2013. The hours of the rainy seasons have also declined substantively from 3 hours in 2013 to 1 hour in 2020 hence the reduced rainfall duration (Ogola et al, 2007). On the other hand, the data provided at the MOA showed that in the same period maize, beans and African nightshade production declined by yielding 67, 50 and 20 bags in 2020 from 110, 89, and 40 bags respectively in 2013 per household.

As Leal et al (2015) assert, crops such as maize, beans and African nightshade require reliable rainfall for their success. Conversely, the change in rainfall patterns such as seasonal and monthly variability of rainfall can reduce the quantity and quality of such crops. As a food crop-producing region, many households have benefited from the farming activities such as enhancing household food security, increasing income and many others. However, the situation is fast changing in recent days as most farms go uncultivated for months due to rainfall variability thus leading to reduced food security in the area. Even though the many studies conducted in the area focused on the effect of rainfall variability on various food crop production, there was still a need to examine the effect of rainfall variability on production beans, maize, and African nightshade.

1.2 Statement of Problem

Nyando sub-county has experienced incidences of rainfall variability leading to uncertainty among the households that rely on rain-fed agriculture. The data from the metrological department showed that over the last ten years, rainfall amounts have reduced and became unpredictable. These changes in rainfall patterns led to reduced food crop production affecting food security at household level. However it is not clearly documented on how the changes in rainfall specifically magnitude, duration and timing affected the specific food crops namely; maize, beans and African Nightshade being planted by the households in Nyando Sub County. For a long time, the area was considered a cake basket and a greater percentage of food crops consumed in Kisumu County are from Nyando Sub County. Since farming in the region is 90% rain-fed, rainfall variability has changed the whole situation as essential food crops like maize, beans and African nightshade cannot be produced, unlike the previous years. The reduced, unpredictable and seasonal variation of rainfall may have made it difficult to continue producing these crops as they are staple foods for the households in Nyando Sub-County. This could have resulted in increased household food insecurity in the area. Therefore the purpose of this study was to assess the effects of rainfall variability on food crop production in Nyando Sub-County, Kisumu County.

1.3 Objective of the Study

The purpose of the study was to assess the effect of rainfall variability on selected food crops production in Nyando Sub County, Kisumu County

The specific objectives of the study were to;

1. To examine the effect of duration of rainfall on Maize, Beans and African Nightshade production Nyando Sub County.
2. To establish the effect of magnitude of rainfall on Maize, Beans and African nightshade production in Nyando Sub County.
3. To assess the effect of timing of rainfall on Maize, Beans and African nightshade production in Nyando Sub County.

1.4 Research Questions

The research questions for the study were;

1. What is the effect of Duration of rainfall on Maize, Beans and African nightshade production in Nyando Sub County?
2. What is the effect of Magnitude of rainfall on Maize, Beans and African nightshade production in Nyando Sub County?

3. What is the effect of Timing of rainfall on Maize, Beans and African nightshade production in Nyando Sub County?

1.5 Justification of the Study

Maize, beans and the nightshade to mention a few are some of the most staple food crops both at local level and national perspective. Rain-fed agriculture has dominated food crop farming in Nyando for a long time. The rainfall data showed that there have been changes in magnitude, timing and duration of rainfall for the last 10 years (Ogola et al, 2007). For instance, in 2012 there was 100mm/hour of rainfall experienced within the area. The data also showed that long and short rains would arrive in time that is the month of March and September respectively (Owino, 2008). The rainfall data in 2012 further revealed that there were more hours of the rainy season hence greater duration. In 2020, the rainfall data showed that magnitude of rainfall changed from 100mm/hour to 50mm/hour. Furthermore, late arrivals of long and shorts rains were witnessed in 2020. The hours of the rainy seasons have also declined substantively from 3 hours in 2012 to 1 hour in 2020 hence the reduced rainfall duration (Ogola et al, 2007). On the other hand, the data provided at the MOA showed that in the same period maize, beans and African nightshade production declined by yielding 67, 50 and 20 bags in 2020 from 110, 89, and 40 bags respectively in 2012 per household. The aim of the current study was therefore to establish the effect that rainfall variability had on maize, beans, and African nightshade production.

1.6 Significance of the Study

The study examined the number of households that had been affected by incidences of rainfall variability leading to changes on food crop production. This provided and availed the much-needed information for farmers thus creating awareness of how they can restore the crop production levels to the Nyando Sub County residents witnessed in the past years. The research further gave a detailed investigation of the quantity of crops produced (maize, beans, and nightshade) and the amount of rainfall experienced over those years. The information acquired was important to the farmers as they understood the relation between the rainfall variability and the quantity of crops produced. Farmers were advised to grow maize during long rains with minimal production of beans and African nightshade, which should be greatly grown during short rains. Moreover, the farmers were encouraged to harvest rampant flood waters for future food crop production. Pertinently, the information gotten from this research acted as a policy guideline to the county government in realizing food security within the Sub County and the entire county. To the policy implementers such as the Ministry of Agriculture (MOA), the research findings was significant in solving the persistent food crisis in the midst of rainfall variability.

1.7 Scope of the Study

The research was carried out in Nyando Sub County, Kisumu County. The research was intended to investigate the effect of rainfall variability on food crop production within the area. The focus was only given to Maize, Beans and African nightshade since they are both staple foods for the people as well as having enormous economic value. Maize was studied due to its starch contributions to households. Beans and African nightshade were studied due to their protein and vitamins contribution respectively. Other factors such as early planting, drought-tolerant crops, altering planting dates and organic farming help in minimizing the effect of rainfall variability on the production of maize, beans and African nightshade were also considered during the study. However, the major interest of the current study was to establish the effect of rainfall variability on the production of maize, beans, and African nightshade.

1.8 Limitations of the Study

The research had some limitations which affected the timely data collection and the completion of the study. For instance, some respondents were not willing to divulge information about the questionnaire items. Some of the study areas were inaccessible due to poor road networks. To solve these, the researcher sought help from village heads who know the area well. The researcher also created a rapport with the respondents and convinced them that the study is strictly research and the information divulged remained confidential.

1.9 Theoretical Framework

This study was guided by the anthropogenic global warming theory. The theory was developed in 1998 by the Intergovernmental Panel on Climate Change (IPCC). This theory explains how greenhouse gases contribute to the electromagnetic radiation from the earth's surface and remit it as heat. The heat remitted back to the atmosphere has an impact on the rainfall events on the earth's surface (Tol, 2014). For instance, warming of the surface caused by the greenhouse effect may lead to aridity due to reduced rainfall in most parts of the world. This theory enabled my study to understand some of the causes of rainfall variability and therefore explain the effect of such variation on food crop production.

The greenhouse gases have led to the increase in surface heat thereby affecting rainfall amounts and trends. As such, areas that used to receive high and reliable rainfall have witnessed a significant fall in the amount of rainfall (Powell, 2015). The quantity of rain-fed crops has reduced due to the seasonal variation of rainfall caused by heat generated by gases such as Carbon(iv)oxide, ammonia, and methane (Tol, 2014). One of the major strengths of this theory is that it shows variations in the amount of rainfall caused by these greenhouse gases that may affect the production of rain-fed crops. Even though theory focuses on human contribution to increase atmospheric heat leading to variation of rainfall, it does not outline other causes of rainfall variability other than greenhouse gases. This is one of the weaknesses of this theory. In his criticism of this theory, Paterson (2011) also argued that scientific arguments should be supported by empirical data and not hypothesis, something that is missing in this theory. Despite the weaknesses, the theory was relevant in the study since it showed one of the major causes of changes in rainfall variability (duration, timing, and magnitude). The heating of the atmosphere caused by the greenhouse gases led to changes on rainfall patterns on the earth's surface. These changes in rainfall trends have an effect on the production of rain-fed food crops such as maize, beans and African nightshade. In view of this theory, the study assessed the effect of rainfall variability on food crop production in Nyando Sub County, Kisumu County, Kenya.

Conceptual Framework

Conceptual Framework on the relationship between Rainfall Variability and Food Crop Production was displayed as shown in Figure 1**.**

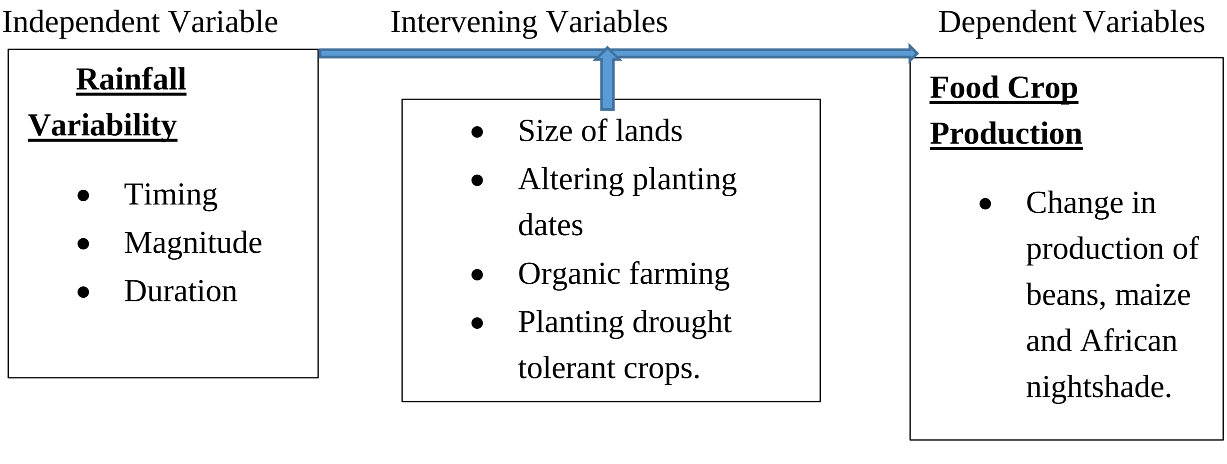

Figure 1. Conceptual Framework on effect of rainfall variability on food crop production in Nyando Sub-County.

Source: Researcher (2021).

Rainfall variability has affected the production of various food crops in the regions where people rely on rain-fed agriculture (Dinar, 2008). As a result of the greenhouse gases, there has been a variation of rainfall in different parts of the world. For instance, rainfall variability can be in form of magnitude, timing and duration leading to changes in the quantity of crops grown. The quantity of maize reduced drastically due to the seasonal decline of rainfall. Vegetables such as African Nightshade are on the downward drop due to reduced monthly rainfall. Moreover, the production of beans also has been affected by the change in timing and duration of rainfall. This framework, therefore, analyzed the effect of rainfall variability on food crop production. Rainfall variability was the independent variable that affected the production of these selected crops (maize, beans and African nightshade). The duration, magnitude and timing of rainfall positively or negatively affected food crop production. The intervening variables were other factors other than rainfall variability that affect food crop production. These factors helped in minimizing the effect of rainfall variability on the production of maize, African nightshade, and beans. They included; early planting, planting drought-tolerant crops, altering planting dates and intercropping. However, the interest of the current study was to establish the effect of rainfall variability on maize, beans, and African nightshade production. The dependent variable was maize, beans, and African nightshade production in tons which was obtained from the MOA and Kisumu County Agricultural offices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter represents a review of previous related research findings on rainfall variability and food crop production. This chapter examined cases of rainfall variability from different areas overtime and their effect on food production in different parts of the world. This section provided a benchmark for comparing the results of the study with other findings.

2.2 Duration of Rainfall on Maize, Beans and Nightshade Production

Rainfall variability effect have been greatly felt in the agricultural sector, particularly on rain-fed crops. The changes witnessed in the magnitude, intensity, reliability and amounts of rainfall experienced in different parts of the world have had a dire impact on crop farming. As rain-fed crops beans, maize and nightshade growing requires high and well distributed rainfall during the initial stages of growth to ensure quality output. However, the changes in rainfall trends have hindered the production of beans, maize, and nightshade due to their full dependence on rainfall. According to Synodinos (2018), rainfall reduction witnessed in Brazil between the last ten years (2005 to 2015) had serious consequences on rainfall sensitive crops like beans. Within six of the ten years, there was a significant reduction of rainfall of close to 838mm which led to a substantial decrease of maize growing within Itaporanga Municipality (Krol & Bronstert, 2007). A study by Karnataka (2007) also showed that seasonal change of rainfall amount in India led to a 20% decline of the area under beans cultivation and a 23% reduction of total yield between 2006 and 2013. These studies agreed that change in rainfall amounts affected food crops' production. However, there was need to examine how the duration of rainfall affected beans, maize and African nightshade production at the household level.

Limited technological advancement in Africa has forced many countries to rely on rain-fed agriculture in the production of various crops. As such, many households in Africa are fast becoming more food insecure due to the changes in rainfall patterns. A report published by World Meteorological Organization (WMO) (2008), showed that there was an annual decrease of about 2mm of rainfall in most parts of Africa. From 2006 to date, rainfall in Angola declined by 24% per decade thus minimizing the production of many rain-fed crops (Kgathi et al, 2006). For instance, there was a substantial reduction of beans production in the Southern Province of Angola by 11% due to the changes in rainfall amounts (Kgathi et al, 2006). As such, many households resorted to the production of drought-resistant crops and irrigation farming which was quite expensive to most farmers. On the other hand, changes in rainfall amounts in DRC Congo affected the production of maize and the common bean (Phaseolus vulgaris). According to Katungi et al (2009), the historical drought experienced in 2017 in DRC Congo led to a 40% drop in common bean production especially in the valley of Ruzizi, the valley of Rutshuru and in Southern Katanga. Moreover, there have been other incidences of drought during the African nightshade growing period over the years which have lowered the quantity of production. This situation increased household food insecurity since these crops are largely consumed by the people of Congo. These existing works of literature examined the effect of the decline in rainfall amounts and drought incidences on the production of these selected crops in Africa. However, there was need to assess the effect of the duration of rainfall on beans, African nightshade, and maize production at a local scale.

Common bean, maize and African nightshade are famous among East African households due to their nutritional value. Majority of farmers rely on rainfall for growing these crops even though there are few cases where new farming techniques have been adopted. As one of the major producers of beans in East Africa, Uganda had experienced changes in their production due to climate variability leading to a change in rainfall patterns. According to Kgathi et al

(2006), a drop in the quantity of beans produced in 2018 was attributed to the changes in rainfall patterns. Since beans were largely grown in Uganda, any slight change in their production affected many households thus causing increased food insecurity. On the other hand, Tanzania is also known as a major maize producer within the East African communities. However, many incidences of reduced rainfall amounts have led to a slip in maize production in the country. A study conducted in Hai District, Kilimanjaro concluded that reduction of rainfall between the years 2000 and 2005 led to a massive decline in food crop production such as maize, beans and vegetables (Kgathi et.al, 2006). As much as these studies agreed on the impact of changes in rainfall amounts on beans production, there was still a need to give more information on the effect of duration of rainfall on the production of the selected crops.

A study by Arunga et al (2012) showed that Kenyans currently consume an average of 755,000 metric tons against total amount produced of about 600,000 metric tons. This showed that beans are one of the staple crops among many households in Kenya. However, changes in rainfall trend in Kenya has led to a drop in bean production in different parts of the country. The change in trend, distribution and onset of rains have vastly reduced the number of beans produced. According to Owino (2008), the change of rainfall distribution within the last 4 years (2017 to 2021) has substantially led to a reduction of total maize produced from 27,488 tons to 21,253 tons. Rosecoco and yellow beans which are the common varieties of beans famous in rift valley, western and eastern Kenya are slowly declining due to the changes in the onset of rains (Arunga et al, 2012). Moreover, rainfall in these regions was also unreliable within the growing periods thus affecting the quantity of beans, African nightshade and maize produced. As much as these studies revealed that changes in rainfall patterns affect beans production, there was a need to do more studies to assess the effect of duration of rainfall on beans, African nightshade, and maize production in various parts of Kenya.

According to Ogola et al (2007), 90% of crops grown in Nyando Sub County rely on rainfall even though new farming adaptation strategies such as irrigation is used on crops such as rice. The area has been affected by changes in rainfall amounts in the last 10 years which led to a major drop in the quantity of crops produced. Countless drought instances in the area within many months interferes with the farming calendar. The reduction of rainfall during growing periods of the major crops increased the level of food insecurity among many households (Owino, 2008). Existing literature in East Africa and Kenya showed the effect of changes in rainfall trends, duration and amounts on beans, African nightshade, and maize farming. However, there was need to investigate the effect of duration on beans, maize, and African nightshade farming in Nyando.

2.3 Timing of Rainfall on Maize, Beans and African Nightshade Production

The change in the onset of rainfall is a great hindrance for growing a majority of food crops that are staple to most households in different parts of the world. According to Nedumaran (2015), the change in the arrival of rainfall had greatly affected food crop production. Brazil as a major maize producer has witnessed a change in production due to the changes in rainfall pattern and duration. A study by Wiliams & Kniveton (2010) shows a steady decline in precipitation by 10% which contributed to the low maize yield within a range of 30% to 60% in Brazil.

The USA on the other hand experienced a variation in the arrival of rainfall due to the emissions of gases in the atmosphere that affected the normal dates when rainfall is received in the major agricultural areas. Such changes have limited the amounts of rainfall used in the growing of beans and maize thus lowering the level of household security (Seo & Mendelsohn, 2008). A study conducted in Hebei province, China on the effect of rainfall variability on vegetable farming shows that delay of rainfall by 31 days led to 150.26kg loss of Chinese cabbage yield per hectare (Seo & Mendelsohn, 2008). Even though these studies revealed the effect of rainfall changes on crop production, there was a need to do more studies on the effect of timing of rainfall on maize, beans, and African nightshade.

Beans, African nightshade, and Maize farming are famous in the majority of African countries since these crops are staple foods in most households. Africa's major maize producers like Nigeria and South Africa depend on rain for such production to be a success. As a result of the large scale, production of maize in such countries, there is a lot of generation of income for the farmers and an increase of the Gross Domestic Product (McCann, 2005). However, Africa is fast becoming food insecure due to many cases of rainfall variability that have led to a monumental decrease in the production of maize, beans and African nightshade thus resulting in importation from other countries. Nigeria as one of the major maize and African nightshade producers in Africa has experienced numerous cases of the timing of rainfall. For instance, the change in the dates of rainfall interfered with the planting days thus leading to the decline in production of such crops thus lowering the GDP by 22% within the last 5 years (Mati, 2010). Moreover, the changing rainfall amounts have increased the incidences of pests and diseases that invade most maize and beans plantations thus minimizing the quantity of maize produced. An almost similar situation was experienced by maize farmers in South Africa who relied greatly on rainfall for maize production. According to Dinar (2008), the reduction of rainfall between 5-10% has forced farmers to look for alternatives of growing maize such as irrigation despite being quite expensive. On most occasions, most households had been rendered food insecure due to the massive decline in maize and beans production as these crops are valued by more than 70% of South Africans as their stable food (McCann, 2005). These studies focused on rainfall patterns on maize, African nightshade and beans growing, however, there was need to assess the effect of timing of rainfall on maize, African nightshade and beans which was the basis of this study.

Kaguongo & Food and Agriculture Organization of the United Nations (2013) also agreed that changes in rainfall patterns such as rainfall events and intensity had led to uncertainties in growing many food crops in different parts of Kenya. Maize and beans are famous among Kenyan households; in fact, they are one the most consumed cereals in the country. On the other hand, African nightshade is also largely consumed by households in Kenya due to its nutritional value. The rain-fed crops like maize, beans and African nightshade are mainly grown in the Rift Valley, Western Kenya, parts of Eastern Province and Central Kenya. These areas constitute 50% of the total cereals and vegetables consumed in the country (Oseni & Masarirambi, 2011). However, there has been a consistent reduction in the quantity production of these crops due to changes in rainfall events. According to Mati (2010), the late arrival of rainfall interfered with the planting dates of most farmers who mainly engage in the production of these crops. For instance, planting of the African nightshade declined in several parts of western Kenya due to the late arrival of rainfall in 2014. As much as some experts held on to other factors for the decline as pest and diseases, limited capital and competition from other crops as the main cause in the decline of production of these crops, changes in the timing of rainfall is considered as the main cause. This, therefore, called for the need to carry out more assessment on the effect of timing of rainfall on maize, beans, and African nightshade farming.

Mati (2010) asserted that the delay in the onset of rainfall between March and June over the last 5 years has contributed to severe loss to farmers. For instance, the tonnage of beans produced has reduced within the last three years (2017, 2018 and 2019), the decline has been 4,000, 3,456 and 3,186 respectively. A similar study carried out by Cohen & Atieno (2010) on the effect of rainfall events on maize farming revealed that the late arrival of September/December 2006 was not enough to sustain maize growing in the country. Countless maize and maize growing regions in Kenya like Trans Nzoia, Narok and Kakamega recorded the least harvest, something that caused panic to the Ministry of Agriculture. According to a report by Government of Kenya (GOK) (2015), more than 1.5 million people were affected by the reduction of maize, beans, and vegetable production in the county during that period. Therefore, there was need to assess the effect of timing of rainfall on maize, beans and African nightshade production in various parts of the country.

Cohen & Atieno (2010) point out in their research the regions in Kenya that are susceptible to rainfall variability and therefore reduced maize production. For instance, the drought experienced in Western Kenya from 2005 to 2009 made it difficult for the vegetables and cereal farmers in the region. The changes in the dates of long rains had disadvantaged the small-scale farmers in cultivating African nightshade, maize, and beans for subsistence use (Food and Agricultural Organization (FAO) (2009). This made the region over-rely on government assistance for them to get access to some of these crops for their consumption. Nyando Sub County also experienced many cases of rainfall variability leading to floods, long droughts and reduced rainfall amounts that affect food crop farming. According to Wani & Rockström (2009), within the last 10 years, the region had experienced a change in rainfall amounts and intensity which have minimized agricultural activities. Initially, there was timely arrival of rainfall that allowed for the production of many crops; however, the late arrival of rainfall has forced farmers to opt for irrigation which was also unreliable and expensive. Many researches focused on the general rainfall amounts and intensity on maize farming, however, this study assessed the effect of timing of rainfall on maize, beans, and African nightshade production in Nyando.

2.4 Magnitude of Rainfall on Maize, Beans and African Nightshade Production

As pointed out by different researchers change in rainfall amount had not only been felt in growing the crops such as beans and maize but also the short-term crops like the vegetables Amaranth, cowpeas, and African Cabbage. Both beans, maize and short-term vegetables are perceived to rely on the concentration of rainfall within the growing periods. The study by Dinar (2008) showed that globally many countries had witnessed a reduction in the intensity of rainfall thus affecting food crop production. Due to the many cases of food insecurity in different parts of the world, particularly Sub-Saharan Africa. Many researchers believe that growing vegetables, maize and beans could help in bridging the gap of food insecurity that could exist in these countries. According to Shackleton, Pasquin & Drescher (2009), vegetables, maize and beans grow in different climatic conditions. The concentration of rainfall within a given hour when it rains is considered as the magnitude of rainfall. For instance, it can rain for 20mm or 30mm within an hour hence the magnitude. The variation in the strength of rainfall can affect the production of several rain-fed crops. Due to the constant variation of rainfall in various parts of the world which could affect growing of vital crops, there was a need to assess the effect of rainfall magnitude on the production of African nightshade, maize, and beans production.

According to McCann (2005), the reduction of rainfall with 4 inches in 2016 had a significant impact on the production of crops such as maize in Iowa State. This meant that most lands under cultivation became moisture deficient leading to minimal production of maize in those areas. On the other hand, Katungi et.al (2009) assert that a 6-hour storm may lead to a 10-inch increase of water levels on the earth's surface. When there are excess water levels, the vital nutrients are leached leading to wilting on crops. As pointed out by Shackleton et al (2009), the 2016 South Eastern Louisiana floods were one of the greatest that has been witnessed in a long time. During this time, there were more than 20 inches of rain that had short term and long-term effect on the crops grown. For instance, leaching and soil erosion caused by the floods affected growing of cotton, sugarcane, and corn. Most farmers had to look for better ways of improving soil fertility to enhance continuity in the production of such crops. High rainfall experienced in July 2020 which was believed to be more than 20 inches severely affected corn production (Guntu et al, 2020). For instance, due to constant waterlogging in the farms, the stalk of the corns started rotting thus affecting their harvesting. As much as these studies agreed that the magnitude of rainfall affect the production of corn and sugarcane, there was need to do more research on the effect of rainfall magnitude on maize, beans, and African nightshade.

Namibia as one of the major food crop and fruits producers had experienced different scenarios on the intensity of rainfall on different crops. In 2015, Southern Namibia experienced one of the highest rainfalls in a long time. For instance, there was 70mm/hour of rainfall received for several days, an occurrence explained by meteorologists as one of the greatest rainfall intensities (Kanyagia, 2009). The production of beans, maize and vegetables were affected during that period as most farmlands were submerged in water. Moreover, pollination was affected due to the high intensity of rainfall thus limiting the efficient reproduction of crops in the region. Edmonds & Chweya (2018) also revealed that reduced rainfall by 8inches in northern Nigeria in 2017 affected growing of maize, beans and other vegetables since most soils became moisture deficient. A study by Guntu et al (2020) also revealed that the long rains in Southern Cameroon between July and November affected the production of African nightshade. For the three months, there was between 60mm/hour and 80mm/hour of rainfall received leading to flooding of the farms. This led to the rotting of most roots and falling off most leaves of the African nightshade. As much as these studies revealed the effect of rainfall intensity on food crop growing, there was need to add more information on the magnitude of rainfall on growing the African nightshade, maize and beans in different parts of Africa.

According to Maundu (2007), reduced rainfall in some parts of East Africa for the last five years has led to a decline in the production of many food crops. In Ethiopia, different rainfall events could affect crop production. For instance, there had been reduced rainfall between

February, March and April affected the production of wheat and corn as the amount of rainfall massively declined by 9cm. In Hai District, Tanzania, the effect of reduced rainfall concentration was witnessed in 2011 and 2013 when rainfall reduced by 20cm up from 100cm required for growing maize Maundu (2007). This led to the fall of the total tonnage of maize produced within that period. Moreover, the production of the common beans was also affected in the region due to a limited supply of moisture as a result of the decline in the duration and amount of rainfall. Research by Abukutsa (2010) showed that Kaboong and Moroto districts were subjected to starvation due to the delay of April to September rainfall. Such delays were also accompanied by a reduced intensity of rainfall affecting the production staple crops such as *Matooke,* Beans and Maize. As much as these studies revealed the effect of change in rainfall events and variation on different crops, there was need to do more research on the effect of rainfall magnitude on maize, beans and African nightshade.

Rainfall intensity increased from 7.7mm/hour to 10.6mm/hour in the last ten years in rift valley (Abukutsa, 2010). This had affected growing of crops such as tea, coffee, maize, and vegetables. Between 2006 and 2009, there was a significant increase in the total amount of wheat produced in Kajiado and Narok districts by 23% due to the increase in the rainfall intensity. The study by Omondi (2018), showed that there was an increase in amount of rainfall in western Kenya by 2% between the period 2012 and 2020 which increased the production of food crops such as beans and Sukuma wiki. According to Owino (2008), improvement of forest cover in Cherengani hills and Mau Forest has helped in improving rainfall in the Lake Victoria region and as well as most parts of Nandi County. It is believed that rainfall had increased between 2019 and 2020 by 10mm due to an improvement of forest cover. As such, crops such as tea, maize and vegetables increased due to an increase in the rainfall amounts in those areas. As much as these studies showed the effect of changes in rainfall/hour on food crop production, there was a need to do more research on the effect of rainfall magnitude on maize, African nightshade, and beans farming.

According to Omondi (2018), there are some vegetables and crops that are grown within Nyando Sub County such as kales, tomatoes, and many others. These crops grown majorly rely on rainfall to enhance their productivity. For instance, growing maize, beans and African nightshade require constant the right (500mm) millimeter per hour of rainfall during the growing period (Omondi, 2018). The change in rainfall trends within the last five years became a major concern for most farmers within Nyando Sub County. A report by Owino, (2008) indicate that tomato farmers are now forced to use irrigation due to reduced rainfall concentration and irregularities, something quite expensive to farmers. Moreover, the reduced rainfall magnitude within the region forced some vegetable farmers to abandon such activities for alternative crops (Owino, 2008). The current studies provided information on the changes in rainfall magnitude on some crops grown in Nyando such as rice, maize, and tomatoes, however, this paper focused on the effect of rainfall magnitude on African nightshade, maize and beans farming in Nyando Sub County.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methods that were used by the researcher to execute the study. This section has research design, the area of study, target population, sampling procedure and sample size. The validity and reliability of the research instruments, data analysis techniques and ethical considerations are also contained in the chapter.

3.1.1 The Study Area

The study was conducted in Nyando Sub County (Figure 2) which is made of five wards; namely, Ahero, Awasi, Kobura, East Kano and Kabonyo respectively. Nyando sub county lies between longitude 33° 20’ to 35° 20' East and latitude 0° 20' to 0° 50' South. The sub-county is sandwiched between the Nandi hills of Rift valley and the Nyabondo plateau of Upper Nyakach. The area covers an area of approximately 163 km^2 with a population of about 122,376

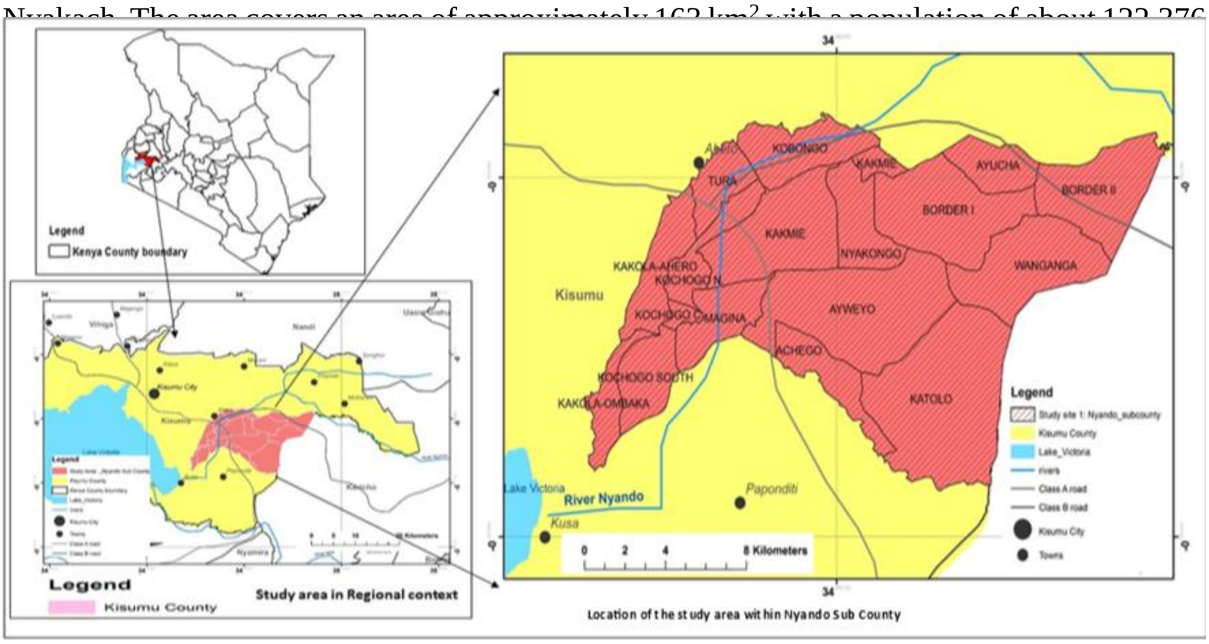

Figure 2: Map of the Study Area.

Source: Adopted and modified from Kisumu District Development Plan (2009).

Nyando Sub-County experiences between 780mm to 1500mm annually, with the mean annual rainfall at approximately 1000mm. The Sub-County experiences two rainy seasons; March, April, and May (MAM) representing long rain season and October, November, and December (OND) representing short rain reason. This double maximum has in the past affected growing of a number of crops that rely on these two rainy seasons. However, the area has in the last 10 years experienced a change in the rainfall timing, duration and magnitude that affected production of many food crops; Maize, Beans and African nightshade being one of them.

3.1.2 Climate

Nyando Sub County is located within a hot climatic region with unpredictable weather patterns. The area experiences mean annual temperatures of about 22 °C. Despite the high temperatures throughout the year, the region experiences a mean annual rainfall of 1000mm. However, these rainfall amounts keep on changing over the last ten years (Mogaka, 2006). This type of climate affected maize, beans and African nightshade production in the sub-county hence the need for carrying out this study.

3.1.3 Soil

The relief (plains) and the climatic conditions have affected the type of soils found within the area. The area is dominated by the black cotton soils that have a distinct feature of developing cracks during dry seasons. However, at the onset of rains, the cracks close thus hindering infiltration thus resulting in floods in most parts of the area. The black cotton soil was ideal for growing of maize, beans and African nightshade due to its high capacity of water retention.

3.2 Research Design

This research used a quasi-longitudinal research design to get the qualitative and quantitative data on rainfall from the meteorological department and data on food crop production from household heads. The unit of data analysis was the household. This design helped in collecting data in order to answer the questions the study seeks to answer regarding the subject. This study obtained data from primary sources which included; field observation, household questionnaires and government officials' interviews. Primary data was collected from household heads. Secondary data was obtained from published and unpublished documents, meteorological data, and MOA.

3.3 Study Population and Sampling

The total number of households in the study area was 24,866 (KNBS, 2010). The target population was 384 household heads from the five agricultural wards of Nyando Sub County (Table 1). The households living within the study area was subdivided into subgroups using the stratified sampling technique (Hennink & Bailey, 2020). The total sample size for Nyando Sub County was calculated using a formula cited in Mugenda & Mugenda (2003) because the population is more than 10,000.

$$n = \frac{(Z)^2 * (p) * (1-p)}{C^2}$$

Where Provided:

n = Sample size

Z= 1.96, the tabulated Z value for 95% confidence level.

P=Sample proportion expressed as decimal (0.5) is the maximum that can yield at least the desired precision.

C=degree of accuracy expressed as decimal (0.05) since estimate of the study should be within 5% of the true value

Hence $n=\frac{(1.96)^2 * 0.5 * (1-0.5)}{(0.05)^2} = 384$

Table 1: Sample Size Determination.

Wards	Population	Male	Female	Households	Formula	Sample size
Ahero	35,679	15,355	20,324	5,878	$\frac{5878}{24,866}*384$	91
Kobura	55,602	25,409	29,801	13,227	$\frac{13,227}{24,866}*384$	205
Kabonyo	11,761	5,019	6,742	1,971	$\frac{1,971}{24,866}*384$	30
East Kano	9,842	4,158	5,684	1,754	$\frac{1,754}{24,866}*384$	27
Awasi	9,492	4,563	4,929	2,036	$\frac{2,036}{24,866}*384$	31
TOTAL	122,376	54,504	67,480	24,866	$\frac{(1.96)^2*0.5*(1-0.5)}{(0.05)^2}$	384

Source: KNBS (2010).

3.4 Sampling Procedures

According to Taylor (2005), sampling procedures is the process of selecting households from a population to represent the characteristics found in the entire group. The study used the following procedures;

3.4.1 Simple Random Sampling

This method was used in selecting the 384 respondents from the 24,866 farming households within the five wards. In this study, every subject was assigned a number then the list of numbers randomized using a computer program (Microsoft Office Excel). The 384 random numbers from the computer program was then selected as the subject of the study. Different household heads were identified with the help of local administrative officers.

3.4.2 Purposive Sampling

Purposive sampling was used to provide key informants that included officers from Ministry of Agriculture (MOA) who provided data on crops grown in the area for the 10 last years and another officer from Kenya meteorological department (KMD) who provided significant data on the rainfall amounts for the last ten years.

3.5 Sources of Data

Both primary and secondary data was collected for this study.

3.5.1 Primary Data

Primary data on food crop production and yields was obtained from household heads' questionnaires, interview schedules for key informants, photography, and observation checklist. This provided data on food crop yield among the farmers over the years.

3.5.2 Secondary Data

Secondary data of rainfall and crop yields was obtained from published and unpublished documents, meteorological data, and MOA. The source centers for these data were; Meteorological Department and Kisumu County Ministry of Agriculture. Documented sources of data on rainfall totals, distribution patterns, and duration was gotten from a meteorological department within the county. Data on food crop production was obtained from the MOA. Data collected was both qualitative and quantitative. The techniques used were;

3.5.3 Questionnaire

Structured questionnaires were used to help in the collection of data. Both open-ended and closed-ended questionnaires were administered to households to collect information on the number of yields per each crop harvested seasonally, rainfall trends and increase in rainfall magnitude within the study area. The target respondents were 384 household heads to ensure the reliability of data. Questionnaires was self-administered to avoid misunderstanding of questions by the respondents and also take care of the high level of illiteracy of some respondents. The questionnaire contained similar questions to allow for the collection of homogenous data from all households.

3.5.4 Key Informant Interviews

The interview schedule was administered to 1 officer at the Kenya Meteorological Department, Kisumu County office to give 10-year data on rainfall duration, timing and magnitude. Another Interview schedule was also administered to 1 officer at the Department of Agriculture within the county offices to provide information on maize, beans, and African nightshade production over the last ten years. Chiefs of the locations within the study area gave further information which would help to corroborate data on the types of crops grown in the area and the possible changes that may have occurred in production over the last ten years.

3.5.5 Photography and Observation

Direct observation was used to establish land that is actually under beans, maize, and African nightshade at the time of data collection. Moreover, photography helped in capturing the farms planted with these crops and these farming systems in the study area. An observation checklist was provided to record information on the amount and types of food crops grown and any other rainfall related information relevant to this study.

3.5.6 Focus Group Discussions

One focus group discussion was conducted in each ward since most households engage in food crop production. Each focus group contained between 8-10 participants who give information amount of yield per crop that they have harvested during a particular season.

3.6 Data Analysis

Quantitative data on food crop yields was analyzed using descriptive statistics such as frequency charts, percentages, and standard deviation. The research had proposed the use of

Pearson's Correlation, Precipitation Concentration Index (PCI) and multiple regression to measure the relationship between rainfall variability and the production of maize, beans and African nightshade. However, during data processing, the emergence of a single independent variable against a set of three dependent variables prompted a unilateral the adoption of simple regression analysis in measuring the effect of timing, duration and magnitude of rainfall on the yields of maize, beans and African nightshade. Documented sources of data on rainfall duration, timing and magnitude from the Kisumu meteorological department was used for regression analysis. These data were processed using Statistical Package for Social Science (*SPSS* Version 22). Qualitative data on types of food crops was edited and cleaned up to allow for organization. Categories, themes, and patterns was created to help in evaluating the usefulness of the information in answering research questions.

3.7 Result Presentation

The analyzed data was presented in form of Charts, Graphs, Tables and Plates. The findings helped in providing solutions on how farmers can adapt to rainfall variability to ensure sustainable food crop production.

3.8 Validity and Reliability

According to Kirk & Miller (2007), the validity of research is the extent to which the research measures the right elements it is intended to. On the other hand, reliability is the degree to which a method used in research produces similar and consistent results. As such, the reliability and validity of this research was attained by pre-testing of questionnaires to ascertain its suitability before the actual administration. There was a pre-testing of 10% of the questionnaires of the total respondents in Nyando Sub County. A reliability test was performed and a Cronbach's alpha of 0.746 attained. This ensured familiarization with respondents, testing the sequence of questions, elimination of biased questions, eliminating repetitive and ambiguous questions. Moreover, it helped in the estimation of the response rate and duration of an interview

3.9 Ethical Considerations

I sought research permission from the university requesting for letter of introduction as well as the Maseno University Ethics Review Committee and NACOSTI to allow me to conduct my research in the study area. Further permission was sought from local administration such as chiefs and assistant chiefs to allow me conduct research in their area of jurisdiction. Permission was also sought at Nyando sub-county offices, Kisumu meteorological department and Kisumu County ministry of agriculture to allow me conduct research in their offices. Informed consent is another key principle of research that was integral in this study. I adhered to this through written informed consent from the respondents after a brief introduction of the study. Participation in the study was on a voluntary basis. Confidentiality, privacy, and anonymity of the participants was maintained to ensure that they were protected. I guaranteed this through the use of codes in the household questionnaires to be administered instead of using exact names of the respondents.

Any suspicion from the respondents on the use of information they provide was cleared upon stating purpose of the study. Risk and benefits of the study was explained to the identified respondents. Further, respondents were informed on their freedom to withdraw from the study. I ensured that information provided by the respondents is secure and not accessed by unauthorized persons. Lockable drawers were used to keep the completed questionnaires to ensure none accesses information already researched until they are due for shredding. The confidentiality and safety of the data obtained from the respondents was ensured by keeping such data in private folder in the computer with password that is only known to the researcher.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1: Introduction

This chapter presents results and discussions on household characteristics and effect of rainfall variability on selected food crop production in Nyando sub county, Kisumu County. The results were presented in Tables, Figures, Plates and themes as guided by the general and specific objectives. Also, information on yearly variation of rainfall duration, magnitude and timing on maize, beans and African nightshade yields both during long and short rains was presented and discussed. The effect of magnitude of rainfall on production of beans, maize and African nightshade crops and the effect of timing of rainfall on the yields of the three crops have presented and discussed as well.

4.2 Demographic Characteristics and Food Crop Farming in Nyando Sub County.

Information on demographic characteristics and farming of maize, beans and African night shade was collected, analyzed and presented on Tables 2. Further results on duration of the farmers' engagement in the production of the three food crops and the amount of yields for each crop between 2013 and 2022.

4.2.1 Gender Distribution, Age, Marital Status and Farming Experience of the Respondents

Data on Gender distribution, age, marital status and farming experience of the respondents was collected and presented as shown in Table 2.

Table 2: Gender Distribution, Age, Marital Status and Farming Experience of the Respondents.

Gender Distribution of the respondents		
Gender	**Count**	**Percentage**
Male	145	38
Female	237	61
Household head's age	**Count**	**Percentage**
20-35	46	12
36-45	85	22
46-55	238	62
>55	15	4
Marital status		
Single	40	10.4
Married	167	43.4
Divorced/separated	57	14.8
Widowed	120	31.4
Household size		
Size	**Count**	**Percentage**
1-2	20	5.2
3-4	262	68.2
5-6	70	18
>6	34	8.8
Farming Experience		
Time in Years	**Frequency**	**Percentage**
≥15	13	39.4
11-15	14	42.4
5-10	4	12.1
0-5	2	6.1

Source: Field data 2022

Out of the total number of the respondents the study established that 145 (38%) were males, 237 (62%) were females (Table 2). This indicates that the majority of the farmers who grew maize, beans and African nightshade were female household heads. This could be explained by the fact that most males are skewed towards the production of cash crops. It therefore supports the general understanding that women household heads (62%) are more interested in food crop farming than the male household heads (38%) to provide food for their children. Moreover, the result indicated that the majority of the rural small holder are resource poor farmers. The findings therefore meant that changes in rainfall duration, magnitude and timing affected food crop production among females than males. The fact that the majority of farmers are resource poor, rainfall variability therefore led to the decline in food crop production since they didn't have better options to mitigate such effects.

The results of the study was similar to that by Arunga et al (2012) which presented that more female respondents than males were engaged in the production of beans in rural areas of Kenya. The findings also agreed with the findings of Abukutsa (2010) that noted a majority of food crop farmers in Kajiado Sub County were women. Men were more engaged in livestock keeping which they considered valuable than food crop farming. Mati (2010) also asserted that women are generally more interested and involved in small scale food crop farming than men. As such, instances of climate variability greatly affect women because they have the burden of providing for their children. These studies focused on gender and food crop production but did not explain how rainfall variability affect food crop production among different gender. This gap was well explained in the current study.

The majority of farmers (62%) were within the 46 – 55 years age bracket. This reveals that food crop farming is majorly done by the middle age population. The younger population normally migrates from rural to urban areas in search for formal employment in other sectors of the economy different from agriculture which is attributed to the uneducated and older generation. Also, agriculture is labour intensive, which makes it difficult for the older, lesser energetic population to practice it. The elderly (>55 years) were less involved in farming since they were less energetic therefore they opted to stay at home to be taken care of by the energetic respondents. Moreover, it was established that the level of income had declined for the elderly which limited their ability in farming. The 62% of the farmers were more exposed to the effects of rainfall variability as they relied on the rain-fed agriculture and engaged more in food crop production (Maize, Beans and African Nightshade) than any other age bracket over the years. The elderly were aware of the changes in rainfall patterns in the area but had the least effect of rainfall variability since they avoided farming. Similar results were observed by Owino (2008) who noted that the younger households in Kisumu District, Kenya shied away agricultural activities since they considered farming as an odd job. Also, the study conducted in Thika by Omondi (2018) and another conducted by Cohen and Atieno (2010) established that the younger generation have been known avoid engaging in agricultural activities.

The study further established that large number of the respondents (43.49%) were married, 14.8% were divorced and 10.4% were single. The widowed respondents constituted around 31.4% of the total population. The married respondents were actively engaged crop production than the widowed, single and the divorced respondents. The married respondents were actively involved in crop production since the couples were able to consolidate funds for better farming unlike the single respondents. The single respondents were least engaged in food crop farming since they had no burden of providing for their families. The majority of the single respondents were also of the young population who considered farming an odd job thus decided to stay away from farming practices. The research done by Owino (2008) also agreed by with the study findings that the single spouse households heads have been known to avoid taking agricultural practice seriously due to financial constraints and the little income they get is directly used in buying food and not for food crop production. On widowhood, the results are identical to the finding by Ooko et al (2015), which observed a higher number of widows in Kisumu County. His research found that HIV/AIDS was the major cause for high mortality rates. His findings agreed with the current study that pointed out that the widowed are rarely engaged in food crop production due to the burden of taking care of the large families left behind.

The largest household size (Table 2) was made up of 3-4 children that stood at 68.2 % of the sampled households. The household size made up of 1-2 children constituted 5.2%, while the household sizes of 5-6 and above 6 constituted 18% and 8.8% respectively. The results showed that the households with few children were less engaged in farming activities since the pressure of feeding them is less compared to the larger families. Most household heads with more than 3 children are actively involved in food crop production to sustain their daily needs. Also, the households that had more than 6 children were actively involved in cash crop farming compared to food crop farming. This is because, cash crops like sugarcane fetch higher income that helped in meeting monetary demands like school fees brought by large families. The results however differed from the finding by Katungi et al (2009) that noted relatively smaller household sizes. This is because Katungi et al (2009) sampled only the educated households. He argued that higher education levels had been known to impact fertility negatively therefore the reduced need to actively engage in food crop production. Research conducted by Mpungose et al (2022) in Northern Nigeria on vegetable production agreed that changes in the rainfall trends affected the growth of pumpkin which is largely consumed by the households. The decline was attributed to reduced rainfall amounts that led to drying up of the farms thus lowering the yields.

The result on the number of years that the participants have engaged in crop farming was determined as shown in Table 2. The farmers that had practiced farming within the period less than five years were the fewest because it is this period that the study area experienced great rainfall variability. The farmers that have engaged in farming for a period (≥5) were the second largest which meant that most of them opted away from food crop production when rainfall duration, magnitude and timing changed within the study area. Most household heads (42.4%) had practiced food crop farming between 11 to 15 years. This communicates the fact that "practice makes perfect". The majority of the household heads had the longest experience in food crop farming. They had studied and mastered rainfall patterns and variations over the years and understood the durations, magnitude and timing of rainfall. As such they were the one who provided information on variations that has occurred on rainfall thus affecting crop production. The knowledge on rainfall patterns in the area was vital to farmers as it informed their cultivation, planting, weeding and other practices that ultimately determined the yields of maize beans and African nightshade. These results are similar to the findings of a survey conducted by Arunga et al (2012) on bean growing areas in Kenya which reported more agricultural experience by farmers in the rural setups. Further, the findings were justified by Ondieki &Kitheka (2019) who established that rural agriculture is the mainstay in the rural areas and that the experience has been ancestrally passed to the current generation. Therefore, the changes in rainfall patterns had a great impact on the level of household food security.

These demographic characteristics established by the study gave the background information on the respondents in the study area. It was important to know the gender, age bracket and the marital status of the respondents that were more involved in food crop production thus understanding how the rainfall variability affected production of the selected crops. Further to the demographic characteristics of the respondents, the study established that maize, beans and African nightshade productions had declined. The results on Figure 3 showed that maize production had been on the decline with few positive fluctuations. Data on mean annual crop yield fluctuations was therefore analyzed and presented in Figure 3

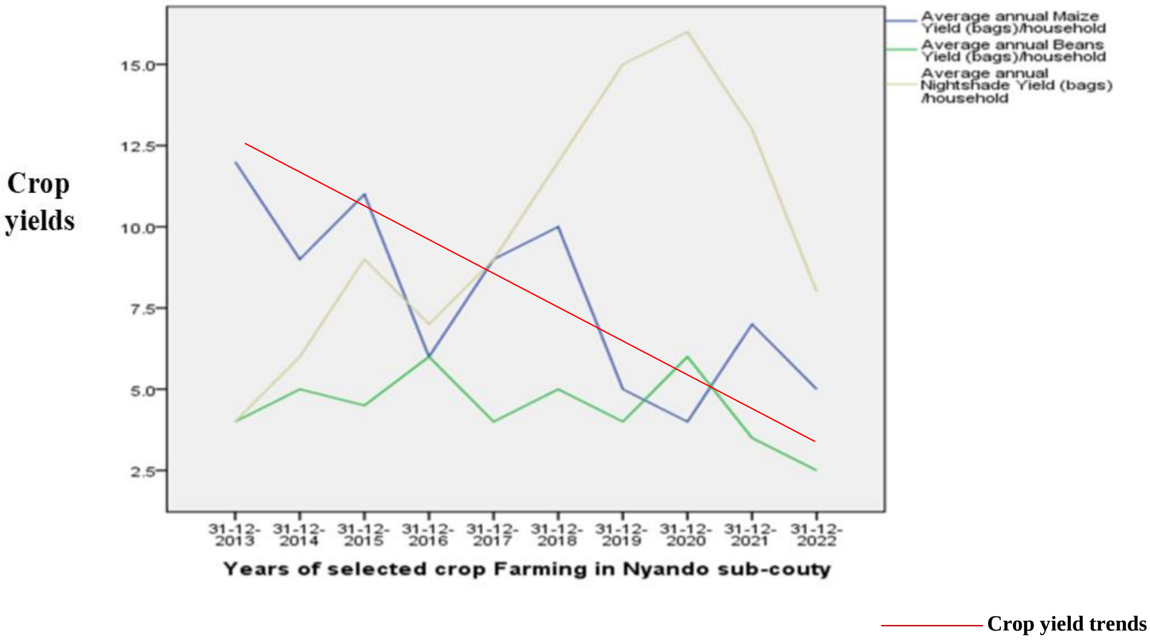

Figure 3: The Mean Annual Fluctuations in yields of Maize, Beans and African Nightshade.

Source: Kisumu County MOA, 2022

The trend of the crop yields (maize, beans and african nightshade) is clearly on shown in Fig 3 to be declining. Further results from Figure 3 showed that the year 2020 marked the lowest maize yield in a ten-year history of its production in Nyando Sub-county. For the case of maize, the decline in production over the years was attributed to the changes in rainfall variability that affected different parts of the country. Prolonged droughts and unpredictable rainfall patterns affected most farmers particularly in the year 2020. The results also indicated that most household were unable to realize steady maize production like in the year 2013. The change in rainfall duration during the weeks made farmers to abandon food crop production since they made massive losses. An interview from FGDs, one of the respondents revealed;

> "I cannot imagine the pain that I have underwent when my only source of livelihood is no longer important. I recall my bumper harvest in the year 2017 when I harvested close to 20 bags of maize on the same farm that now cannot produce even 5 bags of maize in the year 2020. We have now to resort to other drought tolerant crops like sorghum even though we are not used to these crops. My children don't like it at all".

These sentiments confirmed that indeed maize production had a massive decline in the year 2020. Just like the views shared above, other farmers also attributed the decline in maize production to the changes in rainfall amounts. However, most of them could not explain the cause of such variation which was due to global warming that caused rainfall variability. As such, most farmers were forced to venture into drought tolerant crops farming which are not staple among the households.

Beans maintained a low yield of less than 7.5bags for the entire period with 2022 revealing the lowest yield. From the findings, bean crop was massively affected by rainfall variability leading to the reduced yields over the years. The reduction in the weekly rainfall totals affected different varieties of beans such as *nyayo* and *rosecoco* bean. Despite the fact that beans require low rainfall compared to maize, amount of rainfall experienced in 2022 was insufficient for optimal yield of the crop. Most bean crop withered and some were attacked by pests and diseases that thrived well in dry conditions leading to the drop in yields. Therefore, the sharp decline in bean production in 2022 was caused by severe and prolonged drought that ravaged most parts of the country affecting both crops and livestock.

The results further indicated that the African Nightshade production showed a steady increase from 2013-2015 with a slowdown in 2016. However, it gained steadily up to 2020 with a sudden decline in between 2021 to 2022. Between the year 2016 and 2019, there was sufficient rainfall for the production of vegetables such as the African nightshade. The timely arrival of rainfall led to sufficient rains for the African nightshade that had been planted earlier. This highly contributed to the increase in the crop yield. Moreover, there was enough soil moisture that was ideal for growing of the African nightshade hence the rise in the production. However, the 2022 drought also affected the African nightshade just like maize and beans during the same period. The black cotton soil within the study area dried up quickly during the low rainfall seasons in 2022 which led to wilting of the vegetable and eventually leading to its drying up. It was therefore evident that change in rainfall duration, magnitude and timing affected the production of African nightshade just like other crops.

The results on maize fluctuation identified with findings by Ondieki (2019) who showed that the changes in rainfall patterns greatly affected maize production in Siaya County. He noted that most farms under maize cultivation withered at week 4 due to rainfall insufficiency. The findings of Mogaka (2006) on climate variability on resource degradation argued that most crops are weather and climate dependent, therefore, weather variability is responsible for the changes in their yields. Mati (2010) also agreed that rainfall variability has ravaged different parts of the country which has contributed to loss of vital food crops. He argued that mean average rainfall received between 2009 and 2017 was not sufficient for the production maize crop. He also asserted that reduction of rainfall during the maize growing period led to the emergence of pests that destroy the maize crop leading to the decline in production.

4.2.7 Yearly Variation of Rainfall Durations, Magnitude and Timing

From the findings, it was evident that rainfall duration had been steadily declining from 2013 to 2022. Being the year that most parts of the country experienced prolonged droughts, the weekly rainfall reduced greatly in 2020 thus affecting a number of farming activities. This reduction in rainfall duration resulted in most farms drying up leading to the reduced production of maize, beans and African nightshade. The mean average annual rainfall magnitudes had been low and unpredictable in the study area. The millimeter per hour of rainfall reduced over the years which affected the production of maize, beans and African nightshade (Figure 4).

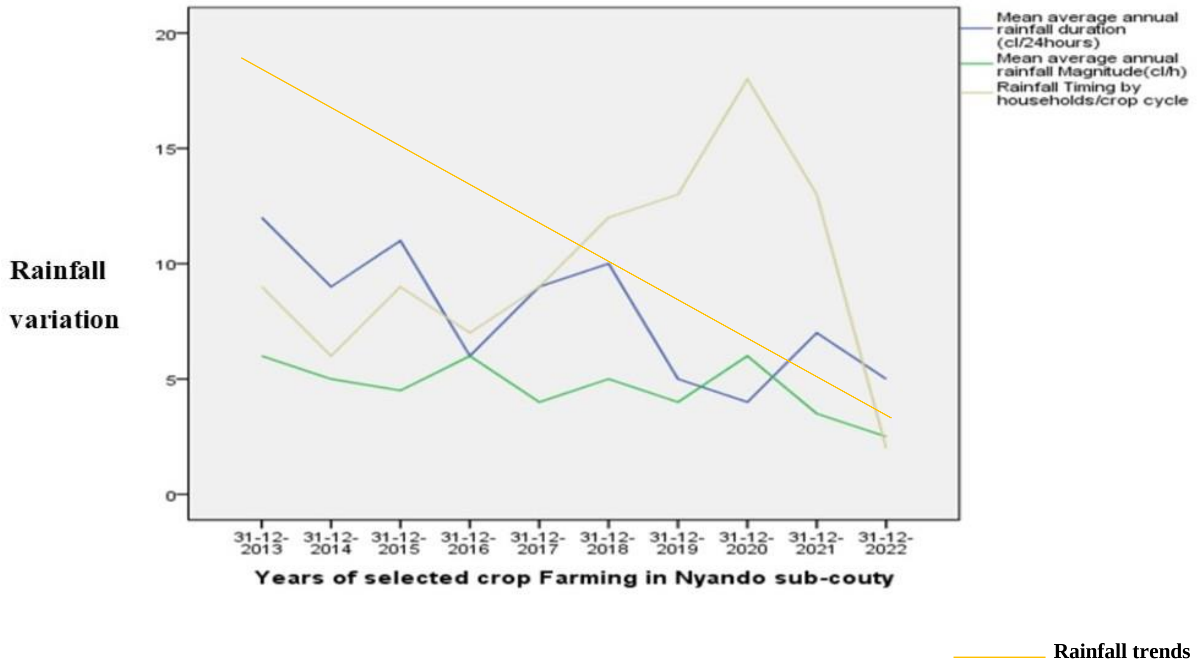

Figure 4: Yearly Variability of Rainfall Durations, Magnitude and Timing.

Source: KMD Data, (2022)

From Figure 4, the yearly variation of rainfall (magnitude, duration and timing) is on the downward trend from 2013 to 2022. It is evident from the results in Figure 4 that there was reduction of hourly rainfall in 2013 from 70mm/hour to 25mm/hour in 2022. This reduction affected the production of maize greatly since it required more rainfall magnitude than beans and African nightshade. The rainfall timing by the households was initially erratic from 2013 to 2018 which affected the crop yields. From 2019 to 2020, the farmers seemed to have optimized on rainfall timing and were able to increase the food crop production since the three crops were grown when the rainfall sufficient. Most farmers failed to predict the weather patterns in the year 2022 just like most parts of Africa that were affected by prolonged droughts. The failure amongst the farmers to predict the onset of rainfall delayed planting of maize, beans and African nightshade therefore leading to decline in their production. Mati (2010) agreed that rainfall duration, magnitude and timing have varied over the years, a fact that he says affects the production of various crops. This variability in rainfall is attributed to global warming due to increase of greenhouse gases in the upper atmosphere thereby altering the hydrological cycle. The anthropogenic global warming theory explained the effects of global warming on the rainfall amounts experienced in different parts of the world affected the food crop production. The findings of Ker (2009) agreed with the current study which asserted that the change in rainfall duration has led to the reduction in the yields of crops among the farmers who rely on rain-fed agriculture.

4.3 Effect of Duration of Rainfall on Maize, Beans and African Nightshade Production

This objective sought to establish the effect of duration of rainfall on the production of maize, beans and African nightshade in Nyando Sub County. Descriptive analysis was conducted to bring out the number of households that engaged in food crop production, the type of food crops grown, the acreage under each crop and the trends of yields of the crops from 2019 and 2022. These results were presented in Table 3.

Table 3: Duration of Rainfall on Production of Maize, Beans and African Nightshade.

Respondents engaged in crop farming	**Food crop Grown**	**Cultivation of Maize, Beans, and Nightshade**	**Average Acreage**	**Crop Yield 2019-2022**	**Crops by land Size per Acreage**
N 384 **No 22** **Yes 362**	N 384 Maize 248 Beans 96 Vegetables30 Sorghum 10	N 384 Yes 159 No 225	1.82	Maize 25 Bags Beans 11.5 Bags Nightshade320kg	Maize 1.54 acre Beans 0.87 acre Nightshade 0.48 acre

Source: Field Data (2022)

The results in Table 3 indicated that the majority of the respondents (94%) were involved in crop production within the sub county. Maize crop was the most popular amongst the households (248) followed by beans (96) while vegetables and sorghum stood were (30) and (10) respectively. The average crop yield from 2019-2020 were; maize-25bags, beans-11.5bags and African nightshade 320 kg per household. The mean land size per households was 1.82 acres. As such, maize occupied an average of 1.54 acres, beans 0.87 acre while night shades took 0.48 acres of the household's agricultural land.

The findings therefore established that the majority of the household heads were engaged in agricultural production. This was attributed to the fact farming is the major source of income due to great unemployment in the rural areas. The household heads were engaged in the production of different crops (maize, beans, sorghum and vegetables), however maize was the most grown crop since it occupied the largest acreage (1.54). This was due to the fact that maize was staple among the households. Other crops were grown alongside maize to spread the risk of having insufficient maize harvest to continue providing food to the households. The crop yields from 2019 to 2022 were insufficient to support the large households with the year 2022 having the peak of food shortage. Most households became food insecure and could not afford the normal meals like the previous years as most of them resorted rice consumption which was considered a 'light meal' according to most respondents. The reduced yields was attributed to changes in rainfall patterns which made it difficult for the production of such crops since farming is purely rain-fed.

The study findings agreed with that of Arunga et al (2012) which asserted that maize and beans being staple food was preferred by most farmers in Kenya. He argued that most Kenyan households preferred eating maize in form of *ugali* or *githeri* at least two meals a day. This increased the production of these two crops in different parts of the country. The study of Kaguongo et al (2013) also agreed that maize forms one of the staple foods among the Kenyan households and any change in its production massively contributed to food insecurity. Bouman (2009)'s findings also agreed with the current study that the majority of African households value maize and beans therefore the changes caused by climate variability increased the level of hunger among the people.

Further analysis was done to establish the effect of rainfall duration on maize, beans and African nightshade yields during the short and long rains. This was done by ascertaining the harvest of the crops during short and long rains, weeks of rainfall and the changes in rainfall duration. The household heads perception on rainfall sufficiency was generated and presented in Table 4.

Table 4: Yields of Maize, Beans and African nightshade During the Short and Long Rains and the Perception of Farmers on Rainfall Sufficiency.

Harvest During long rains	**Weeks of long rain**	**Weeks of short rains**	**Harvest during short rains**	**Change in rainfall Duration**	**Perception of rainfall sufficiency**
Maize 9.00 Bags/acre Beans 4.00 Bags/acre Nightshade100kg/acre	10.89	6.63	Maize 4.26 Bags/acre Beans 4.65 Bags/acre Nightshade 174kg/acre	Increasing 20 Decreasing 355 Constant 9	Yes 378 No 4 Undecided 2

Source: Field data, 2022

The results from Table 4 shows that the harvests during long rains were as follows; Maize 9.00 bags/acre, Beans 4.00 bags/acre and African Nightshade 100kg/acre. On average the long rain went for about 10.89 weeks for the months of March to May while the short rains lasted for at least 6.63 weeks for the months of October to November. The harvests for short rains were Maize 4.26 bags/acre, Beans 4.65 bags/acre and Night shades was 174kg/acre. Further, farmers were asked about their perception on whether the rains were sufficient for the production of maize, beans and African nightshade during the long and short rains. In response, the majority of the respondent (98.4%) indicated that the rainfall duration had decreased during both seasons over the years.

The majority of the female farmers attributed the decrease in crop yields to the changes in weather conditions during the short and long rains seasons. Unlike the male counterparts who engaged in cash crop farming and therefore experience minimal effects of rainfall variations, the female farmers were vast with instances with short and long rain variations. This was also confirmed by an interview from Key informant and revealed;

> "Over the years we have experienced a decline in the duration of rainfall in this place, both during the long and short rains. I think this is because weather has changed a lot leading to little rainfall. We have tried to adopt some crop varieties that mature before the rain stop but still we still have insufficient harvests. The decreasing rainfall has greatly affected maize production, however, it has been favorable for indigenous vegetables"

From the excerpt above, it is evident that the farmers were aware that rainfall duration had decreased and caused decline in maize production during the short rains. However, the short rain duration to them favored growing of vegetables. When probed further, they said that they did not understand the cause of variability of rainfall duration, which is a global problem due to climate variability. They further confirmed that the rains may not have been sufficient for optimal production of maize, beans and African nightshade.

The results of the study agreed with findings Owino (2008) that observed that rainfall was insufficient for the production of most food crops within Nyando area. He also asserted that reduced rainfall duration affected maize and beans greatly but the drought resistant vegetable farmers such as African nightshade had positive fluctuations. Omondi (2018) on the other hand argued that, despite the reduced rainfall durations, the residents of the Sub-county agriculturally rely on the flash flood from the neighboring Nandi County. This has sustained many households in terms of food availability. The results on maize and beans is a similar to the findings by Jalloh et al (2013) who observed more maize and beans productions among the farmers in Gem Sub County, Siaya County. He established that maize and beans are the staples among the Kenyan households who must at least consume these crops twice a day, thus the increase in production.

After establishing the crop yield during the short and long rains, a regression analysis was also conducted to determine the extent of relationship of rainfall duration on production of maize, beans and African nightshade. The results were presented in Table 5.

Table 5: Relationship between Duration of Rainfall on Maize, Beans and African Nightshade Production.

Model		df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.651	1	383	25.63	18.822	.001	384
Bean Yield(bags/acre/annum)	.474	1	383	20.42	-6.035	.001	384
Nightshade(kg/acre/annum	.382	1	383	19.41	-8.049	.001	384

Source: Field data (2022)

Results on Table 5 indicated that there was significant relationship between rainfall duration and maize yield [F (383) =25.63, P < .001, R^2 =. 651] as illustrated in Table 5. Beans yield [F (383) =20.42, P < .001, R^2 = .474], and African Nightshade Yield [F (383) =19.41, P < .001, R^2 = .382]. About 65% of the variation in maize yield could be explained by change in rainfall duration, 47.4% of beans yield was affected by variability in rainfall duration, while 38.2% change in African Nightshade harvest was possibly affected by changes in rainfall duration. From the analysis of the model it was established that maize had significant positive linear association (t = 18.82, p < .001), Beans and Nightshade revealed a significant negative linear relationship (t = -6.04, p < .001), and (t = -8.05, p < .001) respectively. Maize yield showed significant positive linear slope (t=18.82) with mean annual rainfall duration. This is because increase in rainfall production led to increase in maize production. Beans and African Nightshade showed a negative positive linear relationship slope of (t=-6.04) and (t=-8.05) with rainfall duration. This is because more rainfall duration led to more surface run causing these cover crops to wither out.

The above findings justified that there was relationship between of rainfall duration and the production of maize, beans and African nightshade. The study established that rainfall duration was good for the maize production since the long weeks of rainfall increased the maize yields by 65%. During the long rains, the black cotton soil in the area absorbed enough water which was sufficient for the maturity of maize with the growth cycle. The longer rainfall duration did not have severe effect on maize crop since the crop mature faster thus passed the level of getting withered with excess water. The longer weeks of rainfall increased the surface run off which caused water logging of the farms thus affecting beans and African nightshade production which are cover crops. As much as long rainfall duration caused decline in production of beans and African nightshade, the diseases caused by water stagnation on the farms affected these crops greatly. Since the crops are leguminous, the stagnated waters made the crops to be more susceptible to diseases such as root rot leading to the crops' failure. The farmers who had practiced farming in the study area for the longest time (11-15 years) also confirmed that increase in the number of days of rainfall contributed to more water logging in the farms. The stagnation of water in the farms affected cover crops like beans and African nightshade since they become submerged leading of their destruction. This lowered the yields during the long rain duration.

From the findings, maize production increased with escalation in rainfall duration contradicted the findings of by Abukutsa (2010) in Uasin Gishu which reported a reduction on maize yield as a result of increase in rainfall duration. This is because Nyando is a hot and dry agro-ecological zone therefore longer rainfall durations result in increased maize production. Uasin Gishu on the other hand, is a high altitude agro-ecological zone which receives high rainfall that results into rooting of maize on the farms before they are harvested. Both beans and the African nightshade showed a negative trend with reduced rainfall duration, this is because beans require moderate short rains for optimal yields while Nightshade is a drought resistant crop (Owino 2008). Both beans and the nightshade yields depicted the findings by Oseni & Masarirambi (2011) that noticed a reduction in yield as a result of change in rainfall duration. He argued that reduced rainfall duration led to reduction in the moisture content in the soil thus causing the vegetables to dry in the farms.

A linear regression was carried out to examine the effect duration of rainfall during the long and the short rains to establish the variation that there would be in the amounts of yields during the two rainy seasons. Results on the statistical relationship between the variables were presented in Table 6.

Table 6: Effect of Rainfall Duration on Production of Maize, Beans and African Nightshade Production during Long Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.663	1	383	24.34	18.877	.042	384
Bean Yield(bags/acre/annum)	.436	1	383	18.33	-3.035	.037	384
Nightshade(kg/acre/annum	.335	1	383	13.96	-4.049	.011	384

Source: Field data (2022)

Results on Table 6 indicated that there was significant statistical effect between rainfall duration during the long rainy season and maize yield [F (383) =24.34, P < .001, R^2 = 663], Beans yield [F (383) =18.33, P < .001, R^2 =. 436], and African Nightshade Yield [F (383) =13.96, P < .001, R^2 = .335]. Further analysis of the model showed that maize had significant positive linear association (t = 18.87, p < .001), Beans, and Nightshade revealed a significant negative linear relationship (t = -3.04, p < .001), and (t = -4.05, p < .001) respectively. About

66% of the variation in maize yield could be explained by change in rainfall duration during long rains seasons, 43.6% of beans yield was affected by variability in rainfall duration, while 33.5% change in Nightshade harvest was possibly affected by changes in long rainfall duration.

The results indicated that maize yields had a statistical significant positive linear correlation (66%). The long rainfall duration that lasted for about 10 weeks was enough for the growing of maize. Most farmers therefore optimized the production of maize during the long rains since the crops got enough moisture for their maturity. However, with the crops that required low rainfall duration like beans and African nightshade, the long rains affected their production. Bean crop was affected by excessive rainfall which leached the soil thus interfering with nutrients. The increase in number of pests caused by more rainfall duration also affected production of beans. On the other hand, the African nightshade production also reduced since the excess rainfall encouraged thriving of certain diseases thus lowering the yield. Moreover, as a drought resistant crop, most farmers prioritized growing of maize during the long rains hence the decline in the African nightshade production.

The results on maize disagreed with the findings in Kisii County by Oseni & Masarirambi (2011) which reported a reduction on maize yield as a result of increase in rainfall duration. This is because Kisii is a highland which receives high rainfall. However, increase in rainfall duration resulted in abnormal growth of maize crop without necessarily giving the expected outcome. Nyando is a hot and dry agro-ecological zone therefore longer rainfall durations result in more maize production. A study by Owino (2008) agreed that both beans and most vegetables decreased in yields since surface run off flooded the farms thus destroying them. However he argued that for optimal production of beans, there should be moderate rainfall. Similarly, the results on both beans and nightshade yields agreed with findings by Ogola et al

(2007) in Ugenya sub County, Siaya County who reported a significant change in the crop yields during long rainfall durations.

Also, the effect of rainfall duration on maize, beans and African nightshade during the short rains was established through a linear regression analysis and the results were presented in Table 7.

Table 7: Effect of Rainfall Duration on Production of Maize, Beans and African Nightshade during Short Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.441	1	383	15.17	-12.42	.019	384
Bean Yield(bags/acre/annum)	.416	1	383	10.40	5.03	.031	384
Nightshade(kg/acre/annum	.362	1	383	11.21	7.04	.056	384

Source: Field data (2022)

The results on Table 7 showed that there was significant effect of rainfall duration during rainy seasons and maize yield [F (383) =15.17 P < .001, R^2 = .44], Beans yield [F (383) =10.40, P < .001, R^2 =.42], and African Nightshade Yield [F (383) =11.21, P < .001, R^2 =.36]. Further analysis of the model showed that maize had significant negative linear association (t = -12.42, p < .001), Beans (Plate 1), and Nightshade revealed a significant positive linear relationship (t = 5.03, p < .001), and (t = 7.04, p < .001) respectively. In predicting how the short rains affected the yield of maize, beans and night shade, a linear regression model was used. The model was found essential because it significantly predicted the relationship between the independent and the dependent variables: Maize (44%) showed a negative relationship with short rains, both beans (41%) and night shade (36%) revealed positive relationship with the short rains.

The findings showed that the decline in rainfall duration led to a drop in the production of maize. The maize crop required more weeks of rainfall to allow the crop attain it best yield. In most cases, the best harvest for maize are experienced when maize got enough soil moisture due to longer weeks of rainfall. The study showed that the duration (6weeks) that rainfall lasted was not adequate for growing maize and therefore the decline in production. During planting and 3 weeks after planting, there was enough rainfall that enabled maize to germinate and grow. However, the rains declined and eventually stopped at week 5 and 6 thus resulting in drying up of the maize crop in the farms. Beans on the other hand, increased in production since the crop matured within 6 weeks that the rains lasted. Moreover, there was enough moisture in the soil that was sufficient for bean maturity unlike during the long rains which destroyed the crop. Most farmers therefore opted to grow pure bean crop during the short rains season to optimize the yields. The growing of pure bean crop in Ahero ward during the short rain duration was justified by the photograph in Plate 1. From the photograph below, it is evident that short rainfall duration was ideal for beans growing which prompted most household heads to concentrate on pure beans growing. Since short rainfall duration led to massive maize crop failure, it was therefore ideal for farmers to maximize pure bean production to reduce more climate related losses.

Plate 1: Pure Beans Farm in Ahero Ward, Nyando Sub County (Taken on 09/05/22)

Source: Field Data, 2022.

Also as a demand driven crop, most African nightshade farmers took advantage of the short rainfall season to optimize the yield for subsistence use as well as selling the surplus. The vegetable matured under low rainfall duration therefore most farmers preferred to grow it during the short durations. In the FGDs, one of the respondents revealed;

> "I have witnessed changes in the numbers of days in a week that we experience rainfall. In a week we can receive rainfall once and some weeks we go even without rainfall. However, I have opted to plant the African nightshade during the low rainfall duration since it a drought resistant crop and sometimes I irrigate the crop. Secondly, it is a demand driven crop especially during the dry season when most households have no any other vegetable to feed on".

From the excerpt, it is evident that African nightshade was grown during the short rainfall duration due to its tolerance to dry conditions as well high demand during the dry season. However, the farmers had not fully incorporated irrigation farming during the short rainfall duration since it was a very expensive venture among the resource poor farmers.

The results on maize concurred with the findings in Uasin Gishu by Abukutsa (2010) which reported a reduction on maize yield as a result of increase in rainfall amounts. This is because Nyando is a hot and dry agro-ecological zone therefore longer rainfall durations resulted to more maize production. Uasin Gishu being a highland area receives more rainfall results in excessive growth of maize with little yield thus the decline in production. Both beans and the African nightshade showed a negative trend with rainfall duration, this is because beans require moderate short rains for optimal yields while Nightshade is a drought resistant crop. However, the study conducted by Krol &Bronstert (2007) in Southern Brazil on effects of climate change on maize production agreed with the findings of the study that rainfall variability was majorly caused by the global climate change. They established that changes in rainfall patterns such as duration, magnitude and timing have led to a decline in crop production. The study by Seo &Mendelsohn (2008) that was conducted in Hebei province in China on rainfall trends and household food security agreed with the current study. Their findings asserted that change in rainfall patterns lowers the crop yields. As much as these studies focused on changes in rainfall trends, patterns as well as climate change on food crop production, they did not document on the effect of rainfall variability on food crop production. This gap was bridged by the current study.

4.4. Effect of Rainfall Magnitude on Maize, Beans and African Nightshade Production

This objective established the effect of rainfall magnitude on the production of maize, beans and African nightshade in Nyando Sub County. An elaborate analysis was conducted to show hourly variation of rainfall on crop production trends during the low and high rainfall concentrations and expected yields during the low and high rainfall magnitude. The result further established the perception of respondents on fluctuation effect of rainfall on maize, beans and African nightshade production, the crop production trend and expected yields during short and long rains. The results were presented in Table 8.

Table 8: Magnitude of Rainfall Beans, Maize and African Nightshade Production.

Fluctuation effect of rainfall/hour on maize, beans and Nightshade	**The crop production trends(2019-2022)**	**Expected crop yield (90Kg bag) with high rainfall magnitude**	**Expected crop yield with low rainfall magnitude**
No 146 **Yes 228** **Undecided 10**	Maize Increasing 100 Decreasing 240 Constant 40 Undecided 4 Beans Increasing 180 Decreasing 164 Constant 38 Undecided 2 Nightshade Increasing 225 Decreasing 66 Constant 34 Undecided 59	1-10) 85 1-5) 94 5-15) 201 Others) 4	1-10) 72 1-5) 191 5-15) 11 Others) 110

Source: Field data 202

The results from Table 8 showed that most respondents (240) observed that maize production was on the decline between 2019 and 2022. The hourly rainfall received was insufficient for growing of maize as most farms dried because of minimal soil moisture. Moreover, the respondents recognized the great decline in the amount of rainfall witnessed in the area that almost made them abandon maize production. Conversely, 180 respondents agreed that beans production was on the rise during the same time period. This was due to the fact beans required low amount of rainfall and reduced millimeters per hour of rainfall was enough for positive fluctuation of its production. Majority (228) respondents agreed that rainfall fluctuations affected the yield of African night shade. When asked whether the vegetable required a lot of rainfall, most respondents agreed that African night shade never required high rainfall intensity. This therefore confirms the positive rise in African nightshade production despite the reduced rainfall intensity. The modal crop yield expected by most of the households was 5-15 bags. These amount of yields of African nightshade was reasonable to the households as it met their home consumption as well as selling the surplus.

Further analysis was done to determine the number of hours of long and short rains, the respondents' perception on whether there are long hours of rainfall or not. The views of the respondents were also established to know the hourly decline in rainfall as well as the effect of such decline on the selected crop yields. The results were presented in Table 9.

Table 9: Data of Magnitude on Rainfall Maize, Beans and African Nightshade Production.

Long rain hours	**Short rain hours**	**Long rainfall hours and surface runoff**	**Surface runoff effect**	**Hourly rainfall declines and crop yield**	**Effect of Increase in hours of rainfall on crop yield**
0.75	0.54	Yes 306 No 63 Undecided 15	Maize 114 Beans 251 Nightshade 10 Undecided 1	Yes 179 No 156 Undecided 49	Yes 205 No 172 Undecided 7

Source: Field data 2022

Results from Table 9 indicated that most households expected to harvest between 1-5 bags of crops with lower magnitude of rainfall. The data provided from the meteorological department showed that millimeter per hour of rainfall had drastically reduced. For instance, the seasonal average rainfall hours were 0.75 while the short rains reported 0.54. When probed on their perception about the rainfall concentration, majority of the respondents that there was significant reduction on rainfall concentration in the study area. The respondents (306) further agreed that longer rainfall hours contributed massively to surface runoff (higher rainfall concentration), 63 respondents were in disagreement while 15 respondents remained undecided. By perception, bean and African night shade crops were greatly affected by surface runoff unlike maize crop. The females (62%) had a greater feeling on the decline of rainfall magnitude than the males (38%). This is because the females were more engaged in food crop production than males thus were more susceptible to decrease in rainfall magnitude. The respondents generally felt that more rainfall magnitude was the reason for positive increase in maize production. However, leguminous crops like beans were affected by more rainfall which led to stagnation of water on the farms thus withering of bean crop.

From the findings, hourly rainfall is perceived to be reducing among the many respondents (228) which affected the production of the three crops. Most household heads (42.4%) who had practiced food crop farming for a long time (11-15 years) had a better idea on the change in rainfall magnitude in the area. They generally perceived the millimeter per hour of rainfall to be decreasing thus affecting food crop production. Further, the respondents agreed that the decline in maize production was attributed to the change in millimeter per hour of rainfall. The respondents' perception on hourly rainfall amount was confirmed by the data provided by the meteorological department. Information provided by the Meteorological department Kisumu showed that in 2022 the hourly rainfall reduced from 70mm/hour to 35mm/hour. This confirmed that there was a significant reduction on millimeter per hour of rainfall within the study area. As a crop that require high rainfall concentration, maize declined due to insufficient rainfall for optimal yield. Despite the negative influence on maize production, the reduced rainfall magnitude led to positive fluctuations in beans production since the farms had sufficient moisture for bean growing. The African nightshade was the greatest beneficiary of reduced rainfall magnitude as it required least rainfall magnitude among the three crops. Most the married respondents (43.4%) agreed that reduced rainfall hours was great for the maximum maturity of African nightshade since it is a drought tolerant crop. However the single (10.4%) and widowed (31.4%) didn't believe that reduced rainfall hours could increase African nightshade. They believed that during the low rainfall magnitude, farms were abandoned and they would only wait to be engaged in crop production during the rainy season. Therefore, they had little knowledge on vegetables production during low rains.

4.4.1 Rainfall Magnitude (mm/h) and the yields of Maize, Beans and African Nightshade.

Linear regression analysis was conducted to determine the extent of relationship that the rainfall magnitude had on the production of maize, beans and African nightshade as shown in Table 10.

Table 10: Relationship between Rainfall Magnitude on Maize, Beans and African Nightshade Production.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.435	1	383	13.68	15.853	.000	384
Bean Yield(bags/acre/annum)	.376	1	383	21.24	-5.035	.000	384
Nightshade(kg/acre/annum	.337	1	383	14.45	-7.049	.000	384

Source: Field data 2022

Simple linear regression analysis from Table 10 indicated that there was significant effect between rainfall magnitude and maize yield [F (383) =13.68, P < .001, R^2 =.44], Beans yield [F (383) =21.24, P < .001, R^2 =.38], and African Nightshade Yield [F (383) =14.45, P < .001, R^2 =.34]. Further analysis of the model showed that maize had significant positive linear association (t = 15.85, p < .001), Beans and Nightshade revealed a significant negative linear relationship (t =-5.035, p < .001), and (t = -7.05, p < .001) respectively. About 44% of the variation in maize yield could be explained by change in rainfall magnitude, 38% of beans yield was affected by variability in rainfall magnitude, while 34% of change in Nightshade harvest was possibly affected by changes in rainfall magnitude.

The findings established that increase in millimeter per hour of rainfall had a positive influence on maize production. Increase in hours of rainfall influenced quality of cross pollination, reduced cases of pests and diseases as well as improving the overall maize plant yield. The information from the ministry of agriculture showed that the 25-30 inches of rainfall during the long rains increased the maize yields in the study area. However, beans and African nightshade showed a negative relationship with the increased hourly rainfall experienced. This is due to increase in the surface run off that caused logging of the farms thus affecting beans and African nightshade production. The increase in rainfall magnitude affected the bean flowering period thus hindering effective maturity of the crop. African nightshade was greatly affected by increase in millimeter per hour of rainfall since it requires 11 inches of rainfall. However, during high rainfall magnitude the 35 inches of rainfall experienced caused rotting of the vegetables.

The results on maize failed to identify with the findings in Trans Nzoia by Edmonds & Chweya (2018) which reported a reduction on maize yield as a result of increase in rainfall magnitude.

This is because the maize variety grown in Nyando is different as well as the ecological requirements therefore greater rainfall magnitude influenced maize production in the case of Nyando sub-county. The results on African nightshade agreed with findings of Shackleton, (2009) who reported a reduction of beans production due to excess rainfall. His findings pointed out that excess rainfall leaches the top nutrient as well as killing nitrogen fixing bacteria for beans thus the decline. Results on African nightshade agree with that of Ogola et al (2007) that reported an increase in the hours of rainfall lead to early blight disease that lowers the crop yield.

The study went ahead to establish the correlation between the millimeter per hour of rainfall on the production of maize, beans and African nightshade during the long rains. This was done by the use of simple liner regression analysis to establish the extent of relationship between rainfall magnitude and the production of the selected crops during the long rains as shown in Table 11.

Table 11: Relationship between Magnitude of rainfall on Maize, Beans and African Nightshade Production during Long Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.378	1	383	22.31	13.641	.000	384
Bean Yield(bags/acre/annum)	.286	1	383	18.34	-3.325	.000	384
Nightshade(kg/acre/annum	.244	1	383	16.41	-2.347	.000	384

Source: Field data 2022

Simple linear regression analysis from Table 11 indicated that there was significant effect between rainfall magnitude (long rains) and maize yield [F (383) =22.31, $P < .001$, $R^2 = .38$], Beans yield [F (383) =18.34, $P < .001$, $R^2 = .29$], and African Nightshade Yield [F (383) =16.41, $P < .001$, $R^2 = .24$]. Further analysis of the model showed that maize had significant positive linear association ($t = 13.6$, $p < .001$), Beans, and Nightshade revealed a significant negative linear relationship ($t = -3.33$, $p < .001$), and ($t = -2.35$, $p < .001$) respectively. About 38% of the variation in maize yield could be explained by change in rainfall magnitude during long rains season, 29% of beans yield was affected by variability in rainfall magnitude, while 24% of change in Nightshade harvest was possibly affected by changes in rainfall magnitude in long rains seasons.

The findings showed that an increase in the hours of rainfall during the long rain season was good for maize production. This is because the soils had enough moisture that was sufficient for maize maturity. Beans and African nightshade were negatively affected by the increase in millimeter per hour rainfall. The 29% variation of bean yield during the long rains was due to oversaturation of water in the soil which minimized the soil nutrients for optimal harvest. Moreover, most of the respondents confirmed that during the long rains most farmers engage in production of numerous crops thus giving little attention to bean crop. This was confirmed from an interview with a key informant who revealed;

> "The increase in the number of hours of rainfall attract growing of very many crops. Personally, I grow maize, beans, water melon, kales, onions and spinach during the long rains. Watermelon, spinach and kales are on higher demand and fetch higher prices that is why I concentrate more on them than beans. Secondly, the more hours of rainfall attract certain disease that causes several holes on bean crop. This has made me not concentrate on beans production during the long rain cycle".

From the excerpt, it is evident that increase in hours of rainfall affected bean production negatively. The high rainfall concentration led to many diseases thus lowering the yield. Secondly, the high demand for other crops made farmers to grow other crops in large scale and giving little concentration on beans growing. This therefore confirmed the decline in beans production during the long rains.

On the other hand, the 24% of the African nightshade was due the trend of decline of the crop yield during the long rains. Just like beans, the increase in hours of rainfall led to more stagnation of water that forced the African nightshade crop to wither. Secondly, the surface run off also carried away the soil nutrients thus lowering the quality of the crop. This therefore explained the reason for decline in production of African nightshade during the long rains. With such variations in beans and African nightshade production, farmers opted to capitalize on maize production during the long rains.

The results on maize differed with the findings in Bahati Sub County by Edmonds & Chweya, (2018) which reported a reduction on maize yield as a result of change in the amount of hourly rainfall received. This is because other than rainfall magnitude, maize production is influenced by other factors such as altitude, soil type, and temperature. The results by Omondi (2018), on beans are consistent with the findings of the current study which stated that more rainfall magnitude causes decline in beans production. This is because beans unlike maize crop is generally treated as a supplement hence given a low consideration at planting thus the reduction in production. The findings by Leal et al (2015) also agree with the current study that the decline of African Nightshade was due to overemphasis of maize growing during the rainy season as compared to the vegetable.

4.4.2 Effect of Rainfall Magnitude (mm/h) and the yields of Maize, Beans and African Nightshade during Short Rains Season.

Besides the effect of magnitude of rainfall during the long rains, the study also established the effect of rainfall magnitude on the selected crops production during the short rains. This was done to know the extent at which the change in rainfall magnitude affects these crops in different seasons (short and long rains). The results were presented in Table 12.

Table 12: Relationship between Rainfall Magnitude on Maize, Beans and African Nightshade Production during Short Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.583	1	383	27.32	-15.224	.000	384
Bean Yield(bags/acre/annum)	.392	1	383	21.27	4.115	.000	384
Nightshade(kg/acre/annum	.464	1	383	18.24	3.034	.000	384

Source: Field data 2022

Simple linear regression analysis from Table 12 showed that there was significant effect between rainfall magnitude during short rains and maize yield [F (383) =27.32, P < .001, R^2 =.58] as portrayed in Figure 6. Beans yield [F (383) =21.27, P < .001, R^2 = .39], and African Nightshade Yield [F (383) =29.68, P < .001, R^2 =.46]. Further analysis of the model showed that maize had significant negative linear association (t = -15.22, p < .001), Beans, and Nightshade revealed a significant positive linear relationship (t =4.12, p < .001), and (t=3.034, p < .001) respectively. About 58% of the variation in maize yield was explained by change rainfall magnitude during short rains season, 39% of beans yield was affected by variability in Rainfall magnitude, while 46% of change in Nightshade harvest was possibly affected by changes in rainfall magnitude in short rains seasons.

There was a weak positive linear relationship between maize yields and rainfall magnitude (mm/h) during the short rain season in Nyando Sub-county. This is because reduced millimeters per hour of rainfall during the short rains were insufficient for growing of maize. As a crop that require at least 40mm/hour of rainfall during the short rains. However, the 20mm/ hour of rainfall was little for maize production thus the decline. With the reduced hours of rainfall, the soil moisture depreciated leading to failure of most maize crops. The photograph in Plate 2 shows the extent of reduced rainfall magnitude leading to the failure in maize crop production. From the photograph below, it was clear that the millimeter per hour of rainfall was insufficient to sustain maize production. As such, most maize crops failed to attain maximum maturity.

Plate 2: A failed Maize Crop in East Kano, Nyando Sub-County (Taken on 20/09/22)

Source: Field data 2022

Beans and African Nightshade performed positively with short rain season's rainfall magnitude. The 30mm/hour of rainfall received during the short rains was sufficient for the maturity of beans and African nightshade. The *Nyota bean* variety, was famous among the farmers since it required less rainfall compared to *rosecoco bean* that did well during long rain season. The *black nightshade* which is a type of African nightshade increased in the yields since it is drought tolerant.

The findings agree with Edmonds & Chweya, (2018) that established that reduced millimeter per hour of rainfall affects the soil moisture thus reducing maize yield. Furthermore, the results on maize (Plate 2) showed agree with the findings in Nakuru West Sub County by Kgathi et al (2006) which reported a decrease in maize yield as a result of decline in rainfall magnitude.

Similar sentiments were shared by a Key Informant attached to Ministry of Agriculture at Nyando Sub County revealed;

> "Even though maize can withstand excess water for a short period, the crop is adversely affected by the drought. Due to the few hours that rainfall is experienced, the soils become dry making crops such as maize crop to dry up. However some vegetables can be harvested since they are not majorly affected with reduced hours of rainfall."

The results on beans and African nightshade agreed with the findings of Omondi (2018) that indicated that the 30mm/hour was enough for the production of vegetables. The results from Owino (2008) and Ooko et al (2015) agreed with the findings of the current study that reported increase in drought tolerant vegetables with decrease in rainfall magnitude. Their studies reported that reduced rainfall hours prompted farmers to use irrigation in production. For instance, the high demand for vegetables during the dry season had greatly motivated farmers to use irrigation thus the positive fluctuation in African nightshade yields. The findings of Leal (2015) are in agreement of the current study that reported an increase in bean yield despite reduction in hourly rainfall. The current study established that beans took between 27 to 30 days to mature and this period was within the range at which the 20mm/hour of rainfall was received thus sufficient for bean yields.

4.5 Rainfall Timing on Maize, Beans and African Nightshade

This objective established the effect of rainfall timing on maize, beans and African nightshade production in Nyando Sub County. Descriptive analysis was conducted to ascertain farmers' perception on rainfall arrivals during short and long rains, the change in rainfall timing and the crop yields during the two seasons. Moreover, rainfall timing during short rains and long rains and the crop yields during the short and long rains were also obtained. These results were presented in Table 13.

Table 13: Data Summary of Rainfall Timing on Maize, Beans and African Nightshade Production.

Early arrival of long Rains	**Good short rains timing**	**Harvest in untimely Rainfall**	**Harvest in timely rainfall**
Yes 174 **No 203** **Undecided 7**	Yes 164 No 217 Undecided 3	Maize 7 Bags Beans 2.8 Bags Nightshade 285 Kg	Maize 12 Bags Beans 5 Bags Nightshade 350 Kg

Source: Field data 2022

The results in Table 13 established that the majority (203) of household heads agreed that early arrival of long rains was not good for general crop yield in the study area. It was noted that the female respondents (62%) had better timing on rainfall compared to male respondents (38%). This is because the females were more engaged in farming than male respondents and thus had better idea on the onset of short and long rains. Short rain timing was a challenge to majority of the respondents (217). The respondents with large households (3-4) had better rainfall timing than those with fewer households. The large households were in constant speculation on the onset of rains to allow them grow crops early enough to meet the family demands. With poor rainfall timing, the mean crop yield for Maize, beans and African nightshade were7 bags, 2.8bags and 285kg respectively. Such yields were not sufficient for large households and were forced to look for other alternatives to feed their families. With good rainfall timing, crop yields were 12bags, 5 bags and 350kg for maize, beans and African nightshade respectively per household. There was a general consensus by the majority of the respondents that onset of long rains had changed from 2020-2022 thus explaining the decline in crop yields within those years.

In addition, the respondents' perception on rainfall timing was established by the study. The study further established the perception of respondents on onset of rainfall during short and long rains and how it influenced selected crops from 2020 to 2022. Moreover, the respondents' opinion on whether they were considering other crops due to the change in rainfall onset was established. These results were presented in Table 14.

Table 14: Perception of Rainfall Timing on Maize, Beans and African Nightshade Production.

Change in onset of long rains (2020-2022)	**Change in onset of short rains (2020-2022)**	**if yields of the selected crops changed (2020-2022)**	**Consideration of other crops**	**General change in the arrival of rains (2020-2022)**
2020 [Yes 278], [No 111], [Undecided 1] **2021 [Yes 281], [No 96], [Undecided 7]** **2022 [Yes 308], [No 70], [Undecided 6]**	2020 [Yes 278], [No 111], [Undecided 1] 2021 [Yes 281], [No 96], [Undecided 7] 2022 [Yes 308], [No 70], [Undecided 6]	2020 [Yes 278], [No 111], [Undecided 1] 2021 [Yes 281], [No 96], [Undecided 7] 2022 [Yes 308], [No 70], [Undecided 6]	Yes 145 No 227 Undecided 12	Yes 181 No 143 Undecided 60

Source: Field data 2022

Results from Table 14 established the perception of household heads on the rainfall timing on maize, beans and African nightshade production. Most of the household heads observed that the yield of the selected crops changed between 2020 and 2022. This was due to the great drought that was witnessed in different parts of the world. It is believed that global warming led to changes in the rainfall pattern thus lowering the rainfall magnitude. This assertion is supported by Anthropogenic Global warming theory that explains how global warming led to reduced hours of rainfall. Because of such uncertainties in hours of rainfall, most respondents (227) confirmed that they were slowly shifting from rain-fed agriculture to irrigation to meet the crop yields like the previous years. On general change in the arrival of rains between 2020 and 2022 most respondents (181) were in agreement, 143 disagreed while the remaining respondents were undecided. The majority (47%) of respondents who agreed that onset of rains had changed were the female since they were much engaged in food crop production than males. The male respondents (37%) who disagreed on the rainfall arrivals were more involved in cash crop farming and therefore didn't pay keen attention on the short cycle rainfall arrivals.

4.5.1 Rainfall Timing and the yields of Maize, Beans and African Nightshade.

Information on rainfall timing and crop yields was obtained from the primary data sources and displayed using the simple linear regression. This was done to establish the relationship between rainfall timing on the selected food crops production. The results were presented in Table 15.

Table 15: Simple Linear Regression Analysis between Rainfall Timing Beans, Maize and African Nightshade Production.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.651	1	383	11.45	13.842	.000	384
Bean Yield(bags/acre/annum)	.474	1	383	16.08	-6.048	.000	384
Nightshade(kg/acre/annum	.382	1	383	8.73	-4.32	.000	384

Source: Field data 2022

Simple linear regression analysis in Table 15 indicated that there was significant effect between rainfall timing and maize yield [F (383) =11.45, $P < .001$, R^2 =.65], Beans yield [F (383) =16.08, $P < .001$, R^2 = .47], and African Nightshade Yield [F (383) =8.73, $P < .001$, R^2 = .38]. Further analysis of the model showed that maize had significant positive linear association (t =13.84, $p < .001$), Beans, and Nightshade revealed a significant negative linear relationship (t

= -6.05 p < .001), and (t = -4.32, p < .001) respectively. The simple linear regression result revealed that household who had good timing were likely to improve in good maize yield (65%).

The right rainfall timing positively influenced maize production since the crop had enough water within the raining period thus increasing the yield. Previously, most farmers had the challenge of predicting the onset of rains thus derailing growing of crops such as maize. However, with the right prediction, maize yield increased with good margin. Better rainfall timing also positively affected both beans and African night shade yield. Despite requiring low rainfall, good timings among the farmers was enough to encourage faster maturity these crops. Most respondents agreed that timely rainfall allowed for the seeds to germinate faster thus leading to timely maturity. As such, there was about 65% of the variation in maize yield could be explained by change rainfall timing. With the good timings, maize crop had the right amount of rainfall during the maturity period. The information provided from the department of agriculture showed that good rainfall timing enabled maize crop to attain at least 600mm of rainfall for optimal maturity. 47% of beans yield was affected by erratic rainfall timing. Most farmers failed to plant beans in time with the onset of rains which led to insufficient yields of the crop. The 38% change in Nightshade harvest was affected by changes in onset of rains. The change in the arrival of rainfall led to the reduction in the crop harvest since there was extreme water logging or drying of the farms.

The results on maize agreed with findings of McCann (2005) in Mpumalanga province in South Africa which reported an increase in maize yield due good rainfall timing. This is because the two areas of study have similar rainfall events. Mpumalanga province had experienced changes rainfall onset which affected crop yields same as Nyando Sub County. Therefore better rainfall timing improved maize yields within the study area. The findings of Owino (2008) also agreed that both beans and the African nightshade showed a negative trend with rainfall timing, this is because beans require moderate short rains for optimal yields while Nightshade is a drought resistant crop. Such similarities were again discovered by Edmonds & Chweya (2018) that established that in the yields of beans and nightshade which appreciated with good rainfall timing.

Also, linear regression was carried out to examine the effect timing of rainfall during the long and the short rains. This was done to establish the variation that there would be in the amounts of yields during the two rainy seasons. Results on the statistical relationship between the variables was analyzed and presented in Table 16.

Table 16: Effect of Rainfall Timing on Maize, Beans and African Nightshade Production during Long Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.582	1	383	23.21	12.663	.000	384
Bean Yield(bags/acre/annum)	.481	1	383	17.33	-5.332	.000	384
Nightshade(kg/acre/annum	.514	1	383	16.41	-7.518	.053	384

Source: Field data 2022

Simple linear regression analysis from Table 16 indicated that there was significant relationship between rainfall timing (long rains) and maize yield [F (383) =23.21, P < .001, R^2 =. 58], Beans yield [F (383) =17.33, P < .001, R^2 = .48], and African Nightshade Yield [F (383) =16.41, P < .001, R^2 =. 51]. Further analysis of the model showed that maize had significant positive linear association (t = 12.66, p < .001), Beans, and Nightshade revealed a significant negative linear relationship (t =-5.33 p < .001), and (t =-7.52, p < .001) respectively. About 58% of the variation in maize yield could be explained by change rainfall timing in long rains seasons, 48% of beans yield was affected by variability in rainfall timing during long rains, while 51% change in Nightshade harvest was possibly affected by changes in rainfall timing in long rains seasons.

Maize yield indicated a strong positive linear association with right rainfall timing for long crop cycle. This is because maize takes longer duration before it matures therefore proper timing allowed it to get enough rainfall with the growing period. Most respondents agreed that timing of the long rains was a challenge therefore, the few times that they managed to predict the onset of rainfall led to an increase in the maize yields. The female respondents (62%) had better timing on rainfall onset than the males (38%) since they were more involved in food crop production. The female respondents had a vast idea on the extent of rainfall variability thus had to try as hard as possible to predict rainfall arrivals. Also, beans and African Nightshade portrayed positive linear relationship for the same season. The beans and African nightshade crops were popular among the widowed respondents (31.4%) as they perceived the two crops to be less capital intensive. This finding was concretized by a response from a FGDs interview who revealed;

> "I have had a lot of challenges in food crop production like maize and a few other vegetables. My major challenge is coping up with the production of capital intensive maize crop. Some people would think that once the rains are there then maize grow automatically, however you must have good capital to help in land preparation as well as paying the workers in the farm. I am therefore forced to concentrate on beans and African nightshade production that require less capital".

As crops that require low rainfall, poor timing of rainfall had little impact on the yields therefore the reduction of yields would have less impact on their households. Beans and African nightshade takes at 6weeks before their maturity. As such, right rainfall timing led to increase of their yields.

The results on maize changed from the findings in Matabeleland, Zimbabwe by Williams &Kniveton (2011) which reported constant on maize yield as a result of good rainfall timing. This is because unlike Matabeleland which has longer rainfall distributions, Nyando has a relatively shorter rainfall distribution, therefore early rainfall timing ensured that the maize crops had enough moisture for their maturity. This led to increase in the maize yield due to good rainfall timing. The findings on beans differed with that of Leal et al (2015) that reported an increase in yields of beans as a result of predicting the onset of rains. The findings assert that right timing of rainfall ensured that beans matured within the rainfall weeks thus increasing the yields. However, in Nyando most respondents were found to be growing different varieties of beans that responded differently to rainfall timing. The negative trend shown by beans with rainfall timing was due to many bean types that were affected by early rainfall arrival. The findings of Edmonds & Chweya (2018), agreed that African nightshade yields increased with good rainfall timing during long rains seasons. This is because the vegetable takes shorter time (4weeks) for it mature. Therefore right rainfall timing increased its yield.

Further analysis was conducted on the effect of rainfall timing on maize, beans and African nightshade during the short rains. This was established through a linear regression analysis and the results were presented in Table 17.

Table 17: Effect of Rainfall Timing on Maize, Beans and African Nightshade Production during Short Rains.

Model	A R^2	df1	df2	F statistics	T	P-value	N
Maize Yield(bags/acre/annum)	.581	.65	383	22.68	10.74	.020	384
Bean Yield(bags/acre/annum)	.432	.47	383	11.74	-6.039	.009	384
Nightshade(kg/acre/annum	.341	.38	383	18.13	-5.099	.059	384

Source: Field data 2022

Simple linear regression analysis (Table 17) indicated that there was significant effect between rainfall timing (short rains) and maize yield [F (383) =22.68, P < .001, R^2 =58], Beans yield [F (383) =11.74, P = .059, R^2 =.43], however African Nightshade Yield [F (383) =18.13, P < .051, R^2 = .34] was insignificantly predicted. Further analysis of the model showed that maize had significant positive linear association (t = 10.74, p < .001), Beans, and Nightshade (Plate 3) revealed a significant negative linear relationship (t =-6.04, p < .001), and (t =-5.09, p < .057) respectively.

From the findings, Maize crop yield improved with good rainfall timing during (short crop cycle). Short rains that usually lasted for about 6 weeks had to be accurately timed for better maize yield. Most respondents therefore agreed that they had to speculate the onset of rains to allow them get good maize harvest during the short rains. Similar trend was observed with beans and night shade yields. In 2020, 72% of the respondents with the majority being females failed to predict the rainfall onset therefore reducing maize yield by 58%. The study area was worst hit in 2022 when more 80% of the farmers could not tell when the short rains would arrive thus affecting food crop production. Therefore, the 58% variation in maize yield was explained by change rainfall timing in short rains seasons between the years 2022 to 2022. Even though beans require low rainfall, its production was slightly affected by changes in rainfall arrival. Despite the late rainfall arrival, the farmers who planted late managed to harvest beans within the 4-5 weeks that the short rains lasted. However, the bean yield greatly declined in 2022 when short rains delayed for about 4 weeks. During the short rains, farmers' attitude changed towards farming since they could predict the yields. As such the decline beans production was not only attributed to late rainfall arrival but also on the negative attitude of farmers on the expected yields.

Untimely arrival of the short rains affected the quality of African nightshade produced. Therefore, the 34% variation in African nightshade production was not only caused by changes in rainfall timing but also due to diseases that thrive well during the short rains. Moreover, most respondents confirmed that during the short rains, there is great attack by birds on the crops. This means that many farmers usually opt out of farming not only due to untimely rainfall arrival but also due to many incidences of pests' inversion. Despite the great impact caused by late rainfall arrivals and the crop diseases, most respondents confirmed the delay of the short rains forced them to use other alternatives like irrigation to ensure that the crop had a good yield. During the short rains, there was a high demand for the African nightshade and therefore the farmers had to use irrigation to meet the market needs. The use of irrigation to supplement short rainfall cycle in African nightshade production was justified by the photograph in Plate 3. The photograph below indicated that the farmers that opted to do irrigation due to change in rainfall onset managed better yields of African Nightshade.

Plate 3: Vibrant Nightshade Farm in Nyando Sub-County during the Short Rains. (Taken on 17/08/22)

Source: Field data 2022.

The results on maize contrasted the findings in Bahati Sub County by Arunga et al (2012) which reported a reduction on maize yield as a result of good rainfall timing. This is because the anticipated low rains in the second season led to poor timing decisions among the households of Nyando in terms of maize production (Omondi 2018). The result of beans yields is similar to the findings by Edmonds & Chweya (2018) that noted a weak negative correlation between the yield and rainfall timing during the short rains seasons, earlier findings on nightshade yield by Katungi et al (2009) indicated that the vegetable was draught resistant and deed well under irrigation and was on high demand during the dry season.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter Presents Summary, Conclusions, and Recommendations

5.2 Summary of the Findings

The first objective aimed to examine the effect of duration of rainfall on Maize, Beans and African Nightshade production Nyando Sub County. Simple linear regression analysis indicated that there was significant effect of rainfall duration on maize yield. [F (383) =25.63, $P < .001$, $R^2 = .65$], Beans yield [F (383) =20.42, $P < .001$, $R^2 = .47$], and African Nightshade Yield [F (383) =19.41, $P < .001$, $R^2 = .38$]. Majority of the respondents perceived the change in rainfall duration as decreasing. During the long rains that lasted 10.89 weeks, farmers harvested as follows; Maize 9.00 bags/acre, Beans 4.00 bags/acre and Night shades 100kg/acre. During the short rains that lasted about 6.63 weeks the harvests were 4.26 bags/acre, 4.65 bags/acre and 174kg/acre for maize, beans and African nightshade respectively. Further analysis of the model showed that maize had significant positive linear association ($t = 18.82$, $p < .001$), Beans, and Nightshade revealed a significant negative linear relationship ($t = -6.04$, $p < .001$), and ($t = -8.05$, $p < .001$).

The second objective aimed to examine the effect of magnitude of rainfall on Maize, Beans and African Nightshade production Nyando Sub County. Simple linear regression analysis indicated that there was significant effect between rainfall magnitude and maize yield [F (383) =11.45, $P < .001$, $R^2 = .65$], Beans yield [F (383) =16.08, $P < .001$, $R^2 = .47$], and African Nightshade Yield [F (383) =8.73, $P < .001$, $R^2 = .38$]. Longer rainfall magnitude positively increased maize yields during the long rains. However, it led to the reduction of beans and African nightshade. This is because of the excess surface run off that led to withering of the crops. The millimeter per hour of rainfall experienced during the short rains led to the reduction of maize yields. Beans and African nightshade production increased during the short rains since they require low rainfall magnitude compared to maize. Further analysis of the model showed that maize had significant positive linear association (t = 13.84, p < .001), Beans, and Nightshade revealed a significant negative linear relationship (t = -6.05, p < .001), and (t = -4.32 p < .001) respectively.

The third objective aimed to examine the effect of timing of rainfall on Maize, Beans and African Nightshade production Nyando Sub County. Simple linear regression analysis indicated that there was significant effect between rainfall timing and maize yield [F (383) =13.68, P < .001, R^2 = .44], Beans yield [F (383) =21.24, P = .059, R^2 =.38], and African Nightshade Yield [F (383) =14.45, P < .001, R^2 =.34]. Good timing during the long rains improved the production of the three crops with maize getting the best yield. Poor timing during the short rains greatly affected maize yields since the amount of rains received were inadequate. Drought resistant crops like African nightshade did well during the short rain seasons. Further analysis of the model showed that maize had significant positive linear association (t =15.85, p < .001), Beans, and Nightshade (Figure 8) revealed a significant negative linear relationship (t = -5.04, p < .001), and (t = -7.05, p < .001) respectively.

5.3 Conclusion

Rainfall duration was statistically significant in assessing the selected crop yields in Nyando sub-county. Longer rainfall durations were good for maize yields, however it negatively affected both beans and the African nightshade yields. This is because both beans and the African Nightshade are cover crops which are susceptible to excess surface run-off caused by longer rainfall duration. Despite the positive relationship, maize yields were likely to be adversely affected by short rains durations. This was so given that the mean rainfall hours fell short below the minimum requirement for optimal maize yield. The reduction in both beans and nightshade yields was possibly due to nature of the silt deposits that rapidly lost water in hot weather therefore affecting the yield of the mentioned crops negatively during short rains.

The study also established that rainfall magnitude was significant in predicting the selected crop yields in Nyando sub-county. Long rainfall magnitudes were necessary for maize yields, however it inversely affected both beans and the African nightshade yields. This is because both Beans and the African Nightshade are cover crops which are affected when subjected to floods from within and neighboring Nandi County. Even with the positive relationship, maize yields were likely to be affected by short rains magnitudes. This was so because the mean rainfall volume was not enough for maximum maize yield. The reduction in both beans and nightshade yields was possibly due to extreme fluctuations in rainfall volumes during short rains seasons.

Lastly, the study established that rainfall timing was relevant in determining the selected crop yields in Nyando sub-county. Rainfall timing was effective for maize yields, however it violated the principle of better yields for both beans and the African nightshade. This is likely so given that both Beans and the African Nightshade are cover crops which are susceptible to floods. Again poor timing affected maize yields in short rains. Similarly, the depreciation in both beans yields was possibly due to rainfall unpredictability which is common during short rains. However, rainfall timing had statistical effect on the African Nightshade yields, this was so because the vegetable was in demand during the dry season and this motivated the households use irrigation.

5.4 Recommendation

The farmers (Household heads) should minimize production of rain-fed food crops and adopt drought tolerant crops as well resilient livelihoods. Emphasis be placed on maize production during long rains seasons with minimal production of both beans and African Nightshade for output maximization. More beans than maize and African Nightshade be grown in short rains durations to curb weather related loses and the low vegetable demands associated with long rains duration.

Purely rain fed crop farming should be avoided and instead farmers be trained on how to harness the rampant flood waters for future crop production during dry spells. For the households within the riparian landscape, rice farming alternatives be encouraged so as to take advantages of the common flash floods and for food diversification.

Metrological data interpretations and timely predictions be availed to Farmers for timely planting onset. Households be encouraged on the benefits of agricultural extension services and technical contact hours for improved crop yield. Seed varieties be introduced that will perform better in different rainfall timings.

5.5 Areas for Further Research

There is need for a study on rainfall duration on cash crops like sugarcane within the study area or other places with similar geographical conditions.

A study on rainfall magnitude on production of rice which is currently under irrigation in the study area.

A comparative study needs to be conducted the effects on rainfall timing and amounts on the selected crop yields for the entire county.

REFERENCES

Abukutsa, M. O. O. (2010). *African indigenous vegetables in Kenya: Strategic repositioning in the horticultural sector*. Nairobi, Kenya: Jomo Kenyatta University of Agriculture and Technology.

Arunga, E. E., Ochuodho, J. O., Kinyua, M. G., & Owuoche, J. O. (2012). Characterization of Uromyces appendiculatus isolates collected from snap bean growing areas in Kenya.

Bouman, B. A. M., Institut international de recherche sur le riz., & Plant Research International. (2009). *Water-wise rice production*. Los Baños, Philippines: International Rice Research Institute.

Cohen, D. W., & Atieno, O. E. S. (2010). *Siaya: The historical anthropology of an African landscape*. London: J. Currey.

Dinar, A. (2008). *Climate change and agriculture in Africa: Impact assessment and adaptation strategies*. London: Earthscan.

Edmonds, J. M., &Chweya, J. A. (2018). *Black nightshades: Solanum nigrum L. and related species*. Rome: IPGRI.

Food and Agricultural Organization. (2009). The state of insecurity in the world 2009. Food and Agriculture Organization of the United Nations, Rome, 58 pp.

Government of Kenya (2015). Economic Review of Agriculture; Ministry of Agriculture, L. and F. Government printers, Nairobi, Kenya, 62(62).

Government of Kenya (2005). Kenya‘s Climate Change Technology Needs and Needs Assessment Report under the United Nations Framework Convention on Climate Change.

Guntu, R. K., Maheswaran, R., Agarwal, A., & Singh, V. P. (2020). Accounting for temporal variability for improved precipitation regionalization based on self-organizing map coupled with information theory. *Journal of Hydrology*, *590*, 125236.

Kaguongo, W., & Food and Agriculture Organization of the United Nations. (2013). *A policymakers' guide to crop diversification: The case of the potato in Kenya*. Rome: Food and Agriculture Organization of the United Nations.

Karnataka (India). (2007). *Project for integrated development of horticulture in Karnataka, India*. Bangalore: Govt. of Karnataka, Project Formulation Division, Planning Dept.

Katungi, E., Farrow, A., Chianu, J., Sperling, L., & Beebe, S. (2009). Common bean in Eastern and Southern Africa: a situation and outlook analysis. *International Centre for Tropical Agriculture*, *61*, 1-44.

Kgathi, D. L., Kniveton, D., Ringrose, S., Turton, A. R., Vanderpost, C. H. M., Lundqvist, J., & Seely, M. (2006). The Okavango; a river supporting its people, environment, and economic development. *Journal of Hydrology*, *331*(1-2), 3-17.

Kenya National Bureau of Statistics. (2019). Kenya Population and Housing Census. Population Distribution by Age, Sex and Administrative Units, IC. Kenya National Bureau of Statistics, Nairobi: Kenya.

Krol, M. S., & Bronstert, A. (2007). Regional integrated modelling of climate change impacts on natural resources and resource usage in semi-arid Northeast Brazil. *Environmental Modelling & Software*, *22*(2), 259-26.

Hennink, M. M., Hutter, I., & Bailey, A. (2020). *Qualitative research methods*.

International Rice Research Institute. (2012). *Weather and rice: Proceedings of the international workshop on the impact of weather parameters on growth and yield of rice, 7-10 Apr 1986*. Los Baños,

Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Impacts, adaptation, and vulnerability: Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. Laguna, Philippines: International Rice Research Institute.

Jalloh, A., & International Food Policy Research Institute. (2013). *West African agriculture and climate change: A comprehensive analysis*. Washington D.C: International Food Policy Research Institute.

Kanyagia, S. T. (2009). A survey of vegetable nematodes in Kenya. *East African Agricultural and Forestry Journal*, *44*(3), 178-182.

Kenya. (2002). *District development plan, 2002-2008*. Nairobi: Republic of Kenya, Ministry of Finance and Planning.

Ker, A., & International Development Research Centre (Canada). (2009). *Farming systems of the African savanna: A continent in crisis*.

Kirk, J., & Miller, M. L. (2007). *Reliability and validity in qualitative research*. Los Angeles, etc.: Sage.

KNBS. (2010). Population and Housing Census. Nairobi: Kenya Central Bureau of Statistics.

Leal, F. W., Esilaba, A. O., Rao, K. P. C., & Sridhar, G. (2015). *Adapting African Agriculture to Climate Change: Transforming Rural Livelihoods*.

Mati, B. M. (2010). The effect of climate change on maize production in the semi-humid–semi-arid areas of Kenya. *Journal of Arid Environments*, *46*(4), 333-344.

Maundu, P. M. (2007). The status of traditional vegetable utilization in Kenya. In *Traditional African Vegetables. Proceedings of the IPGRI International workshop on Genetic Resources of Traditional Vegetables in Africa. Conservation and Use. ICRAF-HQ, Nairobi. Institute of Plant Genetic and Crop Plant Research, Rome* (pp. 66-71).

Masayi, N., & Netondo, G. W. (2012). Effect of sugarcane farming on diversity of vegetable crops in Mumias Division, Western Kenya.

McCann, J. (2005). *Maize and grace: Africa's encounter with a New World crop, 1500-2000*. Cambridge, Mass: Harvard University Press.

Mogaka, H. (2006). *Climate variability and water resources degradation in Kenya: Improving water resources development and management*. Washington, D.C: World Bank.

Mpungose, N., Thoithi, W., Blamey, R. C., & Reason, C. J. C. (2022). Extreme rainfall events in southeastern Africa during the summer. *Theoretical and Applied Climatology*, *150*(1-2), 185-201.

Nedumaran, S. (2015). *Climate change challenges and adaptations at farm- - case studies from Asia*.

Ogola, J. S., Abira, M. A., Awuor, V. O., & Climate Network Africa. (2007). *Potential impacts of climate change in Kenya*. Nairobi, Kenya: Climate Network Africa.

Ondieki, C. M., & Kitheka, J. U. (2019). *Hydrology and water resources management in arid, semi-arid, and tropical regions*.

Omondi, S. (2018). *Urban-based agriculture and poultry production: The case of Kisumu and Thika in Kenya* (No. 23). Lund University.

Ooko, P. B., Sirera, B., Saruni, S., Topazian, H. M., & White, R. (2015). Pattern of adult intestinal obstruction at Tenwek hospital, in south-western Kenya. *Pan African Medical Journal*, *20*(1)

Owino, R. A. (2008). *Ethnobotany and Mineral Contents of Indigenous Vegetables of Kisumu District in Kenya* (Doctoral dissertation, University of Nairobi).

Oseni, T. O., & Masarirambi, M. T. (2011). Effect of climate change on maize (*Zea mays*) production and food security in Swaziland. *change*, *2*(3).

Paterson, N. (2011). Global Warming: A Critique of the Anthropogenic Model and its Consequences. *Geoscience Canada*, *38*(1), 41-48.

Powell, J. L. (2015). Climate scientists virtually unanimous: Anthropogenic global warming is true. *Bulletin of Science, Technology & Society*, *35*(5-6), 121-124.

Seo, S. N., & Mendelsohn, R. (2008). An analysis of crop choice: Adapting to climate change in South American farms. *Ecological economics*, *67*(1), 109-116.

Shackleton, C. M., Pasquini, M., & Drescher, A. W. (2009). *African indigenous vegetables in urban agriculture*. London: Earthscan.

Synodinos, A. D., Tietjen, B., Lohmann, D., & Jeltsch, F. (2018). The impact of inter-annual rainfall variability on African savannas changes with mean rainfall. *Journal of theoretical biology*, *437*, 92-100.

Taylor, G. R. (2005). *Integrating quantitative and qualitative methods in research*. Lanham, Md: University Press of America.

Tol, R. S. (2014). Quantifying the consensus on anthropogenic global warming in the literature: A re-analysis. *Energy Policy*, *73*, 701-705.

United Nations Environment Programme. (2009). *Kenya, atlas of our changing environment*. Nairobi, Kenya: United Nations Environment Programme.

Williams, C. J. R., & Kniveton, D. R. (2011). *African climate and climate change: Physical, social, and political perspectives*. Dordrecht: Springer.

World Bank. (2007). *Agriculture for development*. Washington, D.C: World Bank and Oxford University Press.

World Meteorological Organization. (2008). *Agrometeorology of the rice crop: Proceedings of a seminar held at IRRI, December 1979*. Los Banos (Phillipines: IRRI.

Yamane, T. (1967). Statistics: An Introductory Analysis, 2nd Edition, New York. Harper and Row.

APPENDICES

APPENDIX 1: Time Schedule

Month / Activity	Aug-Nov 2020	Jan-Sep 2021	Sep-Oct 2021	Oct-Nov 2021	Dec 2021	Jan-Feb 2022	March 2022			July
Literature Review										
Proposal presentation										
Submission of the proposal to SGS										
Questionnaire Administration										
Data Collection										
Data Analysis										
First draft thesis										
Second draft thesis										
Final draft thesis										
Submission of final thesis to S.G.S										
Graduation										

APPENDIX 2:Budget

ITEM	DESCRIPTION	COST (KSH)
1.	MATERIALS Ruled papers 2 reams @ Ksh.390.00 Typing papers 5reams @ Ksh.500.00 Folders 6 pieces @ Ksh.60.00 Pens 1 dozen @ Ksh.250.00 Field notes books 5 pieces @ ksh.80.00	780.00 2,500.00 360.00 250.00 400.00
	SUB TOTAL	4,290.00
2	SERVICES Typesetting Binding Photocopy	 10 000.00 7 000.00 9 000.00
	SUB TOTAL	26,000.00
3.	Commuting cost	30, 000.00
4.	Accommodation	20 000.00
5.	Subsistence	20 000.00
6.	Miscellaneous	20,058.00
	SUB TOTAL	90 058.00
	GRAND TOTAL	120 348.00

APPENDIX 3: Observation Sheet for Objective one

Year	Maize(bags)	Beans(bags)	Nightshade(Kg)	Farm acreage	Mean annual Rainfall Duration(24hours scale)	
2013						
2014						
2015						
2016						
2017						
2018						
2019						
2020						
2021						
2022						

Source: Field data 2022

APPENDIX 4: Observation Sheet for Objective Two

Year	Maize(bags)	Beans(bags)	Nightshade(Kg)	Timing(Long crop cycle)	Timing(Short crop Cycle)
2013					
2014					
2015					
2016					
2017					
2018					
2019					
2020					
2021					
2022					

Source: Field data 2022

APPENDIX 5: Observation Sheet for Objective Three

Year	Maize(bags)	Beans(bags)	Nightshade(Kg)	Magnitude of Rainfalls(mm/h)	
2013					
2014					
2015					
2016					
2017					
2018					
2019					
2020					
2021					
2022					

Source: Field data 2022

APPENDIX 6: An Introduction Letter

P.O BOX, 6

AHERO, KENYA.

TO RESEARCH participants:

Dear Respondent.

RE: PARTICIPANTS CONSENT FORM

You are requested to participate in research study on the effect of rainfall variability on selected food crop production in Nyando Sub-County, Kisumu County Kenya. All your responses and information provided was treated within confidentiality and your identity remain anonymous. You are free to seek clarification before agreeing to be part of the study.

I have been briefed on what the study is about. I am assured that the information I will give is confidential and therefore agree to participate in the above study.

______________________ ______________________________

Signature. Date

APPENDIX 7: The questionnaire

TITLE: ASSESMENT OF THE EFFECT OF RAINFALL VARIABILITY ON SELECTED FOOD CROP PRODUCTION IN NYANDO SUB COUNTY, KISUMU COUNTY.

Introduction

Maseno University is performing an investigation on the effect of rainfall variability on selected food crop production in Nyando sub county, Kisumu County. The questionnaire is directed towards getting an insight of rainfall variability on selected food crop production from households' perception. Your open and honest responses are valued and treated with discretion. The attained information is to be used for academic drives.

Instructions: please tick or fill gaps where suitable.

PARTICULAR INFORMATION

Gender: Female [] Male [] Intersex [] First language __________________(indicate).

Age: < 30 [] 30-39 [] 40-49 [] >50 []

What is your household size for the last 12 months? _______________________________

Education: indicate the highest level reached as specified in the Table below or specify where applicable____

Basic	Higher
Pre-primary Primary Other	Secondary Tertiary Other

Income:

Trade [] Agriculture [] Formal Employment [] Self-employment [] Others []; (tick all that applies) or Specify:

Ward (Geographical Location).

Wards	Tick where appropriate
Ahero	
Kobura	
Kabonyo	

East Kano	
Awasi	

For how long have you been farming in the area (years);

0-5

6-10

11-15

Above 15

In case you have been in farming for more ten years and above, fill in the approximate values of the selected crop yield as guided by the table below.

Year	Maize(bags)	Beans(bags)	Nightshade(Kg)
2013			
2014			
2015			
2016			
2017			
2018			
2019			
2020			
2021			
2022			

A. EFFECT OF RAINFALL DURATION ON PRODUCTION OF MAIZE, BEANS AND AFRICAN NIGHTSHADE.

1. Are you a food crop farmer?
2. Which food crops do you grow?
3. Do you grow maize, beans, and African nightshade……?
4. What acreage of land under the following crops; Maize…………

Beans………….

African Nightshade……….

Provide an approximation of the quantity of crops produced within the last three years?

Crop yield from 2019-2022	Answer in Bags/Tons or Kgs
Maize Beans Nightshade	

5. What is the quantity of bags the crops mentioned above do you get during the long rains?
6. How many weeks does it rain during the long rains?
7. What was quantity (in bags) of these crops harvested during the short rains?

Crop yield during short rains	Answer in Bags or Kgs
Maize Beans Nightshade	

8. How many bags of the crops yield did you harvest during the long rains (March-May)? Bags………………….

Crop yield during long rains(March-May)	Answer in Bags/Tons or Kgs
Maize Beans Nightshade	

9. How many weeks does it rain during the short rainy seasons?
10. Has the duration of rainfall changed in the previous 3 years (2019-2022)?
    - Increased

- Decreased
- Constant
- Tick whichever is appropriate.

11. Assume the rainfall duration declined, what would be the effect on the yield?

Crop yield	Effect	Tick an appropriate choice
Maize	Increasing Decreasing Constant	
Beans	Increasing Decreasing Constant	
Nightshade	Increasing Decreasing Constant	

12. Assume the duration of rainfall was increased, what would be the yield of these crops? Provide answer in bags per acre

Crop yield per acre	Answer in Bags or Kgs
Maize Beans Nightshade	

13. With the consistent rains from planting through to harvesting period, what quantity in yield of these crops does you get? Provide answer in tons.

Harvest	Answer in Bags or Kgs
Maize Beans Nightshade	

14. Does the rainfall received in the area is sufficient for growing of crops in (15) above? [YES], [NO].

B. EFFECT OF TIMING OF RAINFALL ON BEANS, MAIZE, AND AFRICAN NIGHTSHADE

(a) During the long the rains, does the rains arrive at the right time? [YES], [NO]

(b) Does the short rainfall seasons arrive in time? [YES], [NO]

2. When the rains arrive in a timely way, what is the quantity of produce (in bags) you get from these crops?

Harvest in early rainfall onset	Answer in Bags or Kgs
Maize Beans Nightshade	

3.What is the approximate quantity (in bags) of harvest of these crops do you get when the rains arrive late?

Harvest late rainfall onset	Answer in Bags or Kgs
Maize Beans Nightshade	

4. Has the onset of long rains in the last three years changed?

- 2020……… [YES], [NO]
- 2021………[YES], [NO]
- 2022………[YES], [NO]

5. Has the onset of short rains changed in the last three years?

- 2020………[YES], [NO]
- 2021………[YES], [NO]
- 2022………[YES], [NO]

6. Do you believe that when there is timely arrival of rainfall, production of these crops may be affected? Explain….?

7. Based on the arrival patterns of rainfall for the last three years, has production of these crops changed….? [YES], [NO] Tick whichever is appropriate

8. Have you considered resorting to other crops due to changes in arrival of rainfall? [YES], [NO]

9. Has the arrival of rainfall changed in the last three years? [YES], [NO]

EFFECT OF MAGNITUDE OF RAINFALL ON BEANS, MAIZE, AND AFRICAN NIGHTSHADE.

14. (a) How many hours does it rain during the long rains?......

(b) How many hours does it rain during the short rains?......

(c) Do the long hours of rainfall cause exceeding surface run-off? [YES], [NO]

(d) Which among these crops are affected by surface run off? (Tick an appropriate choice)

Crop	Surface Runoff effect
Maize Beans Nightshade	

15. Has growing of these crops (maize, beans and *osuga)* decline due to the change in hourly rainfall experienced?

16. How has the increase in hour/mm of rainfall affected production of these crops? Explain---

- Maize…………………...
- Beans………………….
- Nightshade…………….

17. (a) how does the increase in the soil water concentration due to long hours of rain affect these crops? Explain---

- Maize……………...
- Beans………………
- Nightshade…………

(b)Has the quantity of *osuga* produced fluctuated due to change in rainfall/hour received? [YES], [NO]

(c) Apart from rainfall, is there any other factor/challenge that affect the growing of the vegetable? Explain---

(d) What has been the trend of production of these crops within the last three years based on the intensity of rainfall as experienced?

Crop yield	Trend in Production	Tick an appropriate choice
Maize	Increasing	
	Decreasing	
	Constant	
Beans	Increasing	
	Decreasing	
	Constant	
Nightshade	Increasing	
	Decreasing	
	Constant	

18. (a) From your assessment, does *osuga* needs high rainfall concentration for good yield? [YES], [NO]

(b) With the high rainfall magnitude, how many bags of maize, beans, and Kilograms of *osuga* do you get per acre of land? (Tick one)

- 1-5
- 5-10
- 10-15
- Others (specify)

(c) With the low rainfall magnitude, how many bags of maize, beans and *osuga* (in kg) do you get per acre of land? (Tick one)

- 1-5
- 5-10
- 10-15
- Others (specify)

APPENDIX 8: Interview Schedule for Key Informants (MOA and MET Dept Officer)

1. What are main farming methods in this area?
2. What is the percentage of farmers that rely on rain-fed agriculture?
3. What are main wards where maize, beans and *osuga* is grown in large scale
4. What is the status on Nyando sub county in terms of food security?
5. What is approximate percentage of people who rely on maize, beans and *osuga* as their source of income?
6. Has rainfall changed in the last five years? (Yes/No)
7. Has the timing of rainfall changed in the area in the last three years?
8. Has the early rainfall arrival increased food crop production?
9. Has the late rainfall arrival decreased food crop production in the area?
10. How long does it rain during the long rains?
11. How do the short rains affect growing these crops?

APPENDIX 9: Interview Schedule for FGDs

1. Do you believe that the prolonged rainfall seasons affects the production of Maize, Beans, and African Nightshade in Nyando sub-county?
2. What do you do in case the mentioned crops fail due poor weather?
3. Has early or Late planting ever affected the crop yield?
4. Comment on the yield quantities in flooded years with respect to the mentioned crops?

APPENDIX 10: Rainfall Patterns in Nyando Sub County from 2013

Kenya Meteorological Department

YEAR	Mean Average Annual Rainfall (mm) For Kisumu-Nyando
31-DEC-2013	920 mm
31-DEC-2014	1010 mm
31-DEC-2015	1080 mm
31-DEC-2016	1149 mm
31-DEC-2017	1200 mm
31-DEC-2018	1260 mm
31-DEC-2019	1350 mm
31-DEC-2020	1380 mm
31-DEC-2021	1390 mm
31-DEC-2022	1470 mm

YEAR	Mean Average Rainfall (mm) For Kisumu (FROM MARCH 1ST-JULY 31ST)
March 1ST - JULY 31ST 2013	1240 mm
March 1ST - JULY 31ST 2014	1133 mm
March 1ST - JULY 31ST 2015	1232 mm
March 1ST - JULY 31ST 2016	1460 mm
March 1ST - JULY 31ST 2017	1149 mm
March 1ST - JULY 31ST 2018	1309 mm
March 1ST - JULY 31ST 2019	1260 mm
March 1ST - JULY 31ST 2020	1560 mm
March 1ST - JULY 31ST 2021	1170 mm
March ST - JULY 31ST 2022	1405 mm

YEAR	Mean Average Rainfall (mm) For Kisumu (FROM SEPTEMBER 1ST-DECEMBER 31ST)
SEPTEMBER 1ST – DECEMBER 31ST 2013	780 mm
SEPTEMBER 1ST – DECEMBER 31ST 2014	881 mm
SEPTEMBER 1ST – DECEMBER 31ST 2015	1135 mm
SEPTEMBER 1ST – DECEMBER 31ST 2016	684 mm
SEPTEMBER 1ST – DECEMBER 31ST 2017	901 mm
SEPTEMBER 1ST – DECEMBER 31ST 2018	741 mm
SEPTEMBER 1ST – DECEMBER 31ST 2019	1349 mm
SEPTEMBER 1ST – DECEMBER 31ST 2020	853 mm
SEPTEMBER 1ST – DECEMBER 31ST 2021	1122 mm
SEPTEMBER 1ST – DECEMBER 31ST 2022	755 mm

APPENDIX 11: RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 197862

Date of Issue: 17/July/2023

RESEARCH LICENSE

This is to Certify that Mr.. Tom Onyango Odundo of Maseno University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kisumu on the topic: Effects of Rainfall Varriability on Selected Food Crop Production in Nyando Sub County, Kisumu County Kenya for the period ending : 17/July/2024.

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