INFLUENCE OF RAINFALL VARIABILITY AND TRENDS ON TOMATO PRODUCTION AMONG SMALL SCALE FARMERS IN KIENI EAST SUB COUNTY KENYA

KARIENYE MACHARIA JOSEPH

A THESIS SUBMITTED TO THE SCHOOL OF EDUCATION AND SOCIAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE CONFERMENT OF THE DEGREE OF MASTER OF ARTS IN GEOGRAPHY, KARATINA UNIVERSITY

DECEMBER, 2020

DECLARATION

Declaration of the Candidate

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

Karieye Macharia Joseph

E226/2278P/2013

Signature …….…… Date…….……

Declaration of the Supervisors

We confirm that the work reported in this thesis report was carried out by the candidate under our supervision and has been submitted with our approval as university supervisors.

Dr. Tom Ouna
Department of Humanities and Languages Studies
School of Education, Arts and Social Sciences
Karatina University

Signature …….…… Date…….……

Dr. Hellen Wangechi Kamiri
Department of Agricultural Sciences
School of Agriculture and Biotechnology
Karatina University

Signature …….…… Date…….……

DEDICATION

I dedicate this thesis to my mother Gladys Karienye, my late dad Jackson Karienye, my wife Roselyne, our children Karienye and Mugure, God bless you.

ACKNOWLEDGEMENTS

Thanks to the Almighty God for seeing me through and completion of my education programme. I wish to express my sincere thanks and appreciation to the following people without whose commitments and dedication in one way or another in my learning efforts at starting, continuing, researching and completing this study and would have been truly difficult. To my thesis supervisors and mentors Dr. Tom Ouna and Dr. Hellen Kamiri for relentless effort in guiding me through verbal advice, reading and correcting the many drafts which I had to write towards the completion of this journey. I am very grateful to my brother Dr. Kamau Karienye and all the postgraduate students in the Geography Department of Karatina University for their continued support and motivation towards completion of this course. I am very appreciative to my wife Wairimu, my mother Mugure for their continuous patience, financial and moral support throughout my programme of study.

I appreciate the data and information given to me by the Kenya Meteorological Department (KMD), Nairobi and Kieni East Sub County Agricultural Officers at Narumoru, without their data the study would not have been a success. The farmers where I undertook my research for bearing with the disruptions I caused in their daily farming programs and activities as I gathered the data and information. I would like to appreciate all individuals in various capacity who willingly assisted me to supervise or in other ways the collection of data. Finally, I appreciate the support of my nuclear family members and friends. I could not have completed this without their assistance, tolerance and enthusiasm, my daughter Ivy for her patience and understanding when I was away. To the others whom I may not have mentioned, let the Almighty God kindly bless you for your kindness and love of my work, and it is my prayer that the Lord Jesus Christ will continue to shower you with the desires of your heart. Amen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

ASALs	Arid and Semi-Arid Lands
FFV	Fresh Fruits and Vegetables
GDP	Gross Domestic Product
GoK	Government of Kenya
GTZ	German Technical Cooperation
Ha	Hectares
HCDA	Horticultural Crops Development Authority
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agricultural and Livestock Research Organization
KMD	Kenya Meteorological Department
Kshs	Kenya Shillings
MAM	March, April to May
MT	Metric Tons
OND	October, November to December

ABSTRACT

The future of African agriculture and food security depends mainly on the outcome of climate variables and specifically on rainfall reliability. Consequently, any variability in rainfall trends on a regional or global scale has impacts on crop production. In arid and semi-arid regions, rainfall variability impacts could be adverse especially where the main farming system is rain fed oriented. This study purposed to evaluate the influence of rainfall variability and trends on tomato production in the semi-arid region of central Kenya. The specific objectives were to: identify the rainfall variability and trends between 1981 and 2014; determine the relationship between rainfall variability, tomato yields and market prices; and evaluate farmers' adaptation strategies to rainfall variability and trends on tomato production. The study was conducted in Kieni East sub County and applied cross sectional survey research design. Four wards were sampled, namely Kabaru, Thegu River, Narumoru/ Kiamathaga and Gakawa wards. Data was obtained using questionnaires and interview schedules from a sample of 45 tomato growing farmers who were randomly selected and proportionately distributed among the wards. Data on rainfall was obtained from Kenya Meteorological Department in Nairobi for the stations adjacent the study area while tomato production data was obtained from the sub County Agriculture Office at Narumoru. Data was analysed using the Statistical Package for Social Science (Version 20.0) and summarized using descriptive statistics such as frequencies, percentage and means. Pearson's Product Moment Correlation was used to determine the correlation between rainfall amounts, tomato yields and prices. Results established that rainfall characteristics over the thirty four years under study varied both annually and seasonally. The study area experienced changes in annual rainfall during the years under study (1981 to 2014) as indicated by the trend line equation $y = 5.57778x + 563.8$. Pearson's Product Moment Correlation ($r = 0.429$) showed that there was a positive correlation between rainfall and tomato yield and a relatively weak positive correlation between rainfall and tomato income ($r = 0.334$). The study further revealed that farmers adopted various strategies which included irrigation, crop rotation, crop diversification, use of certified seeds, mulching and use of manure and greenhouse technology to align with rainfall variability and trends. These practices were however influenced by rainfall patterns and social economic status of the farmers. These findings show that there is need to develop policies that will raise tomato production in areas that are characterized by rainfed patterns and therefore able to cushion farmers from adverse effects of rainfall variability.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Agriculture contributes up to 40 percent of the East Africa's region Gross Domestic Product (GDP) and provides a living for 80 percent of East Africans (Seitz & Nyangena, 2009). In Kenya, agriculture is an important sector in the economy, contributing approximately 25 percent of the GDP, and employing 75 percent of the national labour force (HCDA, 2011).

Production of horticultural crops in many regions of the world has been affected by changes in climate resulting in worldwide shortage of market supplies. Varying temperatures and rainfall have influenced horticultural produce, which has led to a reduction and uncertainty in income of farmers (Masahumi., Oda, Maruo, & Shinohara, 2011). Agricultural production and access to food in many countries in Africa is projected to be severely compromised by the changing rainfall variability (IPCC, 2007). Lee, Nadolnyak & Hartarska (2012) noted that there had been a 2 percent overall increase in global land precipitation and rainfall characteristics have shown considerable variations from region to region with some areas experiencing decline and in others increase in precipitation due to increased extreme weather patterns. Falkenmark (2007) projects that there will be challenges in farming due to increased water stress, and areas suitable for cultivation along the margins of the arid and semi-arid lands (ASALs) are predicted to reduce in acreage hence decreased crop production. This vulnerability has risen in Africa particularly where agricultural production is the primary source of livelihoods, for about 66 percent of the total active population (ILO, 2007).

The future of agriculture and food security in Africa depends solely on the outcome of climate variability, global patterns of commodity production, demand and indigenous responses to local and global change (IPCC, 2007). Consequently variability in rainfall and trends on a global scale has impact on crop production (Kumar, Sharmar, Kansal, & Thakur, 2012). The IPCC projections suggest that the changing rainfall trends will impact heavily on agricultural production, and adversely affect human health and wealth (IPCC, 2012). Changing rainfall patterns permits the cultivation of a variety of crops in a pattern that started way back in the 19th century in response to local weather conditions (Ziervogel, Cartwright, Tas, Adejuwon, Zermoglio, Shale & Smith, 2008 and Onyekwelu, Mosandl & Stimm, 2006).

The effects of weather variability are uncertain, but adverse impacts are likely in many regions. Projections of changing rainfall variability suggest that East Africa will experience warmer temperatures and a 5 - 20 percent increased rainfall amounts from December to February as well as a 5 - 10 percent rainfall amount reduction from June - August by 2050 (IPCC, 2012). Increased variations in intensity and frequency of storms, drought and flooding, have greatly altered hydrological cycles, and precipitation variance which have implications on future food availability and highly impacts on agriculture relying on rain fed *vis-à-vis* irrigated systems (FAO, 2007).

Majority of Kenya's population accounting for about 80 percent derive their livelihood from agriculture in rural areas and even for the urban poor, majority make a living from activities related to agriculture like cultivation, hawking and selling of horticultural produce (HCDA, 2011). Changing rainfall trends affect the rural people due to the frequent droughts, floods of different intensity and marketing systems thus impacting

on crop production. A decline in agricultural productivity has a far reaching implication in terms of livelihoods and income inequality for the Kenyan people.

In Kenya, horticulture (growing of vegetables and fruits) is mainly practiced through rain fed system although a number of farms, especially ones growing horticultural crops for export also use irrigation as well as greenhouse technology. The horticulture sub-sector is characterized by a tremendous diversity in terms of farm sizes, variety of produce and geographical area of production. Farm sizes range from large-scale estates with substantial investments in irrigation and high level use of inputs, hired labour and skilled management to small-scale farms, which might be less than one acre (HCDA, 2011). The major high value horticultural crops include tomato, crops from the brassica family and flowers.

In the year 2013 the area under vegetable production was 340,000 Ha with a production of 4.3 million MT and a monetary value of Kshs 70 billion (HCDA, 2013). During the same year, the area under tomatoes farming was 23,865.6 ha and the total production for the country was 494,036.5 MT tons with a value of Kshs 14.1 billion (HCDA, 2013). This provided revenue to the Nyeri County Government, contributed to income and jobs in rural and urban areas.

Tomato is grown in parts of Embu, Meru, Nyeri and Murang'a and Kajiado counties where the altitude is between 800 and 2500 metres above sea level (HCDA, 2011). The national average tomato yield in Kenya is about 30.7 ton per hectare. The total domestic value in the horticulture sector amounted to Kshs 177 billion in the year 2013 and was cultivated in an area of about 605,000 Ha with a total production of 132 million metric

tons, and during the year 2011, the area under tomatoes in Kenya was 21,000 Ha (HCDA, 2013).

In Kenya tomato cultivation is practiced through rain fed, irrigation systems and currently in greenhouses. Use of greenhouse cultivation as well as other modes of controlled environmental cultivation have been evolved to create a more favourable micro-climates, which favour the tomato production throughout the year or part of the year as required and its orientation permit shadow across the greenhouse covered with a transparent plastic film (polythene) for allowing natural light. Tomato is cultivated mainly by small, medium scale farmers and under contract farming (HCDA, 2013). The total water usage of tomato crop varies tremendously depending on the prevailing climatic conditions during growth, thus under hot and relatively dry summer conditions about 550 mm to 600 mm of water is required (HCDA, 2011).

Kenya has experienced climate related impacts such as prolonged drought and frost. In some of the productive agricultural areas, hailstorms, extreme flooding, receding of lake levels, drying of rivers has led to large economic losses and adversely impacting on the livelihood of the people. In the years 2008 and 2010 drought events led to drop in agricultural productivity by 72 percent and 13 percent respectively (GoK, 2010). The two most important climate parameters that are most studied in climate research are temperature and rainfall because of their immediate impact in various socio-economic sectors like agriculture and hydrology (Sayemuzzaman, Jha, Mekonnen, & Schimmel 2014). A number of studies like Tshiala and Olwoch (2010); Chijioke, Haile, and Waschkeit, (2011); Wachira, Mshenga and Saidi (2014); Molla (2008) and Mutumpike (2013) have been carried out on tomato production in various regions. However, few

scholars have looked at influence of rainfall variability and trends on tomato production among small scale farmers Arid and Semi-Arid Lands and hence the knowledge gap that this study sought to fill.

1.2 Statement of the Problem

The Nyeri County Department of Agriculture (Nyeri County, 2018), reports that erratic rainfall, rising temperature and other climatic parameters have resulted to variation in agricultural production. However, tomato production is an important source of income and livelihood to most small-scale farmers in Kieni East sub County, which provides them the opportunity to take up some social economic responsibilities. In recent times the rainfall variability and trends have led to variations in tomato yields and uncertainty to tomato income for the farmers in Kieni East sub County. Production of tomato is constrained by temperature and rainfall, market and marketing imperfection and inability of tomato farmers to access credit. Perishability of the produce as well as attack of the tomato by pests and diseases have paused a major challenge to the farmer. Majority of tomato farmers have continued applying traditional and inappropriate technology in production. This led to reduced production, low profits and inability to create jobs, alleviate perennial economic and social problems in the area. Marketing of tomato produce is affected by high pre-harvest and postharvest losses (HCDA, 2013). A number of studies on tomato production carried out left gaps on identifying some individual constraints on of tomato production.

Changing rainfall trends is a possible cause of the variations in tomato yields and income. There is limited information available at the crop level that addresses tomato production and the influence of rainfall variability and trends. It is not clear how these variations in tomato yields and income are correlated to the changing rainfall variations

and trends. Therefore this study investigated the correlation between the changing rainfall variability and their trends on tomato production in the area under study.

1.3 Purpose of the Study

The purpose of this study is to investigate the influence of rainfall variability and trends on tomato production and assess the adaptation strategies laid to rainfall variability among small scale tomato farmers in Kieni East sub County of Nyeri County, Kenya.

1.4 Specific Objectives

The specific objectives of the study were to:

i. Identify rainfall variability and trends between 1981 and 2014 in Kieni East sub County.
ii. Determine the relationship between rainfall variability, tomato yields and market prices in Kieni East sub County.
iii. Evaluate the farmer's adaptation strategies to rainfall variability and trends on tomato production in Kieni East sub County.

1.5 Research Hypotheses

The following hypotheses guided the study;

$H0_1$ There is no significant influence between rainfall trends and tomato yields in Kieni East sub County.

$H0_2$ There is no significant relationship between rainfall trends and tomato prices in Kieni East sub County.

$H0_3$ There is no significant relationship between farmers adaptation strategies and rainfall variability

1.6 Spatial Context of the Study

1.6.1 Location

Kieni East sub County is located in Nyeri County in Central Kenya. It is expansive and occupies about 817 km^2 (Statistical Abstract, 2018). In terms of geographical coordinates, the region lies between 0^0 00' and 0^0 24' South and 37^0 00' to 37^0 12' East (Figure 1.1). To the North, it boarders Meru Central sub County, Mathira sub County and Nyeri Municipality to the South, Mount Kenya to the East and Kieni West sub County to the West. Mt Kenya serves as a major water tower and a National Park of the Kieni East sub County. The land size per household varies across the sub County but with an average of two hectares per household (Jaetzold, Schmidt & Shisanya, 2006). Majority of the farms in the area are small scale and land ownership is predominantly freehold. The growing seasons are largely determined by two rainfall seasons that occur from October to December (OND) and March to May (MAM) each year. The study area had four administrative wards namely Thegu River, Kabaru, Narumoru/ Kiamathaga and Gakawa.

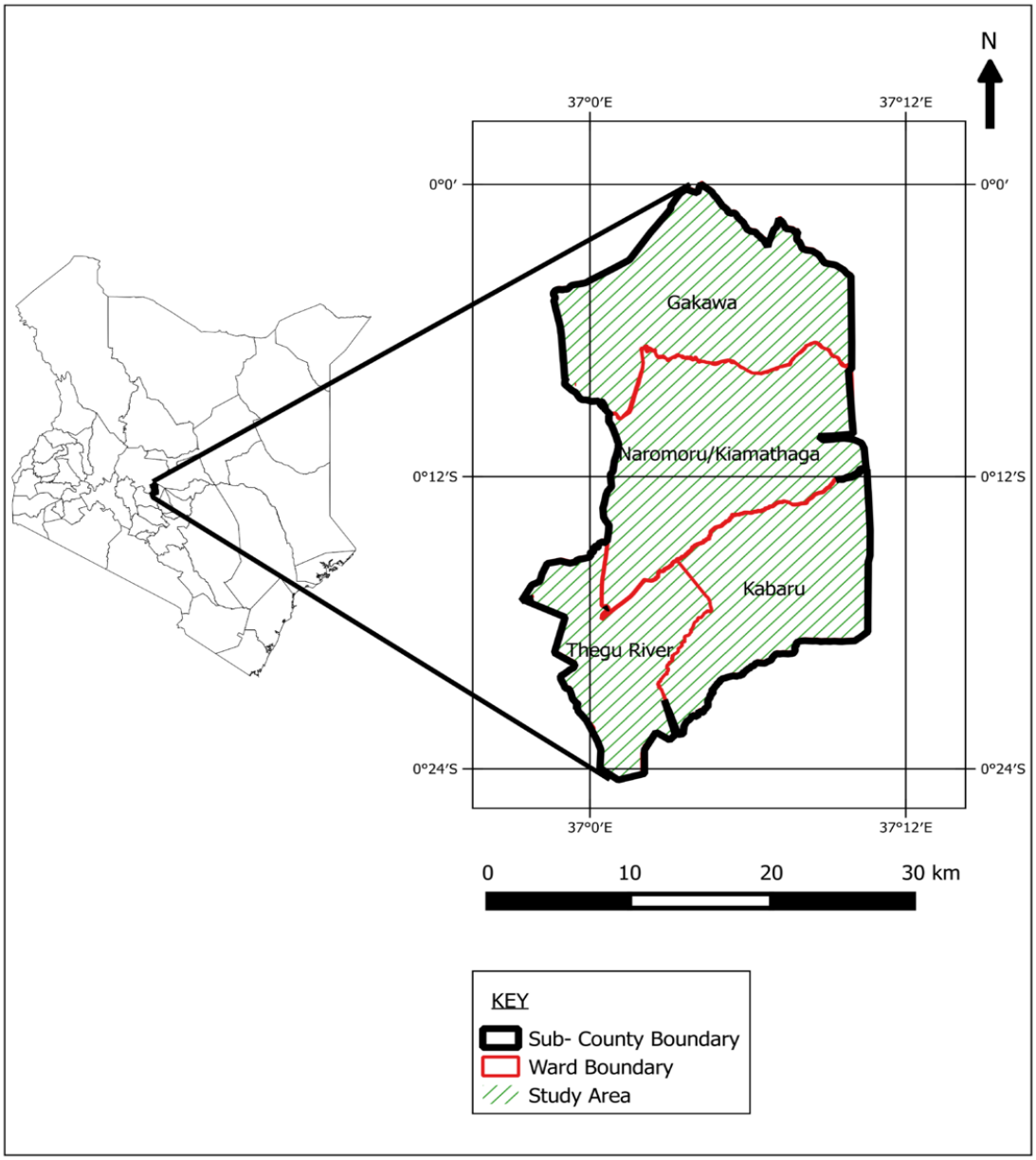


Figure 1.1: Location and Size of the Study Area. (Source: Kieni East Agricultural Office, 2013)

1.6.2 Population of Kieni East Sub County

Kieni East sub County has a population of 109,624 in 36,835 households (KNBS, 2019) and distributed in four electoral wards namely Gakawa, Narumoru/ Kiamathaga Thegu River and Kabaru. The areas (Ndathi, Kimahuri, Waraza Jet and Kamburaini) adjacent to Mt. Kenya are wetter and therefore are more densely populated than Lusoi, Githungo, Karicheni, Gatuamba and Nyange areas which are relatively dry. Table 1.1 shows the

electoral wards, population, and number of households and area of Kieni East Sub County. Gakawa ward is the largest in area while Narumoru/ Kiamathga are the smallest.

Table 1.1: Electoral wards, population, number of households in Kieni East Sub County

Wards	Population	No. of Households	Area (Sq. Km)	Locations
Kabaru	22527	7224	90.2	Ndathi, Munyu, , Huhoini, Mbiriri, Jet, Kairi Kimahuri, Kirima
Thegu River	19974	7000	117.1	Chaka, Lusoi, Thigu, Karicheni, Thigi, Gatei,Thirigitu, Maragima, Karicheni
Naromoru/ Kimathaga	34802	11317	133.6	Narumoru, Murichu, Gikambi, Kabendera Kamburaini, Kiamathaga
Gakawa	33073	11210	107.8	Kahurura, Gathiuru, Githima, Ndiriti

(Source: KNBS, 2019)

1.6.3 Climate

The study area is located on the lee ward side of Mt. Kenya which makes it vulnerable to extreme weather events which are sensitive to the agricultural economy of the area. Like other semi-arid regions, the area is characterized by low primary vegetation productivity and high geographical and seasonal variability in water availability (both surface and accessible ground water) (Nyeri County, 2013). Mount Kenya is one of the geographic features that influence the climate and weather patterns in different parts of Kieni East Sub County.

Climatic aspects like wind, rainfall, temperature and humidity are influenced by Mount Kenya. Temperature ranges between 12^0C during the cold months and 27 ^{0}C in the hottest months. The annual rainfall received in the region ranges between 550 mm in the lowlands parts of Kiganjo area and 1500 mm in the highlands (Kimahuri,

Kamburaini, and Kirima) areas, neighboring Mt Kenya. The area receives mean annual rainfall of 870 mm to 1000 mm. Kieni East sub County is characterized by a bimodal rainfall pattern with short rains esxperienced in OND while long rains is experienced in MAM (KNBS, 2009). The area is prone to flooding, and in 2013 flooding resulted to decrease in food production in parts of Kiamathaga and Thegu River (Orre, Muriithi & Obondo, 2013). There is 66 percent probability of rainfall during the short rains and long rains season (Jaetzold *et al.*, 2006).

1.6.4 Soils of Kieni East Sub County

Soils in the study area are characterized by Vertisols, (black cotton soils) which are dark, with about 30 percent of clay content. The soils are poorly drained and usually crack during dry seasons. The soils have developed on alluvial and colluvial materials as well as on basic rocks like basalts (Jaetzold *et al*., 2006). Areas adjacent to the forest have forest soils which are fertile (Jaetzold *et al*., 2006).

1.6.5 Topography

Kieni East sub County lies 2,300 to 4,000 metres above sea level. The area is served by shallow wells, water pans, piped water, seasonal and permanent rivers (Nyeri County, 2013). Notable permanent rivers include Nairobi, Narumoru and Thegu rivers which originate from Mount Kenya and several seasonal streams namely Lusoi, Tigithi, Kandune, Nyange and Lusoi earth water reservoir. Nyeri County (2013) noted that demand for water (for irrigation and domestic) is high which led to obstruction of rivers by farmers upstream. The area is characterized by gentle rolling plains (Jaetzold *et al.*, 2006).

The study area has two distinct relief features; the highlands which comprises of the mountains slopes and hills while the lowlands are basically stretching rolling plains. The land rises from Kiganjo/ Chaka area northwards towards the equator at Nanyuki, (2300 meters above sea level (ASL), and eastwards towards Mt. Kenya, (4,000 meters ASL). These altitudes are believed to affect the amounts of rainfall received in a given locality. For example, the lower zone of Thegu Ward (Kiganjo area) receives about 500 mm of rainfall per annum and it then increases eastwards to about 1600 mm per annum at Kabaru area on the slopes of Mt. Kenya (Nyeri County, 2013).

1.6.6 Socioeconomic Activities

The study area has a mean household farm size of 7.67 hectare per person. The major economic activities in the region include poultry keeping, apiculture (bee keeping) livestock farming and vegetable farming (baby corn, pepper, tomato, tree tomato, cabbages, kales, spinach, and snow peas and french beans) (Jaetzold *et al.*, 2006). There is farming of cereal crops (maize, wheat, barley, millet and beans) as well as root crops (Irish potatoes, yams, cassavas potatoes, carrots and sweet potatoes) and arrowroots grown along the river beds. Cut flower farming and tourism are commonly practiced around Mt. Kenya (IFAD, 2014). Farming in the study area is mostly practiced through rain fed (HCDA, 2013 and Jaetzold *et al.*, 2006), and largely determined by rainfall patterns.

1.7 Justification and Significance of the Study

The study is justified by the National Goals on economic self-reliance, Vision 2030 on economic development and food security, Sustainable Development Goals (SDG 1 on poverty elleviation, SDG 2 to curb hunger and SDG 5 to enforce gender equality) and

Big 4 agenda on manufacturing and ensuring food security. The horticultural sector provides jobs and wealth creation; alleviate poverty and addresses gender equity especially in rural areas and among the urban poor. Horticultural practices in the arid and semi-arid lands (ASALs), are crucial to overall economic and environment development. In Kenya, poverty rate is 52 percent while 73 percent of the labor force depends on agricultural production. Thus many horticultural farmers are likely to experience adverse impacts from rainfall variations (FAOSTAT, 2010).

Tomato production is mainly practiced by smallholder farmers and has been conventionally under open and rain-fed field conditions until recently when production under modified high tunnels popularly known as 'greenhouses'. Greenhouse method of farming has gained gradual adoption despite the high cost of installation. In the last 2 to 3 years tomato farming provided a large number of jobs and uplifted the living standards of people of Kieni East sub County. In the year 2011, Nyeri County produced 7,916 MT of tomato, with a value of Kshs 230,000,000. In the year 2011, the Kieni East sub County produced 3,700 Metric tons of tomato with a value of Kshs 74,000,000 which represents 46 percent and 32 percent respectively of the Nyeri County tomato production, an indication that tomato production is a major undertaking in the study area (HCDA, 2011 and Kieni East Sub County Agriculture Office, 2013), Tomato farming contributes to employments, food security, gender equality and improved living standards of the people living in Kieni East sub County. Thus a decline in agriculture production has far reaching implications in terms of income, employment, gender inequality as well as the social status of the country (IFAD, 2014).

This study provided an understanding of rainfall variability, the correlation between rainfall variability and trends on tomato income, yields and farmers' adaptation strategies to rainfall variability on tomato production in Kieni East sub County. The study will significantly contribute to Nyeri County Strategic Plan (2018-2022) in promotion of agriculture productivity in ASALs, job creation of the growing population, Kenya Agricultural and Livestock Research Organization (KALRO), Agricultural Extension Officers, Farmers Training Centre, and policy implementers in trying to mitigate tomato farming and seasonal variations of rainfall in Kenya.

1.8 Scope and Limitation of the Study

The study was carried out to assess the influence of rainfall variability and trends on tomato production among small scale farmers, and farmer's adaptation strategies in response to the changing rainfall variation in Kieni East sub County, Kenya. The geographical study area covered Kieni East sub County and is vulnerable to rainfall variability. Farmers produce tomato and undertake other agricultural activities as a means of their livelihood. The weather variables which influence production include rainfall, temperature, wind, humidity and sunshine among others. This study considered rainfall as the most critical element that influences tomato production, as argued by Sayemuzzaman *et al.,* (2014).

Kieni East sub County farmers grow a variety of horticultural crops, but the researcher took the study on tomato production. The questionnaire was designed to capture information on annual tomato production, availability of farm inputs, seeds, planting to marketing and source of agricultural information from tomato growing farmers. Farmers who had planted tomatoes were interviewed, in a survey which sought 45 randomly selected tomato farmers in the identified wards within the sub County.

Annual rainfall data for the period between 1981 and 2014 was obtained from the Kenya Meteorological Department (KMD) Nairobi while data on annual tomato production and annual income from the sale of tomato for the years 2009 to 2014 was provided by the Kieni East sub County Agricultural Office in Narumoru. In the process of data collection some respondents were reluctant to fill the questionnaires administered; this may have been a limitation to accuracy of the data and information collected.

1.9 Operational Definition of Terms

Acreage	Size of land under tomato farming.
Adaptations	Transformation of the environment into opportunities to sustain agricultural production, despite extreme climatic conditions.
Climate	Statistical summary of all weather conditions that occurs at a certain location over a long period (over 30 years is often used).
Demand	Is the function that gives the number of units purchased as a function of the price
Income	Money generated from tomato proceeds.
Livelihood	The major activity that is a source of income to the local people
Rainfall distribution	is the occurrence of storms throughout a growing season.
Rainfall variability	the uneven and unpredictable rainfall during a growing season.
Small-scale Farmer	A farmer cultivating less than four acres of tomato.

Tomato Production	Will refer to tomato yields and prices
Weather	The local conditions of atmosphere at a particular time, which includes temperature, speed of wind and rainfall which varies from daily and from season to season.
Yields	The annual amount of tomato produced by farmers in tons.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the relevant literature on the study and is organized in the following subsections; rainfall characteristics, rainfall variability and tomato farming, farmers' adaptation strategies to the changing climate on tomato farming, theoretical framework and conceptual frame work.

2.2 Climate Variability Effects on Agriculture and Livelihoods

Climate change has a significance effect on global food production and extreme weather events and the year to year variability pose great risk to food security globally. The differences between long term climate over shorter period (a month) is referred to as climate variability (Waliser *et al*., 2012). Many of the largest reductions in crop productivity have been attributed to anomalously low precipitation events (Kumar et. al., 2006). El Niño and La Niña influences agriculture and pose a risk of extreme events in the region such as drought and related food crisis, particularly in countries near the core of the South East African climatic region (Mogaka, Gichere, Davis & Hirji, 2006).

Globally, climatic parameters influence agriculture at varying degrees, but the most important parameters that impact agriculture production are temperature and the rainfall and therefore widely studied. The two variables have direct and indirect effects on agricultural crop production (Sayemuzzaman *et al.,* 2014). Datta (2013) noted that variation of rainfall patterns and fluctuations of temperature greatly affected the production of vegetable crops like pepper in India. Production of crops has a direct relationship with rainfall variation (increase or decrease) and this has a profound impact

on the crop yields (Masahumi *et al.*, 2011). Globally, about 80 percent of the total agricultural production depends on rains and therefore the future of precipitation change will influence the magnitude of crop production (Olesen & Bindi, 2011).

The link between rainfall, socio-economic activities and livelihood in society is very strong. Studies carried out on climatology acknowledge extreme climate events such as drought and hailstone will lead to social economic challenges like poverty and disrupt the livelihood of rural people in many parts of sub Saharan (Walthall, Hatfield, & Backlund, 2012). Majority of rural farmers depend heavily on rain-fed agriculture and rural livelihoods are highly vulnerable to the changing rainfall variability trends such as less than normal rainfall, normal rainfall but in a few days or even more rainfall than normal (Seitz & Nyangena, 2009). Livestock keeping, poultry farming and crop production at various levels remains the main livelihood for most rural communities which account for about 86 percent of the people who live in rural areas, about 2.5 billion (The World Bank, 2008). There is need for improved adaptation strategies in the agricultural sector to cushion the adverse effects of climate change, raise the livelihoods of the rural poor and to ensure food security (FAO, 2012).

Arid and semi-arid lands receive rainfall that is low and erratic variable both in space and time notes (UNDP, 2013). Precipitation is highly variable spatially and temporally, and data is limited in some regions (IPCC, 2007). Any change in climate on a global scale impact on agriculture as a whole and consequently affect the world's food supply. Frequent rainfall and temperature variations and patterns reduce crop productivity (Kumar *et al.*, 2012). With the on-going changing rainfall variability trends, associated with climate variability, African countries must adopt policies and strategies that would make agriculture sector resilient, more productive and sustainable. The model on global

climate predicts a range of about between 5 to 20 percent in rainfall variability in Kenya by the end of the year 2030 (World Wide Fund, 2006). Hydro-meteorological risks such as droughts, cyclones and floods not only endanger human lives and property but also have devastating impact on food production and farmers' livelihood systems sometimes across countries and continents (WMO, 2009).

A number of countries in Africa are located in areas prone to extreme climate variations such prolonged drought, hailstorms, unpredictable rainfall patterns that has led to famine, humanitarian disasters and poverty (Mutimba, 2010). In the last two decades agricultural sector in Kenya has been faced with frequent droughts and occasional flash floods, leading to a decline of reliability of rainfall, particularly in the ASALs. These changes in rainfall amounts received, timing and distribution patterns, had lowered agricultural production (Huho & Kosonei, 2013). Lobell and Burke (2008) reported that a change in growing seasonal precipitation by one standard deviation could be associated with as much as a 10 percent change in crop production. Kenya experienced a severe drought in the year 2009 that led to famine which affected 10 million people countrywide after poor harvest and crop failure (Kenya Red Cross, 2009).

Climatic variability represents a sensitive balance between agricultural production, livelihood and food security. Any change in agricultural related variables such as temperature and rainfall are likely to reduce yields of tomato, maize, beans among other crops in ASALs regions of the world among them Keni East Sub County (Lobell, 2010). However, not all changes in climate related variabilities are seen to be negative. It was observed that parts of the Ethiopian highlands and in Mozambique, changes in climate, increased temperatures and rainfall extended the agricultural growing seasons, resulted to increased production and income (Thornton *et al.,* 2006).

2.3 Impacts of Climate Variability in East Africa

East Africa lies within the tropics where the rainfall regime experienced is mainly bimodal with 'long rains' in March, through April to May (MAM) and the 'short rains' in October through to December (OND). Inter-annual climate variability has resulted in huge impacts on the region's climate leading to El Niño events that result to abnormally high amounts of precipitation in parts of equatorial East Africa and result in flooding and decreased agricultural yields. According to IPCC (2007), East Africa has been faced by large rainfall variability with occurrence of extreme weather events of droughts and floods. Droughts in the last 20 years 1983/84, 1991/92, 1995/96, 1999/2001 and 2004/05, led to famine. The El Niño related floods of 1997/98 were severe events and La Niña in the year 1999 and the year 2000 was the severest in the last 50 years.

Muga (2010) noted that intensification of variability (deviation from the mean) of crop production is also a major concern of farmers in Eastern Africa. It is noted that extreme and harsh weather is more frequent in Kenya. As regards to rainfall, the most visible feature is the increased variability year to year, and during the year. There is a general decline of rainfall in the main rainfall season of March to May (the "Long Rains") and "Short Rains" (October to December) seasons which has been observed to extend into what is normally hot and dry period of January and February (GoK, 2010).

Exposure to impacts of rainfall variability changes and extremes, most particularly drought, poses substantial risks to people living in Central Kenya, especially those deriving their livelihood from rain fed farming in the rural areas causing widespread famine (Kenya Red Cross, 2009). The climatic factor of greatest economic and social significance in Kenya is rainfall. For instance, the southeastern low potential

agricultural areas, of Kieni East Sub County (Chaka, Githungo, Thungari) have been seriously affected by the delayed onset of the season (November instead of October) and an irregular spatial and temporal distribution of rains, as well as above normal temperatures (Rembold, Thomas, Nkunzimana, Pérez-Hoyos & Kayitakire, 2014). Rembold *et al*., (2014) notes that evaporation, radiation, temperature wind speed, sunshine hours and humidity add detail to our understanding of the impact of climate on society.

About 80% of the total land mass in Kenya is occupied by the arid and semi-arid lands. The rainfall is sparse and is characterized by high variability between years and seasons more over extreme and unpredictable. In addition the rain occurs in intense storms which cause flooding and heavy run-offs. Sometimes massive soil erosion results due to the scant vegetation cover (Jaetzold *et al.,* 2006). Ogalleh, Vogl, Eitzinger & Hauser (2012) noted that smallholder farmers in Kenya perceived that excessive rainfall and drought conditions have the potential to cause tomato failure and inaccessibility to food availability.

Changing rainfall patterns directly or indirectly affect crop production by limiting the uptake of agricultural inputs or render them inefficient (e.g. fertilizer, manures, pesticides and herbicides) (Kassie, Van Ittersum, Hengsdijk, Asseng, Wolf, & Rötter, 2014). Over the last three decades East Africa has recorded high frequency of droughts and floods that resulted to increased crop failures, water shortage and loss of livestock (Salami, Kamara. & Brixiova, 2010). More unpredicted rainfall patterns and low to high temperature periods reduce tomato production in terms of quantity and quality. Therefore, stringent measures need to be implemented to mitigate the effects of rainfall

variability on food security which are under threat in developing countries (Kumar *et al.,* 2012).

Unpredictable and prolonged drought periods affect food security, peoples' livelihood and the catalyst of the great famines in many global regions (Kumar *et al.,* 2012). Decreased precipitation cause reduction of water for irrigation availability in reservoirs and raise in evapo-transpiration rate, thus result water-stress conditions in succulent tomato fruit consisting of more than 90 percent water content (Kumar *et al.,* 2012).

2.4 Farmers' Adaptation Strategies to Rainfall Variability

Climate adaptation is defined as the ability, initiatives and measures that are undertaken to cushion the vulnerability of both natural and human systems against actual or expected or predicted change of climate effects (IPCC, 2007). The survival of majority of people in ASALs depend so much on the availability of natural resources which are vulnerable to variability of rainfall (Morton, 2007). Therefore, it is crucial to understand the responses to rainfall variability and come up with effective coping strategies that are community and environment friendly. Droughts pose the main challenge to people who live in rural areas and largely rely on agriculture for their livelihood, therefore proper measures must be put in place to embrace environmental friendly adaptations against drought. Taiz and Zeiger (2010) suggested that drought is a meteorological term for a period of insufficient precipitation and results in plant water deficit, therefore farmers must lay down adaptation strategies.

The horticultural sector is seen to be evolving very fast as a result of increase in demand for production, population increase, decreasing land sizes for cultivation as well as the changes in local and global climates (Odame, Musyoka, Kere & Innovations, 2008). It is noted that persistent low rainfall and high temperature in East Africa region has

resulted in persistent low water levels in rivers, reservoirs and aquifers (VARCC, 2009) and this has influenced biodiversity conservation and water use for domestic, industrial and irrigation purposes and finally the crop production. Alternating cycles of droughts and floods, as a result of climate change have been experienced in Kenya in 2004, 2006 and 2009 where droughts and floods affected crop yields and income (Huho & Kosonei, 2014). In systems reliant on rainfall as a single source of moisture for production of crop, seasonal rainfall variability is inevitably mirrored in both highly variable production levels and in the risk-averse livelihood and adapt strategies that have emerged over time amongst rural populations. The World Bank report on adaptation strategies of small scale holders agriculture to climate change in Kenya, indicates that farmers employs a number of strategies that are cheap and environmental friendly such as changing crop variety and planting dates, changing crop type to cope with prevailing climate.

For most rural communities, agriculture activities remains the main source of livelihood therefore valid and cheap adaptations strategies to the adverse effects of climate change must be imperative to maintain, protect and improve the livelihoods of these communities (FAO, 2012). Different communities respond differently to rainfall variability depending on their adaptive capacities within their agro-ecological zones which they have developed over time to cope with. This explains why there exists region-to-region, village-to-village and household-to-household variation in coping strategies (FAO, 2012). Therefore, adaptation strategies to changing rainfall variability remains crucial phenomena to the communities to enable them absorb shocks and risks that result from rainfall variability.

Adaptation involves the action that the local community takes in response to, or in anticipation of, projected or actual climate changes to reduce adverse impacts or take chance of the opportunities posed by variability of rainfall trends (Parry, Hammill & Drexhage, 2012). Food and Agricultural Organization (FAO, 2008) noted that adaptation strategy is critical to protect the livelihoods and food security developing countries. It entail actions aimed at coping with climatic changes that cannot be avoided to reduce their negative impacts and enhance the capability to capture any benefit arose from climate change.

For example, in West and East Africa, communities living in particularly in ASALs and other dry land have developed traditional water harvesting systems in response to the increasingly frequent droughts (Jama, Kaitho, Wu, & Macopiyo, 2008). Another important issue that has been largely overlooked in the impacts and adaptation studies is that of the inter- and intra-seasonal variability of rainfall. Long-term changes in climatic such as temperatures and rainfall may be dealt with quite successfully if the right crop species/ varieties or cropping techniques are applied (Serigne, Kandji & Jens, 2006).

FAO (2007) adds that adaptation strategies for agricultural cropping systems to the changing rainfall variability trends needs a higher resilience against both excess of water due to high intensity rainfall and deficiency of water during the extended droughts. A solution to both problems entail increase of manure and organic matter (mulch), which improves and stabilizes the soil structure so that the soils can absorb and retain higher amounts of water to be available during extended drought without causing surface run off, which could result in soil erosion and flooding.

Adaptive strategies include developing capacity for drought early warnings, changes in cultivated land area in line with control of pests, weeds, parasites and use of irrigation and fertilizers. Other strategies include changes in crop location, improved flood control activities, rescheduling of planting dates, and wider use of early-maturing varieties (Serigne *et al*., 2006). Other agricultural adaptation strategies include; provision of downscaled weather information and farm input and water harvesting e.g. build of earth dams for irrigation. There is protection of soil as a natural resource and water conservation techniques; use of different crop varieties and varying planting dates.

Finally, there is increased use of water and soil conservation techniques and diversifying from farm to non–farm activities and research and dissemination of superior (drought tolerant, salt-tolerant, pest and disease resistant) crops (GoK, 2010). The attack on tomato by pests and diseases is reduced, tomato fruit size increases, both in quantity and quality per plant. Tshiala & Olwoch (2010) identified irrigation as an effective adaptive strategy that enhances the improvement of horticultural crop yield. In Sub Saharan Africa farmers need tools to adapt and mitigate the adverse effects of rainfall variations on agricultural productivity, and particularly on vegetable production, if quality and quantity of production are to be sustained (Kumar *et al.*, 2012).

2.5 Tomato Production and its Contribution to Food Security and Livelihoods

Tomato (*lycopersicon esculentum*) belongs to Solanaceae family and originated in the South America and was later introduced to Africa. Tomato fruit is one of most important popular, edible and nutritional vegetable crops in the world and ranks next to potato and sweet potato with respect to world vegetable production. It is widely cultivated in tropical, sub-tropical and temperate climates. FAO (2008), estimates that

126 Million Tons (MT) of tomatoes were produced in the world and China, the largest producer accounted for about one fourth of the global output, followed by United State, Turkey, Iran, Mexico, Brazil, and Indonesia. Tomato is one of the Fresh Fruits and Vegetables, (FFV) of high-value that is widely consumed fresh (salads), cooked (sauces and soup) or processed (ketchup) for it is rich in minerals, vitamins and dietary fibre and is grown in almost every country of the world (Starke, 2014; Table 2.1).

Tomato production is water and labour intensive which scales up the production costs, and provides a profitable livelihood for rural and urban people (Koenig, Blatt, Brakel, Kloss, Nilges & Woellert, 2008). Tomato fruits are consumed in many countries in world, becoming the main supplier of several plant nutrients and providing an important nutritional value to the human diet (Willcox, Catignani & S. Lazarus, 2010). Tusiime (2014) evaluated horticultural practices for sustainable tomato production in Kamuli, Uganda and noted that tomato farming is a source of income and job creation for small-landholder farmers across Uganda. In Ethiopia tomato is among the most important vegetable crops produced in private horticultural enterprises, commercial farms and small farmers scattered in various parts of the country.

2.6 Tomato farming in Kenya

In Kenya, tomato production is ranked second after Irish potato. Tomato farming has demonstrated proven price elasticity, caused by the additional costs the farmers face in the dry and rainy seasons respectively (Koenig *et al*., 2008). Field production of tomatoes generally involves exposure to various sub optimal environmental conditions and environmental stress factors including high temperature, scarcity of water or excessive water. Long dry periods lead to water stress in tomato plant, that cause tomato flowers to wilt, buds dry off and fruits drop off. High rainfall and heavy humidity

increases incidences of early and late diseases and growth of molds, fruit rot and fall off (Starke, 2014), and the eventual result is decreased yields in term of quality and quantity. Tomato crop is sensitive to weather change and not resistant to drought and during periods of water deficiency yields reduce considerably. During the periods of inadequate rainfall when tomato plant is flowering and forming fruits, adequate water must be provided regularly through irrigation and mulching done. Starke (2014) noted that the amount of water a tomato plant need will depend on the locality amount of rainfall available, prevailing winds, temperature and humidity. Tomato harvesting is ideal when it is warm and usually harvesting commence in about 14 weeks from transplanting in the farm. Once the tomato fruits start to ripen, marketing follows since the fruits are highly perishable and need to be transported to the markets immediately since they cannot be stored for long. Therefore, farmers should know the size of the market outlets ready and most rewarding financially. Figure 2.1 shows the average price of tomato per kilogram from the year 2006 to year 2012 in Kenya.

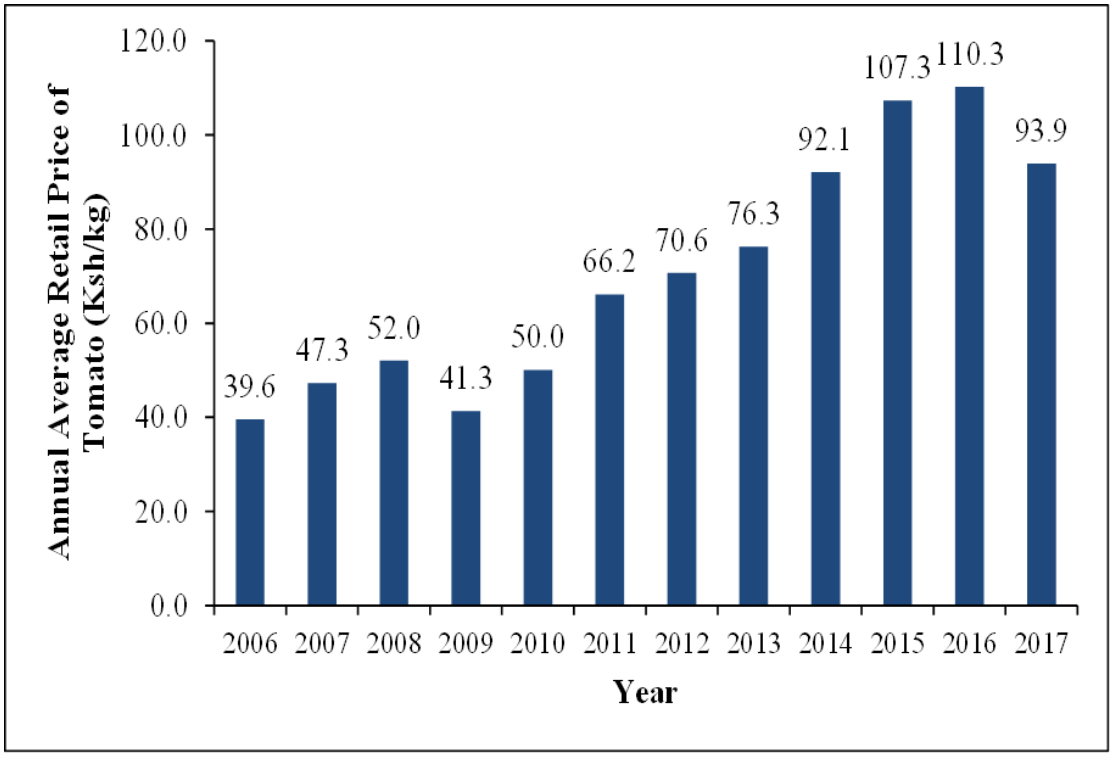


Figure 2.1: Average Price of Tomato per Kilogram in Kenya. (Source with modifications: Kenya Statistical Abstract, 2018)

The average price of a kilogram of tomato has been on a gradual increase since the year 2006 but dropped significantly in the year 2009 and again adopted the rising trend in the subsequent years. The variability of price is as a result of production (quantity and quality), market forces, human and rainfall factors. It was noted that during the periods of high rainfall, the demand of tomato increased and this led to high market prices and consequently the tomato farmers were able to receive high income.

The most commonly reported adaptation strategies of smallholder farmers to rainfall variability in Kenya are changing crop varieties, changes in planting dates, irrigation, soil conservation measures, tree planting, water harvesting and changing crop types (Bryan, Ringler, Okoba, Roncoli, Silvestri & Herrero, 2013). Depending on the locality and season, tomato farmers must identify and embrace potential strategies that will

cushion against shocks due to varying rainfall amounts and would contribute towards refinement of policies to deal with rainfall variability. Therefore, in wake of changing rainfall variability, the tomato farmers should reduce risks by employing several adaptation strategies which start from land preparation to harvesting. In most agricultural potential areas, tomato production has been adopted as a way of ensuring incomes and food for the communities and households.

Table 2.1: Performance of Selected horticultural crops grown in Kenya

	Year 2011			Year 2012			Year 2013		
Crop	**Area (000Ha)**	**Quantity (000MT)**	**Value (,000,000 Kshs)**	**Area (000Ha)**	**Quantity (000MT)**	**Value (,000,000 Kshs)**	**Area (000Ha)**	**Quantity (000MT)**	**Value (,000,000 Kshs)**
Irish potatoes	124	1593	474	117	1546	20424	140	2064	28250
Tomato	21	397	10231	22	445	12272	24	494	14137
Cabbage	19	542	141	19	503	6658	25	762	7842
Kales	25	418	107	29	367	5730	29	399	5691
Carrots	4	84	53	4	169	2045	5	235	2799
French beans	4	29	21	4	34	1273	5	38	1824
Garden peas	13	57	28	11	46	756	14	61	1582

Source: Horticulture Report, 2013

2.7 Conceptual Framework

The conceptual frame work presented in Figure 2.2 guided this study. Rain fed tomato farming is affected by droughts which cause water deficit to the plants, and excessive rainfall which cause soils to be logged. In Kieni East sub County, rainfall constitutes the main water source for crops. Rainfall characteristics such as rainfall amount, early onset, early cessation, rainfall distribution and rainfall intensity affect tomato yield and quality. The rainfall characteristics determines the adaptive capacity to be applied such as farm level decisions on the appropriate time of planting, the methods of farming and sustainable land management practices such as mulching, digging trenches and irrigation to be put in place during the entire farming season.

Intervening variables such, as soil type, soil fertility, seed quality of tomato, government policy on farming and weather forecast cannot be overlooked for they are important in determining the tomato yields. The tomato farmers have little or no influence on those factors. It is noted that small-scale farmers face additional problems such as inadequate visits from extension field officers, inaccessible to climatical information, inadequate knowledge and the wildlife menace (Lamarque, Anderson, Ferguson, Lagrange, Osei-Owusu & Bakker, 2009).

Moderating variables, such as farming methods employed, farming decisions, transport, labour, capital, literacy and the time for planting affect tomato yields. The adaptive capacity and moderating factors depends on the socio-economic factors such as the tomato production experience, financial capability and education level of the farmers. Literate farmers are more receptive to new ideas and fast in decision making thus influencing tomato farming which may lead to increase in production and consequently high income. Availability of land and land tenure system is also a factor that adaptive

capacity and intervening factors have to depend on for tomato production to take place. Transport costs affect the market price of the tomato yields and communication enable farmers receive information on rainfall intensity and distribution, which eventually affect farming, yields and the income. Farmers who are financially stable are able to practice intensive tomato production in case of reduction or inadequate income from tomato sales.

Therefore, tomato farmers must adopt strategies against rainfall variability to enable them absorb risk shocks and increase production of tomato. The adoptive strategies depend on farmers' knowledge, experience and finances. Farmers may put up greenhouses to enable tomato production throughout the year, dig water reservoirs to irrigate during dry season, mulching, pump water from the rivers and even grow tomato alongside other crops like maize and beans to ensure a harvest should the tomato fail. Some tomato farmers also grow greenhouse tomato seedlings in open fields as a way to increase production.

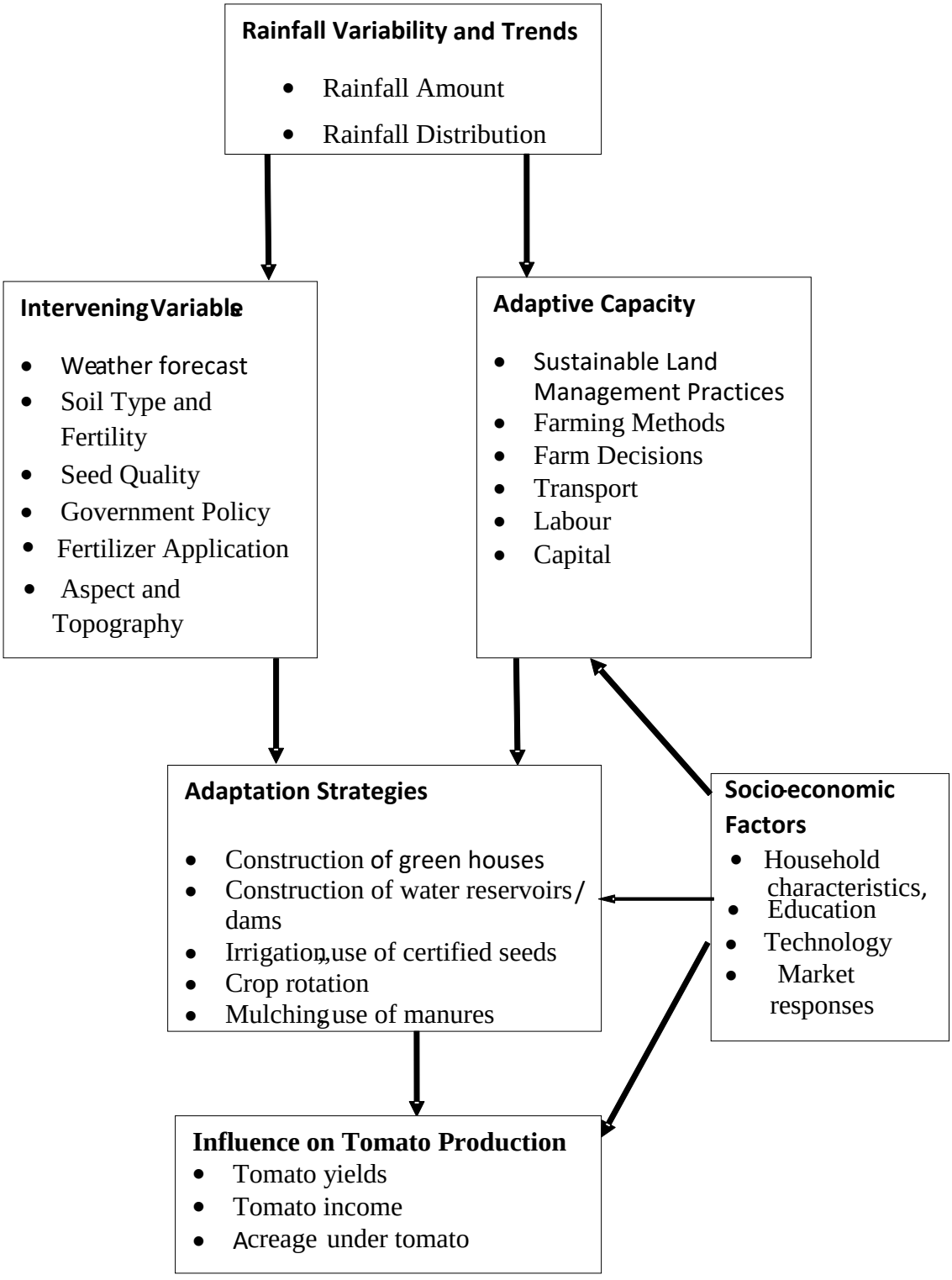


Figure 2.2: Conceptual Framework for rainfall variability and Tomato Production (Developed by the Researcher)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter looks at the methodology employed in the study. It discusses research designs, research instruments, sample and sampling procedures, validity and reliability instruments, ethical considerations, data collection as well as data analysis techniques.

3.2 Research Design

The study adopted quantitative research approach in which cross sectional survey design was employed. The design involved selecting a sample of a population at a particular point within a shorter period of time without manipulation of the study environment. Quantitative research method is the philosophical assumption that the world is relatively stable, uniform and coherent that researchers could measure, describe, understand and make generalizations (Gay, Geoffry & Peter, 2009). This design was appropriate for the study as it used the sampled views of the population in order to make generalization about the target population. The samples tomato farmers in Kieni East sub County gave their views which were quantitatively analyzed. To complement the household questionnaires, Ward Agricultural Officers and extension staff in the ministry of Agriculture were also interviewed.

3.3 Selection of Study Area and Sites

The study area in Kieni East sub County was purposely selected based on its geographical location in semi-arid region and to include diverse wards where tomato has been grown for the target period from 2009-2014. The four wards namely Thegu River, Kabaru, Gakwa and Narumoru/ Kiamathaga within Kieni East sub County were selected.

3.3.1 Target Population for the Study

The population targeted included all the tomato farmers and the unit of analysis was the farm household. The respondents for the study were selected using simple random sampling method which gave a high level of representation that provided the respondents with equal opportunity of being selected to participate in the study. The target population for this study consisted of smallholder's tomato farmers. According to Ministry of Agriculture Kieni East sub County, the number of tomato growing farmers was 142. The sample size was calculated following Borg & Gall (2003) procedure where thirty percent of the total population is considered a good representative in research (Table 3.1). The size of the sample of 45 farmers was thus considered adequate to derive sufficient data within the project time frame, finances and human resource (Neumann, 2000).

Table 3.1: Tabulation of sampled tomato growing farmers in Kieni East sub County

Wards	**Total number of tomato growing farmers**	**Sample size (30%)**
Kabaru	35	11
Thegu River	51	16
Naromoru /Kiamathaga	39	12
Gakawa	17	6
Total	**142**	**45**

3.4 Data Collection Procedures

All the necessary authorization documents required for the research to be carried out including the permit from National Commission for Science Technology and Innovation (NACOSTI) were obtained prior the planning of collecting the data. The local administrative officers and agricultural officers were contacted and permission sought to collect data and to explain the purpose of the study. A field data collection plan was made during the fieldwork preparation period which outlined fieldwork

activities and the data collection schedule to be followed. Once this was done data collection instruments were distributed as further explained below.

3.4.1 Research Instruments

The reliability and validity of the data collected was maximized through use of properly constructed tools, appropriate data collection procedures targeting the right population and sampling techniques to yield accurate data (Mugenda, 2011). This study used semi structured questionnaires administered to tomato farmers and interview schedules with agricultural extension officers.

3.4.2 Questionnaires

Primary data was collected from randomly selected tomato farmers in the area through questionnaires. A questionnaire containing questions (Appendix 2) was administered on the selected tomato farmers in the four wards, namely Gakawa, Thegu River, Kabaru, and Narumoru/ Kiamathaga. The farmers filled questionnaires, and then the researcher collected them immediately. Farmers with low literacy level were assisted by the researcher to fill the questionnaire. The questionnaire sought to collect data on social and demographic characteristics (location, farmers' age, land size, types of vegetables grown, household characteristics); and tenure; scale of tomato production (land under tomato cultivation, sources of labour and farming trends); market of vegetables (markets, income from vegetable sales etc.) and finally farmers' adaptation to rainfall variability.

3.4.3 Observation and Photography

The researcher would make observations on the tomato crop grown, size of land and how they are produced in the area under study, then made necessary recording on field

note book. The researcher also took photographs of the crops in the farms, adaptation evidences and transport methods to various markets.

3.4.4 Interview

Then study used face-to-face interviews with agricultural extension officers and individual farmers who produce tomatoes and earn income from the sales of tomato. This was meant to validate the information obtained in the questionnaires.

3.4.5 Secondary Data Collection

Secondary data was collected from journals and reports from Kieni East Sub County agricultural offices in Narumoru. Monthly rainfall data from 1981 to 2014 was collected from the Kenya Meteorological Department in Nairobi. Annual rainfall data was used to correlate with annual tomato yields and income which was availed by the Agricultural office. The Kieni East sub County Agricultural Office at Narumoru provided the annual data on tomato yields and income for the years 2009 to 2014.

3.5 Data Analysis and Presentation Techniques

The data collected was analyzed quantitatively. Quantitative approaches applied involved descriptive and inferential analysis of the data. Data from questionnaire was coded and analyzed using Statistical Package for Social Science (SPSS) version 20.0 Pie charts, bar graphs, tables and percentages were used to present the various data. Pearson's Product Moment Correlation Coefficient was applied to determine the correlation between rainfall characteristics and tomato yields. When Pearson's Correlation *r* is close to 1, indicate existence of a strong correlation between rainfall and yields. A positive Pearson's *r* means that when one variable increases in value, the second variable also increases in value, and similarly as one variable decreases in value,

the second variable also decreases in value. Trend analysis was carried out on annual and mean rainfall and tomato yields between 2009 and 2014.

3.6 Validity and Reliability of Research Instruments

3.6.1 Validity

Validity is the accuracy and meaningfulness of inferences observed, based on the research results. It is the level to which results obtained from the analysed data actually represent the truthfulness of the study (Mugenda & Mugenda, 1999). The researcher validated the research instruments in terms of content and face validity. The validation of the questionnaires and interview guide were done through the following ways: the researcher requested research experts, professionals involved in related study to review the items on the instrument to determine whether the set of items accurately represented the variables under study after which the research experts requested to judge, make recommendations and give feedback to the researcher. The instruments were improved through their recomendations. The validity of the instruments were tested through piloting done in an area with similar climatic conditions as the study area. Piloting was done in Mweiga Ward in Kieni West sub-County, neighbouring Thegu and Narumoru/ Kiamathaga Wards in Kieni East sub-County with similar climatical conditions. A total of 12 questionaries were administered.

3.6.2 Reliability

Reliability focuses on the degree of internal consistency over time of a research instrument. A research instrument must be reliable to yield consistent results when applied more than one instances in data collection or when gathering information from two samples drawn randomly from the same population (Mugenda & Mugenda, 1999). Reliability of the instruments was computed using SPSS version 20.0 by applying

Cronbach's Alpha reliability test. Cronbach's Alpha reliability test estimates internal consistency by determining how items on a test relate to all other test items and to the total test (Gay *et al.,* 2009). According to Bowling (2011), an Alpha index of 0.7 or higher is considered a sign of acceptable internal consistency. The pilot study found that Cronbach Alpha index was more than 0.7 which was considered to be adequate.

3.7 Ethical Considerations

The authority to conduct the study was sought from Board of Post Graduate studies of Karatina University and NACOSTI. The questionnaire did not contain the name of the respondents. Research ethics was upheld at all stages of data collection. Honesty and objectivity prevailed when collecting, analyzing, interpreting and presenting data. Information obtained from respondents was treated with great care and confidence.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.0 Introduction

The study was carried out to evaluate influence of rainfall variability and trends on tomato production among small scale farmers in Kieni East sub County, Kenya. The key findings of the study are presented in the proceeding sections. First, the chapter addresses the respondents' demographic characteristics; followed by the annual rainfall characteristics and trends for the period 1981 – 2014. Section three presents status of tomato farming, production and yields and finally the chapter focuses on farmers' adaptation strategies against changing rainfall variability trends.

4.1 Demographic Characteristics of Tomato Farmers in the Study Area

4.1.1 Gender

About 83.3 percent of the respondents were men while about 16.7 percent were female as presented in Figure 4.1, an indication that men were the majority.

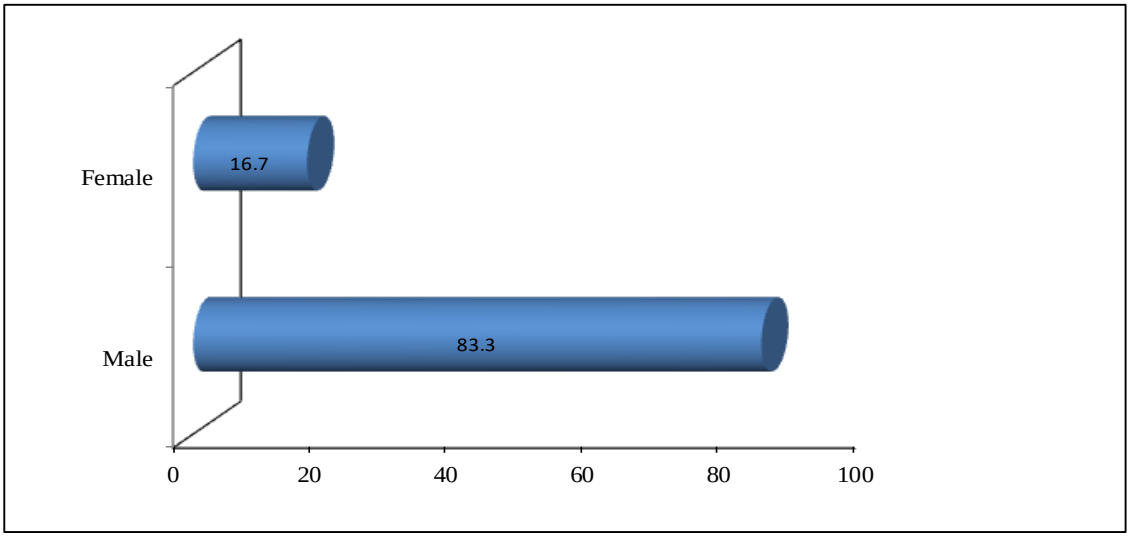


Figure 4.1: Gender of the Respondents

The sex distribution of the respondents indicates that tomato production in the sub County is mainly male dominated. This was attributed to more labour demand like clearing and digging new farmlands like in Thegu River ward, preparing of seedbeds (nurseries), digging water reservoirs, pumping water from rivers and water reservoirs to the tomato farms, constructing earth water reservoirs and spraying tomatoes against diseases and pests. Tomato production demands more skills during the transplanting, staking, pruning, application of fertilizers, loading of crates (a crate weighs 50 to 70 Kg) of tomatoes into the vehicles and motorcycles and transporting to the markets while the females carried out lighter domestic duties like weeding, harvesting, sorting, grading and packing.

4.1.2 Education Level of Tomato Farmers

The respondents who participated in the study had varying education levels. About 45.3 percent had acquired secondary level of education; 45.2 percent had attained primary level of education while about 9.5 percent were university graduates (Figure 4.2). This implies that the tomato farmers had acquired some basic knowledge and information relating to tomato farming, which enabled them apply and adopt the various modern methods of tomato production and to practice it as a source of income.

Results in Figure 4.2 imply that respondents who had a greater level of education had a higher potential of identifying, influencing, adopting and implementing sound adaptive strategies to improve the yields of tomatoes in the sub county. The literate tomato farmers in the sub county understood a number of management practices of tomato production, prevention and control of pests and diseases. As noted, literacy is a vital aspect in farming that influence farming (Awan, Hussain, Azhar, Abbas & Karamu, 2012).

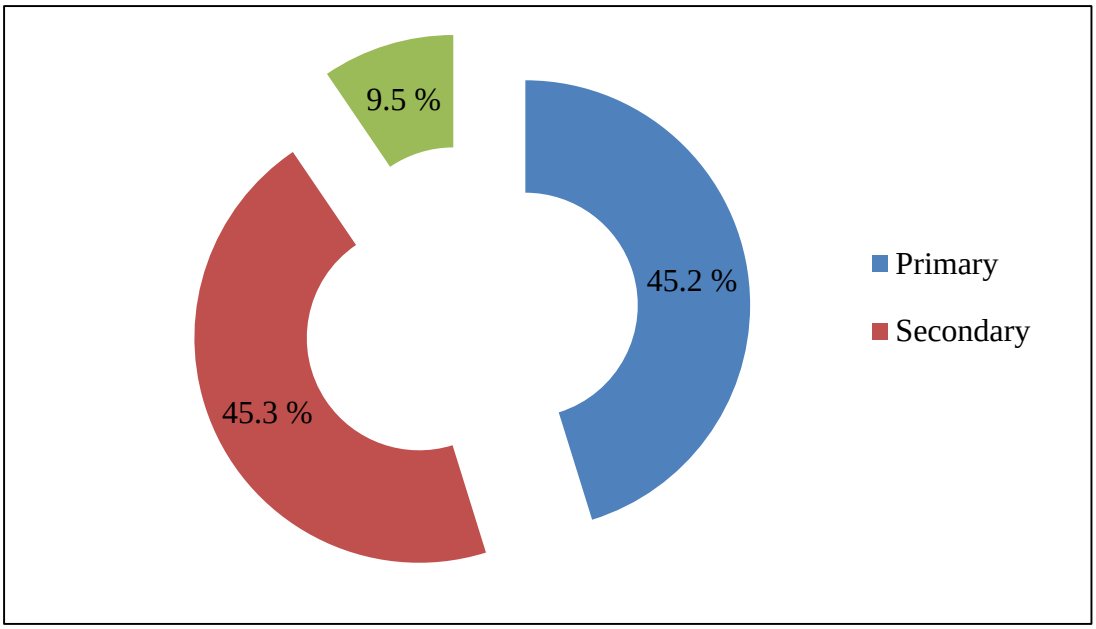


Figure 4.2: Education Level of the Respondents

4.1.3 Distribution of Age of the Respondents

The age differentials of the farmers engaged in tomato production in Kieni East sub county was analyzed as shown in Table 4.1. It was noted that 6.7 percent of the tomato farmer were in the age group of 15 to 24 years. Majority of the respondents in this age group were young people in primary and secondary schools, polytechnics, colleges and universities, leaving only a few in the sector of tomato production. The respondents in the age group between 35 and 44 years accounted for 33.3 percent. This comprised of young families venturing in tomato production to earn income and uplift their standards of living.

The age group with highest number of respondents was 45 to 54 years which accounted for 35.6 percent. These were respondents who have been in tomato production for a longer period and might have adapted it as a means of livelihood. The majority of the tomatoes farmers in the sub county were of over 35 years old which constituted of about 80 percent. They had acquired adequate information, knowledge, skills and experience over years about tomato production and hence practiced it as a source of livelihood.

The respondents who were over 54 years old constituted 11.1 percent. The study established the labour demand of tomato production made the elderly people shy off, they were aging, becoming weak and could not carry on with the practice opted to leave tomato production for lighter tasks.

Table 4.1: **Respondents' Age Cohorts**

Age group	Frequency	Percentage (%)
15 – 24 years	3	6.7
25 – 34 years	6	13.3
35 – 44 years	15	33.3
45 – 54 years	16	35.6
Above 54 years	5	11.1
Total	**45**	**100**

The study established that respondents who had practiced tomato production for a longer period had adequate experience that enhanced adaptation strategies to the changing rainfall variability trends and therefore they were able to increase tomato production in the sub county.

4.1.4 Occupations of the Respondents

Apart from tomato production they undertook, the respondents were required to state other occupations they carried out. The respondents gave their job status and the results are presented in Figure 4.3. The findings showed that 82.0 percent of the respondents grew other vegetables like cabbages, peas, cereals like beans, maize, kept cows, goats, sheep as well as poultry. The respondents in various professional employments accounted for 10.3 percent. Only 5.1 percent of the total respondents were in business and 2.6 percent were involved in informal sector respectively for extra income.

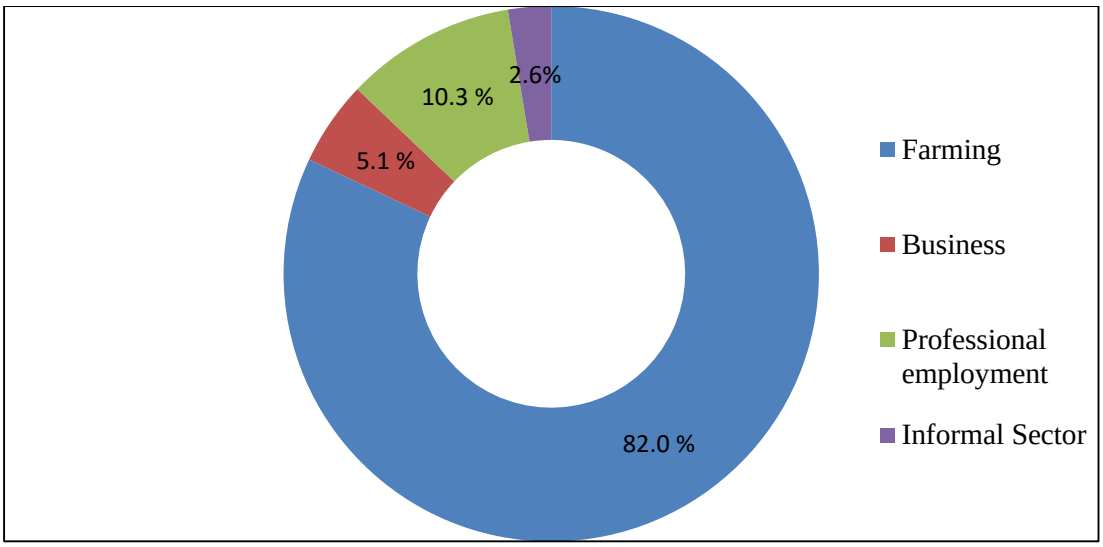


Figure 4.3: Other Occupations of the Respondents

The respondents argued that they undertook extra occupations to supplement income from tomato production and for food security in case the tomato production failed or decreased because unpredicted weather or market disorientation. Those in professional employments, informal sector as well as in other businesses supported tomato production through purchase of tomato seeds, pesticides, herbicides, fertilizers, putting up water reservoirs, purchasing of water pumps, leasing of land, paying the labourers and putting up of greenhouses. It was observed that tomato farms where owners had extra and alternative source of income were better managed, employed several labourers and therefore generated more yields and income.

4.1.5 Accessibility of Finances by Respondents

Tomato production is finance oriented and therefore the study sought to establish farmers' accessibility to finances to improve the production. It was found that of the total respondents, 17.8 percent were able to access loans from the local commercial banks. About 6.7 percent received loans from savings and credit cooperative organizations (Saccos), while 2.2 percent got finances from other sources like

borrowing from fellow farmers. A high number of the respondents (73.3%) did not access loans or finances from financial institutions as indicated in Table 4.2.

Table 4.2 Accessibility of Finances by the Respondents

No.	Financial Institutions	Respondents	Percentage (%)
1	Bank	8	17.8
2	SACCO	3	6.7
3	Any other Source	1	2.2
4	None	33	73.3
	Total	**45**	**100.0**

The study established that accessibility to quick loans from reputable financial institutions helped tomato farmers to improve tomato production. This was through leasing farmland, purchase of quality and clean seeds, farm chemicals and manure, hiring of labour, put up dams and construction of greenhouses which enhanced tomato production.

4.2 Rainfall Characteristics in the Study Areas

4.2.1 Rainfall Trends Between 1981 and 2014 in Kieni East Sub County

The data on mean, monthly and total annual rainfall for the period 1981 to 2014 for Kieni East sub county was provided by the KMD, Nairobi and presented in Figure 4.4. The study area received a mean annual rainfall of 637 mm during the entire study period, a characteristic of Semi-Arid climates which receive less than 850 mm of rainfall annually. The rainfall favours mixed rain-fed irrigation and agro pastoral agriculture in smallholdings, typical of Kieni East sub county. In addition to the low annual rainfall, as recorded in the years 1984 (298.0 mm), 1993 (495.6 mm), 2001 (297.1 mm) and 2010 when the study area received 480.1 mm, there was a wide range of year-to-year variability in rainfall which makes drought a common occurrence in Kieni East sub county (Republic of Kenya, 2012).

The data indicated a higher annual rainfall in the years 1981 (802.2 mm), 1986 (810.8 mm), 1998 (967.8 mm) and 2012 (844.9 mm) in the study area. The sub county received the total annual rainfall amount above the mean rainfall in the years 1981, 1986, 1989, 1992, 1998, 1999, 2002, 2004, 2005, 2006, 2007, 2008, 2011, 2012, 2013 and 2014. The year with the highest rainfall amount was 1998 when 980 mm rainfall was recorded and coincided with the period Kenya experienced the El Niño phenomena (IPCC, 2007). In the years 1991/92, 1995/96, and 1999/2000, Kieni East experienced drought period.

The trend line equation y = 5.57778x + 563.8 indicates an increasing trend (5.57778x) which means that the average of annual rainfall has been increasing over the years (1981 to 2014). From the year 1981 to 1995, the total annual rainfall is below the annual mean rainfall while from the year 1996 to 2014 the total annual rainfall is above the mean. The driest years were 1984, and 2001, when the sub county received an annual mean rainfall of 298.0 mm and 287.1 mm respectively.

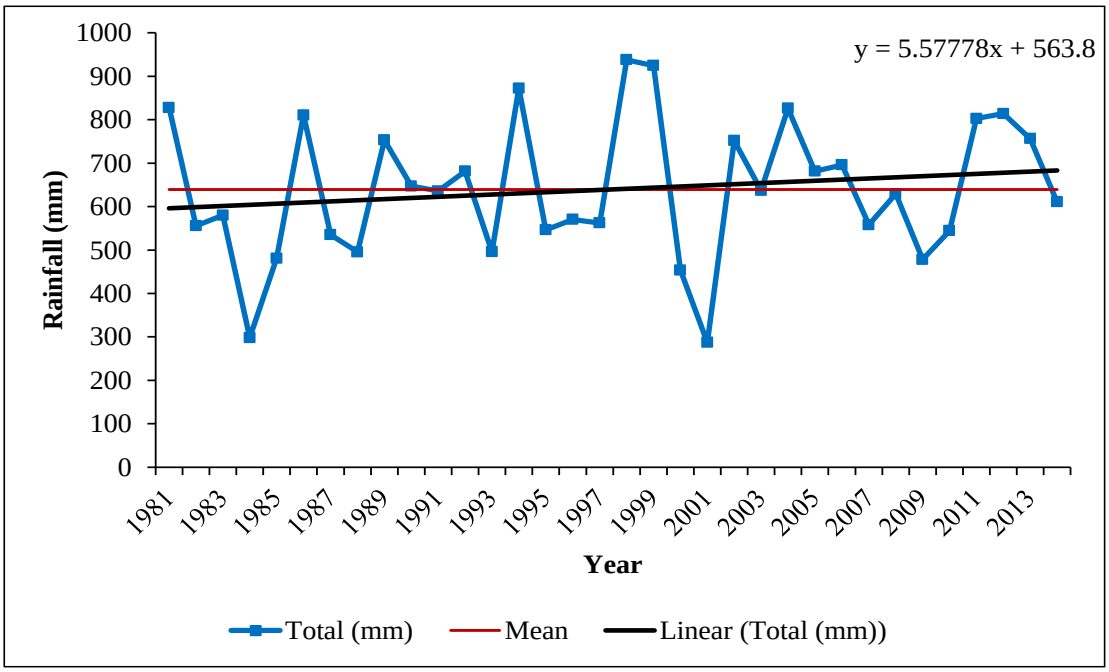


Figure 4.4: Annual Total and Mean Rainfall (mm) for the Period between 1981 and 2014 in Kieni East Sub County (Data source: Kenya Meteorological Department)

The severest drought was experienced in 1984 when most of crops failed, animals died and people faced starvation. The years which the sub county experienced drought included 1982, 1983, 1984, 1985, 1987, 1988, 1991, 1993, 1994, 1995, 2000, 2001, 2004 and 2010. The drought phenomena had the cumulative effect of reducing household food availability, purchasing power, and coping capacity, impoverishing the rural population.

IPCC (2007) noted that East Africa has been faced by large variability in rainfall with occurrence of extreme events like droughts and floods. El Niño related floods of the year 1997 and 1998 were very severe and the La Niña event of 1999 to 2000 was regarded as the most severe in 50 years. All through the years under study, the sub county received the highest amounts of rains during the MAM season and OND season where about 50 percent of the annual rains were concentrated.

Results further showed that between the year 1981 and 2014, there was occurrence of rainfall variability over the entire period. In the year 1998 the study area received the highest annual rainfall of about 967.8 mm while in the year 1984 the study area received the lowest annual rainfall of about 298.0 mm. The year 1998 corresponds with the period of El Niño when there was an extreme event of flooding. In the years 1984 and 2001 the study area recorded 298.0 mm and 453.8 mm of rainfall coinciding with La-Niña event. Year - to - year and season - to - season rainfall variations are persistent in East Africa, a phenomenon that continued to present a challenge to tomato production (Jaetzold *et al.,* 2006). Most respondents concurred that the area received varying and unpredictable amounts of rainfall across the farming season (MAM and OND). The impacts of the 1997 (562.2 mm) and 1998 (967.8 mm) El Niño rains, had devastating

impacts, as the rains caused loss in tomato production and led to reduced income (IPCC, 2007).

4.2.2 Rainfall Distribution and Variability (2009 to 2014)

For the period between 2009 and 2014, the study sought to establish rainfall distribution and trends. This is when tomato production data and income were available from Kieni East sub county Agricultural Office in Narumoru. The data on mean and the total annual rainfall for the period 2009 to 2014 in Kieni East sub county are represented in Figure 4.5. The study established existence of the two seasons MAM and OND. For MAM, the month of April in the year 2009 to 2010 received the highest amount of rainfall and OND the year 2011 and 2014 November received the highest amount of rainfall.

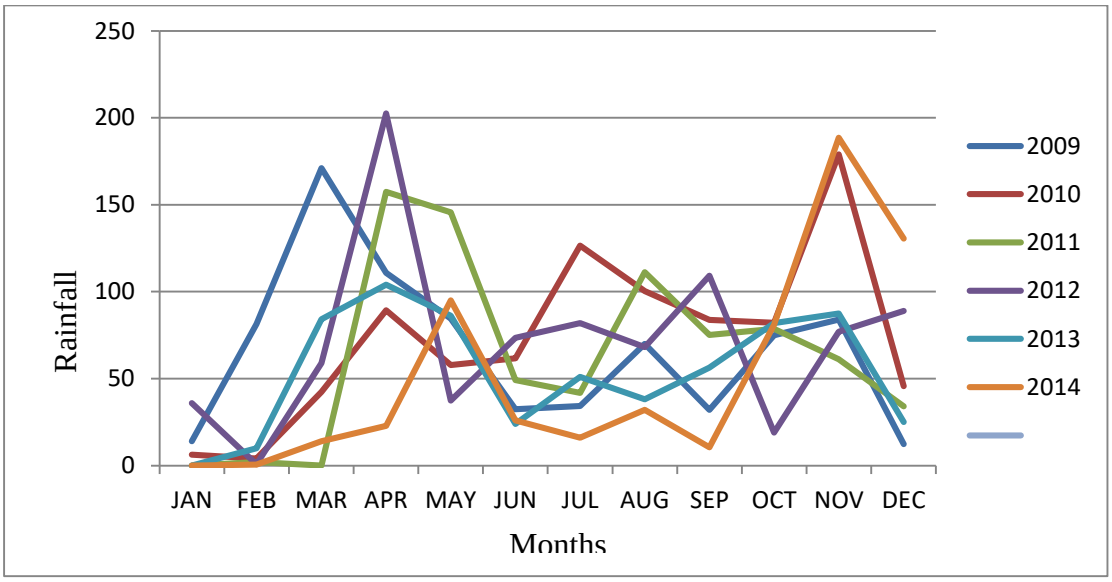


Figure 4.5: Rainfall Variability and Trends for the Period between 2009 and 2014 in Kieni East Sub County. (Data source: Kenya Meteorological Department, Nairobi)

Total annual rainfall in Kieni East sub county has been fluctuating between highs of 564.6 mm in 2014 and lows of 534.5 mm in 2009 over the period under study. The years that received below annual mean rainfall are considered as drought years while years that received above the mean annual rainfall are considered as wet years. The year

2009, 2010 and 2014 were drought years but the years 2011 through 2012 to 2013 received total annual rainfall above the mean and therefore are considered as outliers.

4.2.3 Rainfall Trends during the Short Season (OND)

The results in Figure 4.6 showed that OND seasonal rainfall amount varied between 2009 and 2014 in Kieni East sub county. High rainfall was recorded in years 2011, 2012 and 2014 while rainfall amount decreased in the years 2010, 2012 and 2014.

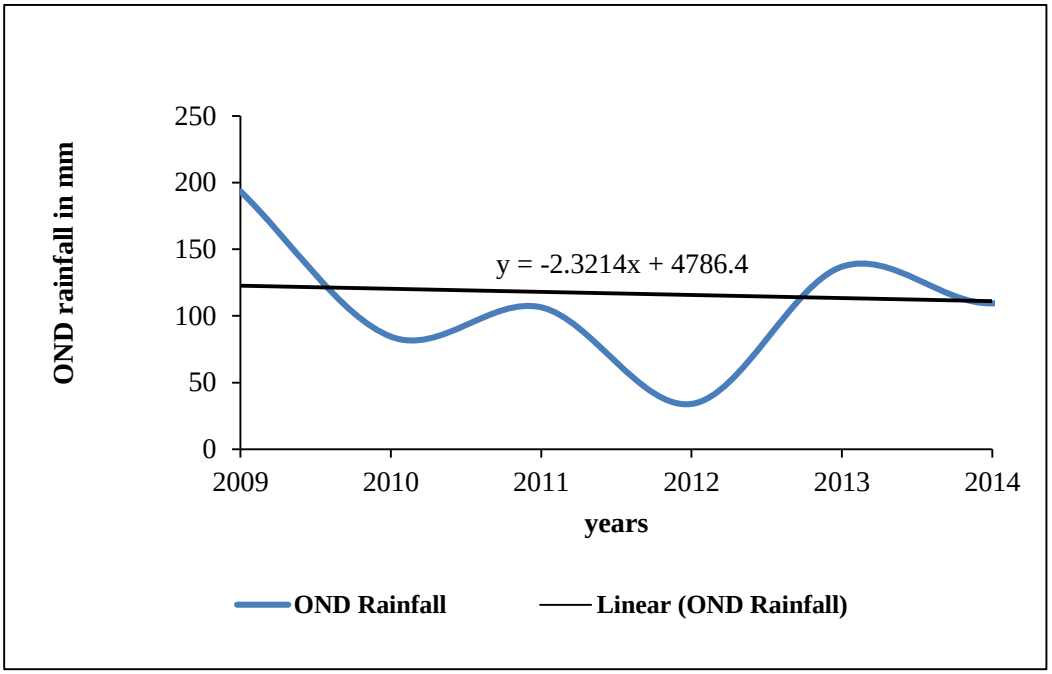


Figure 4.6: Short Season (OND) rainfall trend for years 2009 to 2014

These findings indicate that rainfall received in Kieni East sub county varied during the period (2009 to 2014). Notably, the highest amount of rainfall was recorded in the years 2011, 2012 and 2014. The seasonal trend line indicates a gradual decrease at a rate of 2.3 mm per season. This indicated year to year and season to season rainfall

variability persisted in the sub county, a phenomenal that continue to present a challenge to many farmers.

4.2.4 Rainfall Trends during the Long Rain Season (MAM)

Data presented in Figure 4.7 shows increasing MAM rainfall amount from year 2009 to 2014. There was a slight decrease in MAM rainfall amount for the year 2010, an increase in the year 2012, a decrease in the year 2013 and a gradual increase to 2014. The study area received 480.1 mm and 844.9 mm of rainfall in 2010 and 2012 respectively. The low rainfall in 2010 (Figure 4.8) caused drought in Munyu, Kimahuri, Narumoru, Gaturii and Thunga'ari areas of the sub county. The high rainfall received in 2012 caused water logging in Kamburai-ini, Ndathi, Kabendera, Warazo Jet and Munyu areas.

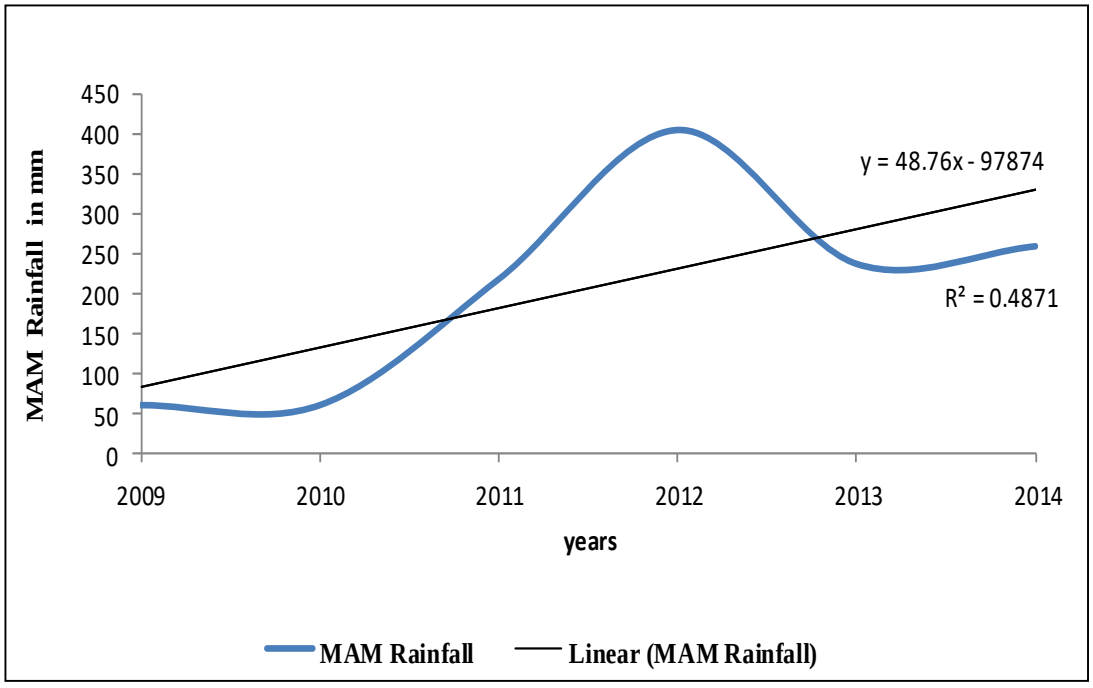


Figure 4.7: Long Season (MAM) Rainfall Trend for years 2009 to 2014

The trend line equation $y = 48.76x - 97874$ showed a gradual increase at a rate of 48 mm per season. The findings showed that the MAM rainfall amount has been on increase over the 2009-2014. In year 2012, the area received an abnormal high MAM rainfall, most of it in the month of April (202.5 mm), Appendix 4.

4.3 Tomato Production in the Study Area

4.3.1 Duration of Tomato Production by Farmers

Findings presented in Table 4.3 indicated that the respondents who had produced tomato for a period of less than 3 years accounted for about 26.7 percent while those who had tomato production for a period of 4 to 7 years accounted for about 35.6 percent of the total respondents in the sub county. Of the respondents who had produced tomato for a period of between 8 and 11 years accounted for 17.7 percent while those who had produced tomatoes for a period exceeding 11 years accounted for 20 percent.

Table 4.3: **Duration of Tomato Production by Respondents**

Duration of Tomato farming	No. of Farmers	Percentage (%)
0 – 3 years	12	26.7
4 – 7 years	16	35.6
8 – 11 years	8	17.7
Over 11 years	9	20.0
Total	**45**	**100.0**

4.3.2 Land Sizes under Tomato

The study established that about 41.8 percent of the respondents grew tomato in less than two acres of land, about 25.6 percent in land sizes of 2 to 4 acres while another 32.6 percent grew tomato in land sizes of more than 4 acres as revealed in the Figure 4.8. The low acreage of land was attributed to land fragmentation due to increase in population and selling off the land to other people and new immigrants. These finding

are further supported by Ogola, Milton, Ayieko, Orawa and Kimani, (2011) who established that small sizes of land for farming indicated intensive level of farming.

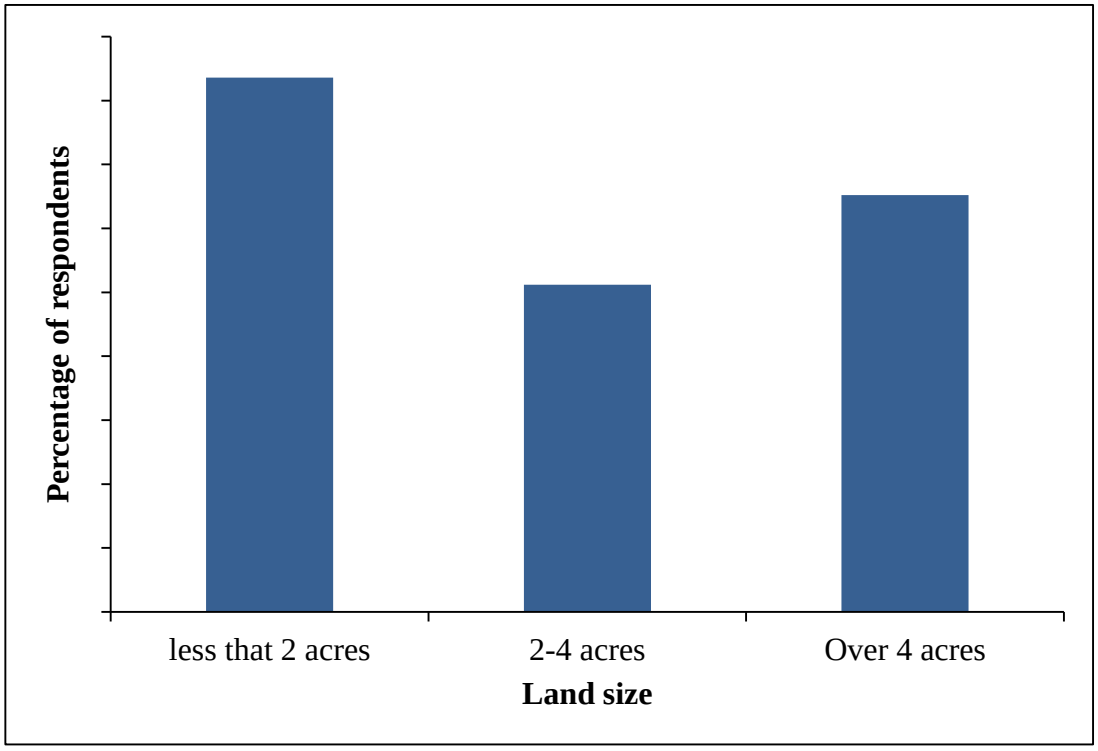


Figure 4.8: Land Size under Tomato Farming

The findings also concur with Starke (2014), who argues that tomato growing is demanding, labour intensive and expensive in terms of inputs, therefore farmers grew tomato in small parcels of land which were manageable throughout the entire production period.

4.3.3 Tomato Production Activities in the Study Area

Tomato production activities undertaken by the farmers in the study area annually are presented in the Figure 4.9. The main farming activities included seed bed preparation, preparing the land, planting, spraying against pests and diseases, weeding, staking, harvesting, sorting and packing. Seed bed preparation and sowing were done between January to March followed by transplanting of tomato seedlings in April for the March-

April-May (MAM) and November for October-November-December (OND) season. This is because tomato plants cannot withstand heavy rainfall (Molla, 2008). A moisture content of about 600 mm (evenly distributed throughout the season) is required. This is because tomato plants cannot withstand heavy rainfall (Kelly & Boyhan, 2010). Additionally, an optimum day temperature of 20-25^{0}C and 15-17^{0}C (night) is needed. Relatively warm and sunny period is suitable for ripening of the tomato fruit and would fall in the months of January and June respectively for each growing season. New cultivars of tomatoes like as *Rio-Grande, Kilele F1, Prostar F1* are preferred by the farmers for the high yielding and can withstand a number of diseases. The famers growing tomatoes in greenhouses preferred *Anna F1* variety commonly grown in greenhouses.

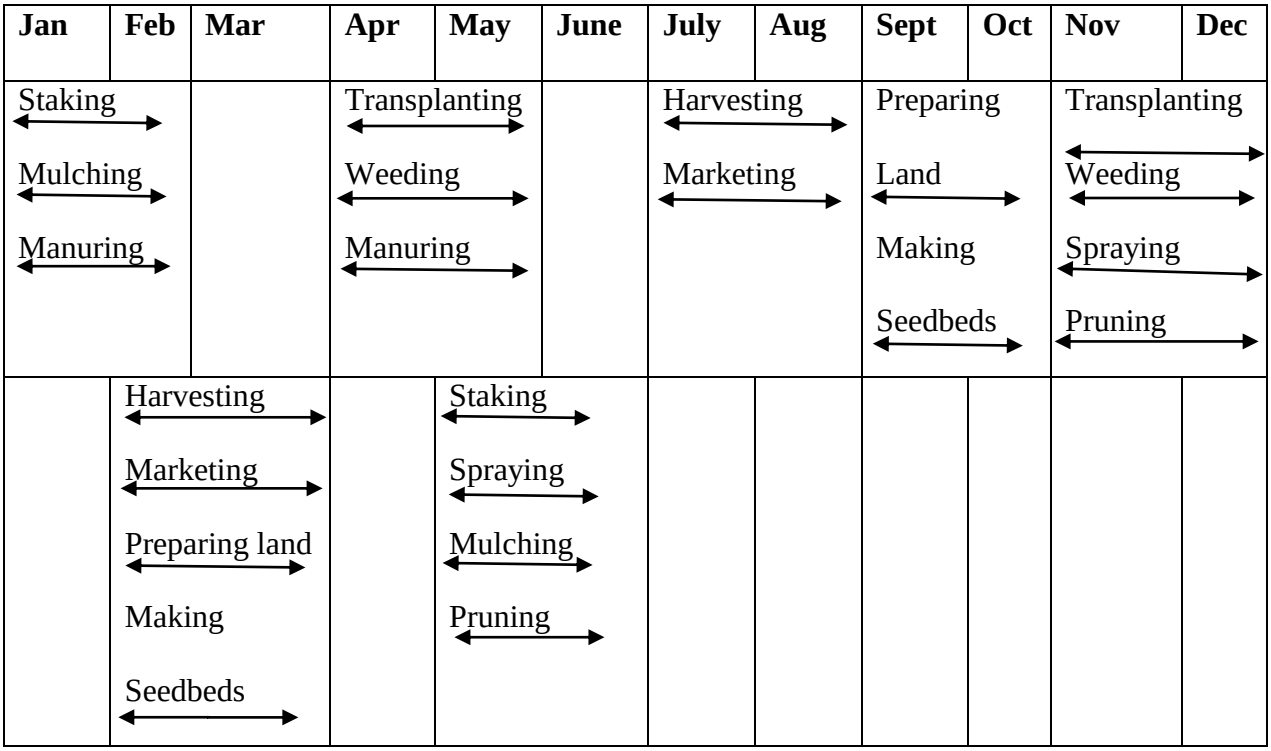


Figure 4.9: Tomato Growing Calendar in Kieni East
Source: (Field Data, 2016)

However, Agricultural Officers recommended planting of hybrid varieties which had a longer harvesting period and led to higher yields. The *Money Maker* variety of tomato is very popular to farmers in the study area for its ability to withstand weather variations therefore requiring less maintance costs, high yielding and able to remain flesh longer in the market. *Money maker* variety does well in poor soil, and it can withstand low rainfall and needs warmer environment to mature well. Tomatoes were harvested during the coolest part of the day, such as early morning or late afternoon, sorted, graded according to sizes and packed in wooden or plastic crates ready for transport to the market.

4.4 Correlation between Annual Rainfall, Tomato Yields and Income

4.4.1 Correlation between Annual Rainfall and Tomato Yields

The study also looked at the correlation between rainfall and tomato yields. Figure 4.10 shows the annual rainfall and tomato yields for the years 2009 to 2014. In the year 2009 the area recorded an annual rainfall of about 534.5 mm, and realized 1800 MT of tomato. In 2010, the area received annual rainfall of about 480.1 mm and the same year a yield of 5250 MT was realized. In 2012 despite the high rainfall of 844.9 mm, 4520 MT of tomato was harvested.

Most rainfall was received after OND season and was probably the contributory factor of reduced tomato production in 2009. In 2009, about 29.2 mm of rainfall was recorded for the month of January to March (Appendix 4), when farmers did the staking, mulching, manuring, harvesting, marketing of tomato fruits and preparing land for the next season. In the year 2010 there was a longer ripening period due to reduced rainfall and hence a prolonged duration of harvesting tomatoes that may have led to high yields. In the year 2010, the area recorded annual rainfall of 480.1 mm. In periods of moderate

rainfall the tomato crop had minimal attack by diseases like wilt, early and late blight, leaf spots, mildews, yellow and leaf curl. Control of pests like aphids, white flies, red spider mites, thrips, American bollworm caterpillars and *tuta abosulata* could have been more effective since pesticides sprayed on the crop remain on the leave surface for a longer period.

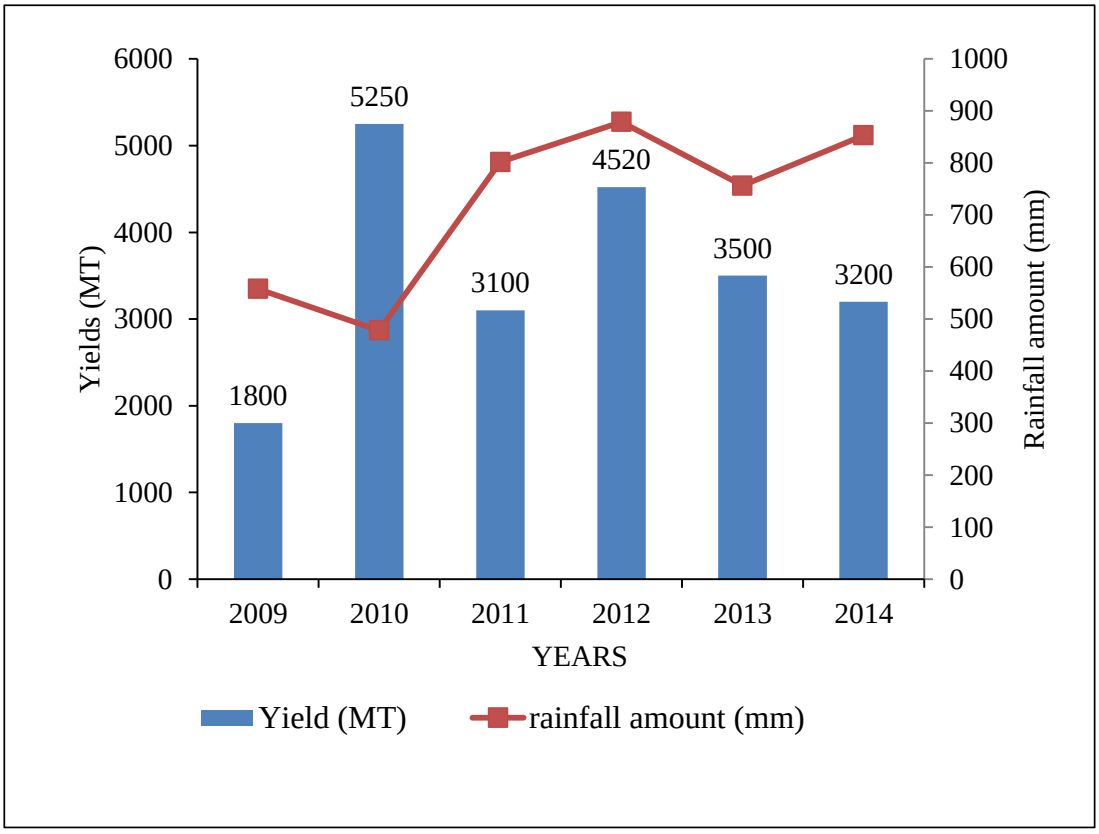


Figure 4.10: Annual Rainfall Amounts (mm) and Tomatoes Yields (MT) between the periods 2009 to 2014.

Annual rainfall was highest in the year 2012 amounting to 844.9 mm. However, it was evenly distributed through the year (Appendix 4), causing less water logging in the soil, and control of pests as well as diseases was effective, relatively high yields were recorded. In 2012 the area received 202.5 mm rainfall in the month of April during manuring, weeding and transplanting period of tomato and this had minimal effects on the yields. In 2013 the area received about 2.0 mm of rainfall in the month of January

to March, annual rainfall of 756.4 mm and therefore there was insufficient rainfall during the period, however most of the rain was received as from April to December. In 2013, annual rainfall reduced and so were the yields, 3500 MT from 4250 MT in 2012. Crop-yield-variability is a significant characteristic of agriculture which is strongly influenced by fluctuations in rainfall and studies show that the year-to-year variations in crop yields are normally associated with the fluctuations in rainfall (Edeh, Eboh & Mbam, 2011). The respondents concurred that the drought period of the years 1984 and 2001, they never harvested crops, some seasonal rivers dried, cows and goats died because of insufficient feeds and they received food assistance from the government (Muthama, Njeri & Manene, 2013).

4.4.2 Farmers Perception on Rainfall Variability and Tomato Production

Tomato framers were asked of their views as related to tomato production and rainfall variability. The result of their responses is presented on Table 4.4. Of the total number of respondents about 22.2 percent agreed and 17.8 percent strongly agreed respectively that high amounts of rainfall led to decreased tomato production. About 42.2 of the total respondents concurred that frequent dry period's lowers quantity and quality of tomato production. About 83.8 percent of respondents agreed that during the drought period tomato face a lot of attack from pests, while about 84.4 of the total respondents agreed that during periods of high rainfall incidences of diseases in tomato farms rose, and control was less effective.

The results further showed that about 83.8 percent of the respondents agreed that tomato pests like aphids, white flies, red spider mites, thrips, American bollworm caterpillars and tuta abosulata increases in seasons of dry and low rainfall. Seasons of low rainfall offered suitable warm environment for pests to survive and fast breed, as indicated by

the area Agricultural officers (Personal Interview, 2016). About 84.4 percent of the respondents concurred that incidences of diseases such as, stem rot, early and late blight increase with high rainfall. High rainfall triggered early blight and late tomato diseases which eventually lowered tomato production in terms of yields and quality. About 70.1 percent of the respondents agreed that during rainy seasons, transport cost of tomato produce to the market escalated thus reduced, the profit margin of the farmers.

4.4.3: Correlation between Annual Rainfall and Tomato Income

Results from the Figure 4.11 showed that in the year 2010, despite the reduced annual rainfall of 480.1 mm Kshs 105,000,000 was realized from the sale of 5,250 MT of tomato, while in the year 2012, the annual rainfall increased to 844.9 mm, and Kshs 101,600,000 representing 3.24 percent increase in sales was realized from the sale of 4,520 MT of tomato. In the year 2014, despite high rainfall of 810 mm, the study area recorded Ksh 75,000,000 from tomato sales. Annual rainfall amount was lowest in the year 2010 and showed a varying trend thereafter.

As shown in Table 4.4, about 64.4 of the total number of respondents argued that high amounts of rainfall lowered the production of tomato. During the study it was noted that cases of tomato diseases like wilts, early and late blight, leaf spots and mildews rose with increase of rainfall and destroyed the tomato plants thus reducing the yields as indicated by 84.4 percent of the total respondents (Table 4.4).

Table 4.4: Farmers Perception on Tomato Production and Rainfall Variability

	Responses	**Strongly disagree**	**disagree**	**neutral**	**agree**	**Strongly agree**	**Total**
During rainy season transport charges reduce profit margin in tomato sales	Frequency	7	1	5	19	13	45
	Percentage	*15.6*	*2.2*	*11.1*	*42.2*	*28.9*	*100*
Frequent dry periods lowers quantity/ quality of tomato production	Frequency	6	10	10	13	6	45
	Percentage	*13.3*	*22.2*	*22.2*	*28.9*	*13.3*	*100*
Tomato pests increases in drought periods	Frequency	1	3	3	18	18	43
	Percentage	*2.3*	*7*	*7*	*41.9*	*41.9*	*100*
Tomato diseases increases with high rainfall	Frequency	2	4	1	18	20	45
	Percentage	*4.4*	*8.9*	*2.2*	*40*	*44.4*	*100*
Profits from tomatoes are low during rainy seasons	Frequency	5	10	4	13	6	38
	Percentage	*13.2*	*26.3*	*10.5*	*34.2*	*15.8*	*100*
Rainfall shortages reduces tomato production	Frequency	5	10	5	17	8	45
	Percentage	*11.1*	*22.2*	*11.1*	*37.8*	*17.8*	*100*
Too much rainfall lowers tomato productions	Frequency	5	8	3	19	10	45
	Percentage	11.1	17.8	6.7	42.2	22.2	100

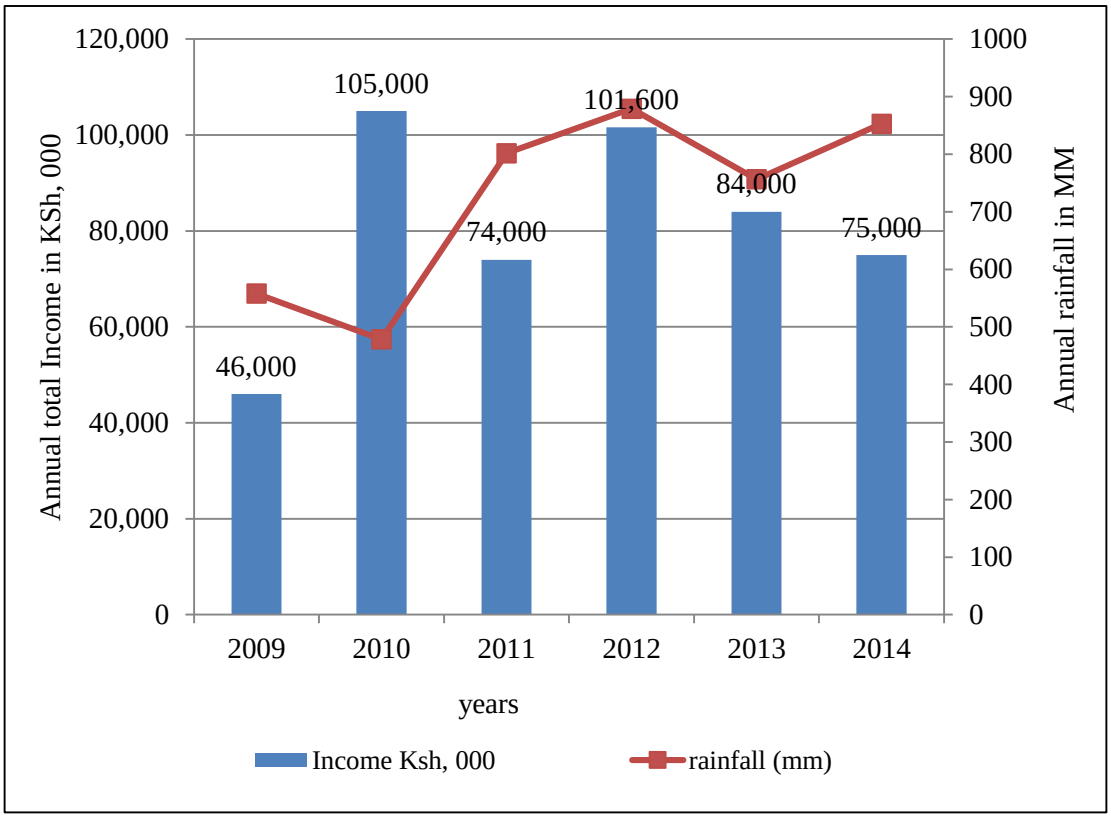


Figure 4.11: Annual Rainfall Amount (mm) and Tomatoes Income

High rainfall amount led to increased transport costs and thus increased prices of tomato as revealed by 15.6 percent of the total respondents. Increased rainfall led to water logging of soils, reduced the flowering period of tomato plants and ripening of tomato fruits and consequently resulted to low yields of tomato. The findings concur with the study by (Molla, 2008).

4.4.4 Farmers' Perception on Annual Rainfall Amounts for Tomato Production

The study revealed that the Kieni East sub county experienced low amount of rainfall that was below the mean of 637 mm per annum and which varied over the five year period studied in relation to production as revealed in Table 4.5. The study revealed that over 71.1 percent of the respondents stated that amount of rainfall was inadequate for the last five years. In the year 2014, 24.4 percent of the respondents stated that

amount of rainfall received was adequate and only 4.4 percent observed that rainfall amount was excess in the same year as presented on the Table 4.5.

In the year 2013, 29.9 percent of the respondents indicated that rainfall amount was excess, while in the year 2012 of the total number of respondents, 26.6 percent stated that rainfall was adequate. In the year 2011, results showed that 75.6 percent and 24.4 percent of the respondents noted the rainfall was inadequate and adequate respectively.

Table 4.5: Farmers' Perception on Annual Rainfall amounts in Kieni East Sub County

Year		Inadequate	Adequate	Excess	Total
2014	Frequency	34	11	2	45
	Percent	*75.6*	*24.4*	*4.4*	*100*
2013	Frequency	32	13	1	45
	Percent	*71.1*	*29.9*	*2.2*	*100*
2012	Frequency	33	12	1	45
	Percent	*73.3*	*26.6*	*2.2*	*100*
2011	Frequency	34	11	0	45
	Percent	*75.6*	*24.4*	*0*	*100*
2010	Frequency	34	5	6	45
	Percent	*75.6*	*11.1*	*13.3*	*100*

Rainfall variability in the area was also observed to be on the rise as the farmers reported decreasing and unpredictable of seasonal rainfall onset. The rainfall amount was low to cultivate tomatoes as majority of the respondent stated.

4.4.5 Correlation between Tomato Yields, Income and Annual Rainfall

The correlation between annual rainfall amounts and tomato yields were analyzed using Pearson *r* as shown in Table 4.6. A positive correlation between rainfall and tomato yield was noted as indicated by a Pearson of 0.429. Similarly, Pearson's *r* of 0.334 against annual rainfall and income indicated a positive correlation between rainfall and tomato income. The study established a strong correlation between yields and income

Pearson's r = 0.982. A positive Pearson's *r* indicated that as one variable increases in value, the second variable also increases in value and likewise as a variable decreases in value, the second variable also decreases in value.

Table 4.6: Correlations Matrix of Tomato Yields, Income and Annual Rainfall

		Yields	**Income**	**Rainfall**
Yields	Pearson Correlation	1	0.982	0.429
	Sig. (2-tailed)		0.001	0.395
	N		6	6
Income	Pearson Correlation		1	0.334
	Sig. (2-tailed)			0.518
	N			6
Rainfall	Pearson Correlation			1
	Sig. (2-tailed)			
	N			6

4.5 Farmers Adaptation Strategies to Rainfall Variability on Tomato Farming

Results in Table 4.7 show the various adaptation methods adopted by the tomato farmers to cushion against the effects of the changing rainfall variability on tomato farming. The tomato farmers adopted diverse strategies either on-farm or off-farm. The on-farm strategies included mulching, application of manure, crop rotation, construction of greenhouses, irrigation, looking for new farmlands and use of certified tomato seeds (seeds from reputable seed companies, like Sygenta, Kenya Seed Company, Simlaw etc.). The off-farm included construction of water dams for irrigation.

Table 4.7: Adaptation Strategies Adopted by Tomato Farmers

Adaptation methods	N	Percent
Use of certified seeds	37	29.1%
Use of manure	41	32.3%
Use of greenhouses	4	3.1%
Heed to advice from Agricultural Officers	10	7.9%
Mulching	12	9.4%
Planting on new farmlands	3	2.4%
Use of irrigation/ Dam	11	8.7%
Practicing crop rotation	9	7.1%
Total	**127**	**100.0%**

It was noted that a farmers adapted to more than one strategy. The adaptation strategies that are employed by the tomato farmers are in line and relevant to the conceptual framework for this study. It was observed that farmers prepared well and employed strategies that would cushion their social and economic livelihoods. Depending on variations on rainfall characteristics, tomato farmers in different wards adopted different adaptation strategies as indicated in Table 4.8. Use of manure and certified seeds were adopted by about 61.4 percent of the total respondents in all the wards in the sub county. Use of greenhouse technology and opening of new farmlands was the least adopted by about 5.7 percent of the respondents across all the wards in the sub county.

Table 4.8: **On Farm Adaptations Strategies Undertaken by Tomato Farmers per Ward**

	Ward				
Adaptations Strategy	**Kabaru**	**Thegu River**	**Naromoru/ Kimathaga**	**Gakawa**	**Total**
Certified seeds	10	14	9	4	37
	90.90%	*87.50%*	*81.80%*	*66.70%*	
Use of manure	10	16	9	6	41
	90.90%	*100.00%*	*81.80%*	*100.00%*	
Use of greenhouses	2	1	1	0	4
	18.20%	*6.20%*	*9.10%*	*0.00%*	
Follow advice from Agricultural officers	5	1	2	2	10
	45.50%	*6.20%*	*18.20%*	*33.30%*	
Mulching	3	4	5	0	12
	27.30%	*25.00%*	*45.50%*	*0.00%*	
New farmlands	0	2	1	0	3
	0.00%	*12.50%*	*9.10%*	*0.00%*	
Irrigation/ dams	3	8	0	0	11
	27.30%	*50.00%*	*0.00%*	*0.00%*	
Crop rotation	2	4	1	2	9
	18.20%	*25.00%*	*9.10%*	*33.30%*	
Total	35	50	28	14	127

4.5.1 Use of Certified Seeds

The choice of cultivars is based on fruit quality, adaptability and reliability, susceptibility to diseases and pests, plant growth habit, the specific market and the planting time (Naika, Jeude, Goffau, Hilmi & Dam, 2005). It was noted that about 37 tomato farmers across the study area used certified seeds. Across all the wards, over 65 percent of the tomato farmers used certified tomato seeds (Table 4.9). It was noted that improved seeds are associated with high productivity level and better capacity to resist pests and diseases (Abay, 2007).

Certified seeds are hybrids which are reliable in germination, grow in greenhouses and outdoor, produce large attractive red oval shaped fruits depending on the variety, mature early, have a very long harvesting period and are tolerant to Tomato Leaf Curl

virus and Bacterial Wilt (Tshiala & Olwoch, 2010). Certified seeds are expensive and it was noted that some farmers used seeds from the tomato fruits in their farms. Use of certified seeds was adopted by about 29.1 percent. Tshiala & Olwoch (2010) reported that use of certified tomato seeds led to high yields and was thus an adaptation strategy for increases tomato yields.

4.5.2 Application of Manure and Mulching

Mulching is defined as covering or spreading a layer of plant materials on the soil surface (Erenstein, 2008). Majority of the respondents practiced dairy farming hence manure was cheaply available to all households. Use of manure was applied by about 32.3 percent of the total respondents. Mulching (Plate1) was a common phenomena in Narumoru/ Kiamathaga wards where it was adopted by 45.5 percent of the total respondents (Table 4.9).

Plate 1: A Section of Farmland under Mulching in Narumoru / Kiamathaga Ward. Source: Field data (2016)

Use of farmyard manure added more nutrients into the soil and increased the soils' ability to retain water. This cushioned the tomato farmers during the drought and continuous use of tomato on the same farm. Thegu River and Gakawa wards are relatively dry and therefore a suitable adaptation strategy. Mulch can be of organic

origin, such as straw, grass, leaves and composted yard waste. This practice has been used in moisture conservation in dry area farming and sustainable agriculture to improve crop yields through water retention, soil ecology improvement, and general environmental maintenance (Erenstein, 2008).

4.5.3 Use of Greenhouses

Use of greenhouse provides opportunities for year- round production of tomato in terms of quality and quantity. Use of greenhouses was yet to be adopted in this area mainly due to inadequate of startup capital. The respondents who accessed finances from SACCOs and commercial banks accounted for only 24.5 percent (Table 4.2). Use of greenhouse was applied by 18.2 percent of the total respondents in Kabaru ward.

Plate 2: Tomato Grown in a Greenhouse in Gakawa Ward. Source: Field data (2016)

Growing tomato in greenhouses is meant to increase yields and production of high quality tomato throughout the year (Osure, 2010). Tomato pests and diseases were easily controlled in greenhouses. The greenhouse farming technology used in a smaller portion of land, consumed less water as compared to drip and overhead irrigation hence economically viable. The use of greenhouse in cultivation is not fully embraced by the farmers because of high cost involved in installation. For instance, installation of a 120 square meter greenhouse would cost Kshs 150,000 (Osure, 2010) taking into this

consideration only about 24.5 percent (Table 4.2) are able to access finances from Banks and SACCOs.

4.5.4 Advice from Agricultural Officers

The sub ounty's Agricultural Officers often visited the farmers in various wards for advice and guidance and only 7.9 percent of the farmers were able to follow up. Such farmers obtained high and reliable tomato production despite shortage or unreliable annual rainfall. Agricultural Officers guide farmers on the proper seeds, spraying and applying manures and fertilizer throughout the entire production period. They are however unable to meet the tomato farmers regularly, because some of the farmers are far apart and lack of adequate transport to cover the expansive areas.

4.5.5 New Farmlands

New (virgin) lands were a great potential to tomatoes farmers. New farmlands have fertile soils, high moisture retention and have minimal cases of pests and diseases. About 2.4 percent of the respondents planted tomato in new farmlands (Table 4.9; Plate 3). New farmlands for cultivation were available along Thegu River and Kandune stream sides in Thegu and Narumoru/ Kiamathaga wards. The tomato farmers highlighted a number of challenges for not engaging tomato faming on those lands. New farmlands were not readily available because of the increasing population pressure and demands for lands. Cultivation of tomato in new farmlands was said to be cumbersome and expensive. It involved process of leasing, clearing bushes and burning, digging, putting a farm house to guard tomatoes from destruction by wild animals and fencing of such lands.

Plate 3: Tomato Grown in New Lands in Thegu River Ward Source: Field data (2016)

New farmlands were ideal for tomato farming because soils were very fertile and less toxic, free of tomato soil related diseases and pests that would attack the tomato crop. The soils had high water retention capacity and this increased tomato production in times of drought. New farmlands require less farm inputs (fertilizers, herbicides, manures and pesticides) thus increasing the profitability.

4.5.6 Use of Irrigation and Construction of Water Reservoir

Irrigation is critical in tomato production. It is important to supply sufficient water at critical times, such as immediately after sowing or transplanting. Use of man-made water reservoir to irrigate tomato was not applied in Kiamathaga/ Narumoru and Gakwa wards. Most of the tomato farms were along rivers while other farmers used greenhouses to grow tomato. In Thegu River and Kabaru wards, 50 percent and 27.3 percent of the tomato farmers respectively adopted irrigation as a strategy (Table 4.9; Plate 4) since water was available from rivers and water reservoir (Plate 4).

Plate 4: A Man Made Earth Water Reservoir in Thegu Ward (Source: Field data, 2016)

In the study area, water was readily available from the seasonal streams namely Kandune, Lusoi, Nyange and rivers Nairobi, Thegu, Tigithi but the water volume decreased considerably during drought periods. This called for farmers to construct water reservoirs, (Plate 4) and harvest water during the rainy months and use in tomato farms in times of drought. Irrigation is an ideal adoption strategy against rainfall variability especially during the drought as argued by Tshiala and Olwoch (2010).

4.5.7 Practicing Crop Rotation

About 7.1 percent of the total respondents, practiced crop rotation (Table 4.9). Thegu Ward recorded the highest number of respondents about 25 percent practicing crop rotation. Growing of tomato in different parcels of land in each season and going back to initial parcel after a year interrupted or broke pathogen cycles and therefore reduced tomato attack by pests and diseases (Starke, 2014) and this led to increase in tomato production and less maintained cost.

Plate 5: Use of Manure in Planting Tomato in Land Previously Planted Maize in Thegu Ward (Source: Field data 2016)

CHAPTER FIVE

SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

The study sought to determine the influence of rainfall variability and trends on tomato production among small scale farmers in Kieni East sub county and identify the adaptation strategies they employ. In this regard, three objectives were set, whose key findings are summarized in this chapter as conclusion, policy recommendation and areas for future research.

5.1 Summary of Findings

The effects of rainfall variability on tomato production have forced the tomato farmers to adopt several strategies to enable them absorb the shock. The first objective established the rainfall characteristics for the period 1981 and 2014 in the study area. Secondly, annual rainfall characteristics were analysed and correlated with tomato production trends, yields and prices between 2009 and 2014. Thirdly, the study established farmers' adaptation strategies to the changing rainfall variability trends on tomato farming. To achieve the three objectives of the study, a total of 45 tomato farmers selected random from the four study wards namely, Thegu River, Kabaru, Narumoru/ Kiamathaga and Gakawa with estimated 142 tomato farmers whose participation in the study gave firsthand information.

5.2 Key Findings of the Study

The key findings based on discussion and results are summarized as:

5.2.1 Rainfall Variability

The study established existence of variability in rainfall characteristics over the past thirty three years (1981 – 2014) in Kieni East sub county. Rainfall variability observed

in both annual and seasonal trends was significant as revealed in Figure 4.5. Some anomalies were observed from annual rainfall which gave evidence of unpredictable and varying nature of the rainfall patterns. The study area has a climate that permits production of a number of tomato varieties within seasons in the year and when produced timely can provide a reliable livelihood to the producers.

5.2.2 Effects of Rainfall Variability Trends on Tomato Yields

The study gave the evidence that rainfall had some statistically significant positive correlation with tomato yields ($r = 0.429$). High annual rainfall directly affected tomato production with other variables as soil type, application of irrigation, pests and diseases, and application of certified seeds and variety, regular weeding held constant. Tomato needs regular watering naturally (rains) or artificially (through irrigation), but too much rainfall or prolonged drought period is detrimental to production and quality. High yields of the tomato resulted to low prices in line with law of demand and supply.

5.2.3 Adaptation Strategies to Rainfall Variability on Tomato Farming

The last objective of the study established the strategies employed by tomato farmers towards coping with changing rainfall in Kieni East sub county. The study established adaptation strategies the tomato farmers employed in various wards. They include mixed farming, flood irrigation, crop rotation, looking for new farmlands, growing new tomato varieties, practicing mixed cropping, planting of certified seeds and use of greenhouse technology. Proper tomato production system and application of appropriate technology determined farmers' ability of adaptation strategies. Tomato farmers who practiced mixed crop, kept livestock and poultry had more available strategies (use of manure, use mulch) to adapt to than the farmers who specialized in a single crop production (Nhemachena & Hassan, 2008).

However the study revealed that most of the farmers practiced crop rotation, application of certified seeds, use of manure, use of irrigation and growing tomatoes in new farmlands in response to rainfall variability. Only 3.1 percent of the farmers adopted tomato production through use of greenhouses due to limited access to finances. The ability of a farmer to control their production environment, such as in greenhouses in those unfavourable seasons, boosts crop productivity and avoided supply shocks.

From the study it was noted that tomato farmers were faced with challenges in a bid to employ adoption strategies to rainfall variability such as inadequate markets and little or no information on weather (weather forecast) and access of information, guidance and advice from Agricultural field officers.

5.3 Policy Recommendation

Production of tomatoes is well placed to contribute significantly to the paradigm shift aimed at transforming small holder agriculture from subsistence to a modern, innovative business and commercially - oriented sector.

5.3.1 Developing Rainfall Resistant Tomato Varieties

The effects of high amount of rainfall in the growing season on tomato production showed that farmers faced both financial and production losses and consequently negatively affected their social, economic and agricultural livelihood. Kieni East sub county is vulnerable to rainfall variability and tomato production provides a livelihood for the people living there. A tomato variety resistant to high rainfall conditions and with a longer harvesting period can be developed. Institutions such as KALRO, Kenya Seed and Syngenta can research, develop and avail resistant tomato varieties which can withstand the varying weather conditions such dry spells, pests, diseases and raise production as well as income.

There is a very wide range of tomato cultivars available for planting constantly being released by crop breeders to the farmers. Farmers were strongly advised to test any proposed new cultivar on a small scale, together with a proven one, for purposes of comparison, and should the new cultivar appear to have some advantage over the other one, the proportion of the planting made with the new cultivar could be increased gradually. It was noted that different tomato cultivars responded differently to changes in planting periods, cultural practices and the general environmental conditions.

5.3.2 Availability of Climate Information

Information about the local climate of the study area should be availed to farmers regularly to enable them prepare the strategies to apply. Advance access to weather information could enable farmers cope with rainfall variability effects in terms of costs and increase production. It was noted that very few farmers were able to access or follow online weather forecast. From County or sub county levels farmers can be provided with local climate information through electronic media such as radio, television and mobile phones which are currently available to majority of the people. Farmers could also form social meadia (*WhatsApp)* groups to share various information, challenges, markets and experiences about tomato production.

Farmers should be trained on the need of timely land preparation to utilize the available rains at various stages of growth such as flowering, fruit formation and ripening. Rainfall change impacts to rural farming communities can be reduced by distributing climate data regarding seasonal local weather conditions to small farmers. The farmers will be able to make more informed decision in line with the available information and cushion on rainfall variability. Farmers may use this information to prepare themselves for dry conditions by planting drought-tolerant crops (Patt, Suarez & C. Gwata, 2012).

Farmers should be enlightened on the need to cultivate cherry tomato. Cherry tomatoes, rounded small fruited tomatoes thought to be an intermediate genetic mixture between wild currant-type tomatoes and the domesticated garden tomatoes (Ndegwa, Gathambiri, Magot, Wesonga & Maim, 2019). They are more nutritious as a source of potassium and sodium, are less attacked by diseases and pests and fetch high prices. Cherry tomatoes are commonly sold in major super markets in upper class suburbs (Ndegwa *et al,* 2019).

5.3.3 Provision of Farm Inputs and Fiscal Empowerment

The low yields are an indicative of a tomato crop grown outside favourable growing conditions (excess rainy or cold seasons) that attract high weed management requirements, frequent pest and disease outbreaks or retarded growth. It is worth to empower the tomato farmers technically and financially to control their production environment, open farms and greenhouse, in those unfavourable seasons, to boost crop productivity and avoids supply shocks. Several challenges involving tomato farmers such as high cost of certified seeds, fertilizer, pesticides, herbicides and labour costs influence tomato farmers' responsiveness to rainfall variability and related risks. Nyeri county government through sub county and ward agricultural field officers should ensure tomato farmers access the subsidized farm inputs in specific stores. The County Government should identify institutions to offer low interest loans and subsidize these inputs. The availability and accessibility of cheaper farm input will motivate the farmers to produce more tomato at lower cost and maximize on profit.

Very few small scale tomato farmers are able to access loans from commercial banks and micro finance institutions. The institutions should provide funds at low interest to farmers. This would enable the farmers to put up earth water reservoirs in their farms,

greenhouses and earth ponds across rivers to enable them produce tomatoes throughout the year and shield their farming against rainfall variability. However, since poor communities are mostly financially incapacitated, they lack the empowerment to adapt, which keep them in a more vulnerable situation Mudombi (2011) noted that poor rural people have shortage of finances and therefore not empowered to implement strategies leaving them vulnerable to climate variability.

5.3.4 Set up Tomato Processing Factories

The tomato fruits are very perishable and cannot remain in the market for long and buyers and brokers take the opportunity to buy the commodity at a low price. The study suggested tomato factories to be constructed in the sub county to process and market tomato and thus provide jobs to the youth. The farmers will sell their tomato yields without going through the brokers and add value (make tomato sauce) and reduce waste, as small size tomatoes are regarded as grade two and are never taken to the market and make more profit. Consumption of vegetables that are produced in the peri-urban and rural areas can be improved by reducing the cost price throughout the chain. If cold storage and logistics are improved, then losses will be reduced which should in principle reduce product prices for the consumer. Realization of irrigation in the dry season will have an enormous impact.

The wholesalers and farmers having travelled far from the farms are tired and need to rest therefore they engage brokers to sell their FFV on their behalf on agreed commission basis. The brokers having been in these markets for long have established relationship with the retailers than wholesaler therefore can sell faster and this reduces farmers' profit.

Some farmers mentioned that the intervention of brokers, collusion of local traders and weak farmers' organizations have also constrained potential income from tomato production by farmers in the area. Setting up a tomato processing factory would ensure farmers have an avenue to sell more tomatoes at a better price and therefore be motivated. More youth will be motivated to venture into production of tomato business and reduce crime, unemployment, create wealth and reduce gender inequality.

5.3.5 Pests, Diseases and Water Management

Crop rotation is a cheaper and available strategy for farmers to adopt to increase tomato production. The farmers should be motivated to practice on Good Agricultural Practices (GAP) in the management of the tomato pests through crop rotation with non-solanaceous crops, removal of crop residues, selective removal of infested plant materials and removal of alternative wild host plants. In most instances, weeds are controlled by means of mechanical and/or hand cultivation. Such cultivation needs to be started timeously, before any damage to the tomato resulting from competition.

It was noted that the in Kamburaini and Kabaru was more prone to diseases such as early blight and late blight due to the high rainfall received. Tomato farmers in Lusoi, Nyange and Gatuamba faced more attack from pests such as aphid, *tuta absoluta* (a new type of pathogen that was very resistant to pesticides). Farmers can also use herbicides to clear weeds and thereafter plant tomatoes in rows without disrupting soils between the rows. In so doing cultivation and watering is only limited to the plants are therefore reducing incidences of weeds, pests and conserving water in the soil. As general rule, farmers should observe at least a 3-season break from tomato, pepper, potato, eggplant, tobacco or any other related crop from the solanaceous family as they

are often alternative hosts to some of the lethal tomato diseases and pests. This is done to avoid disease cycles and ensure less cost in disease management.

Research should focus on understanding the biology and ecology of the pest as well as the socio-economic impact of infestation both in the medium and long term. The farmers should be advised on the need of proper application of herbicides and pesticides. The farmers whose farm neighbors the forest have wild animals like elephants, buffaloes, monkeys and birds destroying their tomatoes in the farms especially during the periods of drought. This is common in Thegu River and Kabaru wards and therefore the Ministry of wildlife can fence off the forest reserves.

5.3.6 Soil and Water Management

Proper management of soil and water practices should be encouraged to reduce loss of moisture from the soil and increase soil water retention capacity during the periods of low rainfall in Nyange, Lusoi and Gakawa area of the sub county. These include mulching, and more use of manures than fertilizers. In the Narumoru and Kabaru wards of the sub county more trenches should be dug to reduce cases of water logging during heavy rain seasons. This water can be drained into man made earth water reservoir which can store water which can be utilized for irrigation in Lusoi, Gatuamba and Nyange areas of the sub county especially during the seasons of low rainfall. Farmers can also lease new farmlands where available which have less or no incidences of soil diseases as it were observed in Thegu River and Gakawa wards.

Tomato farmers along various rivers like Tigithi, Rongai, Kandune, Nairobi and Thegu should construct dam across the rivers to cushion against shortages during the periods of drought. During the periods of drought, farmers in Lusoi, Gatuamba and Ndiriti receive low water levels in the rivers due too much use in irrigating the farms

Kamburaini and Ndathi, farmers water the tomato crops at night which makes farming difficult since farmers experience cold, get sick and attack from wild animals. The farmers can also shift tomato cultivating lands near water sources, as were the cases in Gakawa and Thegu River wards.

5.3.7 Government Policies

The Kenya government should set policies and guidelines to ensure standard package of tomatoes for sale. Currently there two types of packages of fifty and seventy kilograms. Sometimes, those packages go beyond the designated weight at the same prevailing or less market prices at the expense of the farmers. The County government should also make the tomato farmers aware of the prevailing tomato market prices in various County and sub county markets, via radio, television and short mobile text to ensure they sell their fruits in competitive prices. The government, through the Ministry of Agriculture can take advantages of the many radio and television stations in the country to air the modern tomato farming techniques and programs.

This would enlighten and motivate farmers on the current farming methods, new pesticides and herbicides in the market and probably the recommended friendly prices. Kenya has two main production seasons: November – February and April – June with peak production in May. The farmers should be safeguarded from intraregional tomato productions to the local market. There is a lot of flow of tomato from Northern Tanzania that compete with Kenyan tomato production from neighboring Taita Taveta and even in Nairobi.

In Kieni East sub county, the existing situations to exploit the potential of tomato sector with regard to tomato production and marketing sector are not encouraging. Supportive service in line with improving tomato production and marketing, producers and traders'

cooperatives, and formal market information were very weak. These problems can be addressed via formation of tomato producer unions and cooperatives and through intervention of governmental or non-governmental organizations in terms of improving possibilities for strong and successful collective marketing of the tomatoes.

5.3.8 Improvements of Roads

The geographical location of Kieni East sub county makes it suitable to connect with external markets through the Nairobi - Nyeri – Nanyuki highway. Many feeder roads connecting the farm to main roads in the area are not murramed and pose a great challenge in transporting of tomato to the markets especially during the wet seasons. The County department of roads should upgrade these feeder roads make them accessible throughout the year. This will reduce significantly transport costs of the produce to the markets and increase the profit margin. External tomato buyers can also reach up the farms easily, buy and transport their tomatoes to the markets before they go bad.

5.4 Nature and Scope of Tomato Production in Kenya

Tomato farmers in Kenya should be encouraged and trained to adopt sustainable and environmental farming practices so that they can reduce their cost of production to improve on their economic sustainability. This can reduce natural soil degradation which is occasioned by current unsustainable farming practices. The communities living in the ASALs where crop farming has not been in practice due to lack of reliable rainfall should be trained on conservation agriculture principles with which farmers are able to grow crops with limited water availability.

5.5 Conclusion

The study sought to investigate influence of rainfall variability and trends on tomato production among small scale farmers in Kieni East sub county. From the study, most farmers practice tomato production according to traditions, long time experience and do not follow the seasonal information from weather forecast from KMD and rarely receive advice from sub county or ward field officers. The study has set a base for further study on relationships, effects and adaptation strategies to rainfall variability and trends. The high cost of production, rainfall variation, expensive clean seeds, soil degeneration, effects of diseases and pests, inaccessible roads during wet seasons, interference of marketing and markets by brokers, far markets and inadequate field officers presented major challenges to tomato production. Clean seeds are either not available or when available are very expensive to farmers. Sub county agricultural field officers ratio to that of farmers is inadequate and this denied the farmers an opportunity to receive vital scientific information applied to increase tomato production.

Finally, tomatoes are a potential source of income to most rural farmers engaged in horticulture production. The sector is faced by a number of constrains restricting their full exploitation, the present players are doing their best within the limited framework especially those in the Kieni East sub county of Kenya. Smallholder farmers can be harnessed to exploit high value markets in the region. They could be assisted to gain certification status to penetrate global market. Effort can be made at the farm level with a view to improving the overall status of marketing, distribution, infrastructure, technology and other management efforts of the farmer. This will substantially help quality growth of the domestic market as well as reduce poverty among the small holder tomato farmers.

5.6. Recommendations

The study established existence of significant correlation between the yields and the income and so is between rainfall and income. An increase of rainfall reduced the yields and income from the tomato proceeds. Rainfall directly affect up 20 percent of tomato yields as compared to tomato grown during the dry season is on irrigation or under greenhouse.

5.6.1 Recommendations for Policy Action

i. Soil and water management practices are enhanced to reduce loss of moisture from the soil and increase soil nutrients and water retention capacity during dry seasons in Lusoi, Nyange and Githungo areas. In Kabaru, Kamburaini and Warazo Jet more trenches should be dug to reduce cases of water logging during heavy rain seasons. This water should be drained into earth water reservoir to be utilized for irrigation during the dry seasons.
ii. Farmers should be encouraged to enhance crop diversification to cushion them from rainfall variability and to increase tomato production.
iii. Training of farmers on the importance of timely planting should be intensified to utilize the available rains at their different stages of growth such as flowering and maturity, hence the KMD should avail relevant data information on weather predictions.
iv. County department of Agriculture, KMD and KALRO should hold frequent open field days to update the farmers on timely climate and other relevant information on tomato production.
v. Kenya Agricultural and Livestock Research Organisation (KARLO), Syngenta, Kenya Seed Company should develop tomato varieties that are resistant to high rainfall or can survive on little water (adaptable in ASALs).

5.6.2 Suggested Further Research

i. The study was carried out in Kieni East sub county alone involving randomly selected tomato farmers future researchers can be done in other areas with different climatic conditions. This would assess and compare the level of production and strategies employed. The same study can also focus on temperature variability and focus on more horticultural crops, such as cabbages french beans and potatoes.

ii. A study on adoption capacity of Climate-Smart Agriculture (CSA) as an adoption strategy.

iii. A study on regional uptake of technology in adapting to the changing rainfall variability.

iv. Research is required on selection of tomato varieties that will do well with the changing rainfall variability in Kieni East sub county.

REFERENCES

Abay, A. (2007). Vegetable market chain analysis: the case of Fogera Woreda in North Rift Valley State of Ethiopia. A M.Sc. Thesis Presented to the *School of Graduate Studies of Haramaya University*.

Awan, S. M., Hussain, Azhar, Abbas, T. & Karamu, R. (2012). Assessment of production practices of small scale farm holders of tomato in Bagrote Valley, CKNP region of Gilgit-Baltistan, Pakistan. *Acta Agriculture Slovenica***.**

Borg, W. & Gall, M. D. (2003). Educational Research: An Introduction (5^{th} edition), *Longman Publishing*.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of environmental management*, *114*, 26-35.

Chijioke, O. B., Haile, M., & Waschkeit, C. (2011). Implication of climate change on crop yield and food accessibility in Sub-Saharan Africa. *Centre for Development Research. Bonn: University of Bonn*.

Datta, S. (2013), "Impact of climate change in Indian Horticulture - A review", *International Journal of Science, Environment and Technology*, Vol 2, No. 4, pp. 661– 671.

Edeh, H.O., E.C. Eboh & B.N.Mbam (2011); *Analysis of Environmental Risk Factors Affecting Rice Farming in Ebonyi State,* Southeastern Nigeria

Erenstein, O. (2008). Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. *J.Agri. Ecosystems and Environ*.100 (1):17-37.

Falkenmark, M. (2007). Global Warming: Water the Main Mediator. Stockholm Water Front. *Stockholm International Water Institute (SIWI),* No.2, June 2007, page 6-7. Stockholm, Sweden.

FAOSTAT. (2010). *FAOSTAT Agricultural Data*. www.faostat.fao.org.

Food and Agriculture Organization (FAO) (2012). Economics of plant genetic resource management for adaptation to climate change. *A review of selected literature*. S. Asfaw and L. Lipper (available at: http://www.fao.org/ docrep/015/ an649e/ an649e00.pdf).

Food and Agriculture Organization (FAO) (2007). Adaptation to climate change in agriculture, forestry and fisheries: *Perspective, framework and priorities.* Rome, Italy.

Food and Agriculture Organization (FAO) (2008). Climate change adaptation and mitigation: challenges and opportunities for food security. *High-level conference on world food security: The challenges of climate change and bioenergy*, Rome.

Gay, L. R., Geoffry, E. M. & Peter, A. (2009). Educational Research: *Competencies for Analysis and Applications*, Pearson London.

Government of Kenya (2010). National Climate Change Response Strategy, *Government Press Nairobi*, Kenya.

Hassan, R. M. & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5521), 83-104.

Horticultural Crops Development Authority (HCDA) (2011). National Horticulture Report 2011. *Republic of Kenya. Ministry of Agriculture*, Nairobi.

Horticultural Crops Development Authority (HCDA) (2013). National Horticulture Report 2013. *Republic of Kenya. Ministry of Agriculture*. Nairobi.

Huho, J. M., & Kosonei, R. C. (2014). Understanding extreme climatic events for economic development in Kenya. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*(2), 14-24.

ILO (2007). The Decent Work Agenda in Africa, Report. Geneva: *International Labour Organization.*

International Fund for Agricultural Development (IFAD), (2014). Upper Tana Natural Resources Management Project (UTaNRMP) Baseline Survey Report. *Government of Kenya*, Nairobi.

IPCC, (2007). Climate Change: Impact adaptation and vulnerability, contribution of working Group II to Fourth Assessment Report on IPCC. *United Kingdom, Cambridge University Press*.

IPCC, (2012). Managing the risks of extreme events and disasters to advance climate change adaptation, *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.*

Jaetzold, R., Schmidt. H & Shisanya. C (2006*). Farm Management Handbook of Kenya,Central Kenya– Natural Conditions and Farm Management Informatio*n, Ministry of Agriculture, Nairobi.

Jama, A., Kaitho, R., Wu, J., & Macopiyo, L. (2008). A new toolkit for monitoring and forecasting forage supply in the grazing lands of Eastern Africa. In The Future of Drylands (pp. 349-358). *Springer, Dordrecht*.

Kassie, B. T., Van Ittersum, M. K., Hengsdijk, H., Asseng, S., Wolf, J., & Rötter, R. P. (2014). Climate-induced yield variability and yield gaps of maize (Zea mays L.) in the Central Rift Valley of Ethiopia. *Field Crops Research*, *160*, 41-53.

Kelly, T.W. and G. Boyhan. (2010). *Commercial tomato production handbook.* University of Georgia Coop. Ext. Res. Bul.1312.

Kenya National Bureau of Statistics (KNBS, 2019) *Kenya Population and Housing Census.* Nairobi Kenya.

Kenya National Bureau of Statistics (KNBS, 2009). *Kenya Population and Housing Census.* Nairobi Kenya.

Kenya Red Cross (2009). Drought Appeal: *Alleviating Human Suffering*. Nairobi, Red Cross Society (KRCS).

Koenig, T. (Team Leader), Blatt, J., Brakel, K., Kloss, K., T Nilges, T. & Woellert, F. (2008) *Market-driven development and poverty reduction*: A value chain analysis of fresh vegetables in Kenya and Tanzania, Nairobi, Berlin.

Kumar, K. K., Kumar, K. R., Ashrit, R. G., Deshpande, N. R. & Hansen J. W. (2006). Climate impacts on Indian agriculture. *Int. J. Climatol*.

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

Lamarque, F., Anderson, J., Ferguson, R., Lagrange, M., Osei-Owusu, Y. & Bakker, L. (2009). *Human-wildlife Conflict in Africa: Causes, Consequences and Management Strategies*, Italy. FAO.

Lee, J., Nadolnyak, D. & Hartarska, V. (2012), "Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study", *Department of Agricultural Economics and Rural Sociology, University of Auburn, Auburn*.

Lobell, D. (2010), "Crop responses to climate: Time-series models, in Climate Change and Food Security", *Springer, Dordrecht*, pp. 85-98.

Lobell, D. and Burke, M. (2008). *Why are agriculturE impacts of climate change.* Longman, New York.

Masahumi., Oda, M., Maruo, T., & Shinohara, Y. (2011). Crop production and global warming. *Global warming impacts-case studies on the economy, human health, and on urban and natural environments*, 139-152.

Mogaka, H., Gichere, S., Davis, R. & Hirji, R (2006). Climate Variability and Water Resources in Kenya. Improving Water and Management, T*he World Bank, Washington DC*

Molla, M. N. (2008). *Effects of water stress on tomato at different growth stages*. McGill University Canada.

Morton, J. F. (2007), "The impact of climate change on smallholder and subsistence agriculture", *Proceedings of the National Academy of Sciences,* Vol. 104, No. 50, pp.19680-19685.

Mudombi, G. (2011), "Factors affecting perceptions and responsiveness to climate variability induced hazards", a thesis submitted to the *Department of Agricultural Economics and Extension, Faculty of Agriculture, University of Zimbabwe.*

Muga, M. (2010). Climate Change: A Major Challenge and Revelation for EA Nationals. *A journal on resource, reflection and discourse for sustainable development*, *32*, 201-207.

Mugenda, A.G. (2011). Social Science Research, Theory and Principles. Applied Research and Training Services, Nairobi: *Acts Press.*

Mugenda, O. M., & Mugenda, A. G. (1999). Research methods: Quantitative and qualitative approaches. *Acts press.*

Muthama, N.J., Njeri J.K. & Manene M.M. (2013). *The influence of El Niño Southern Oscillation on seasonal rainfall over the 47counties of Kenya*. University of Nairobi, Kenya.

Mutimba, S., Mayieko, S, Olum, P. & Wanyama, K. (2010). *Climate Change Vulnerability and Adaptation Preparedness in Kenya*. Berlin Heinrich Böll Stiftung.

Mutumpike, M. (2013). Growth Responses of Tomato (Lycopersicon esculentum Mill) to Different Growing Media under Greenhouse and Field Conditions, *University of Zambia, Lusaka.*

Ndegwa, A., Gathambiri, C., Magot, R., Wesonga, J., & Maim, M. (2019). Climate Smart Agriculture Tomato Technologies, innovations and Management practices KALRO

Naika, S, Jeude, J., Goffau, M., Hilmi, M., & Dam, B. (2005). *Cultivation of tomato: Production, Processing and Marketing* Wagenigen, Netherlands.

Neumann, L. (2000). Social research methods quantitative and qualitative approach. Allyn and Bacon. Boston.

Nyangena, W., & Seitz, J. (2009). *Economic Impact of Climate Change in the East African Community (EAC),* Nairobi: *GTZ.*

Nyeri County (2018). County integrated development plan (2018-2022). *County Government of Nyeri.*

Nyeri County (2013). *Rains, food security assessment report,* Nyeri

Odame, H., Musyoka, P., Kere, J., & Innovations, A. (2008). How national public policies encourage or Impede agribusiness innovation: Cases of maize, tomato and dairy in Kenya. *Agribusiness and Innovation Systems in Africa.*

Ogalleh, S,A., Vogl, C.R., Eitzinger & Hauser, M. (2012). Local perception and responses to climate change and variability. *The case of Laikipia District Kenya, Sustainability*

Ogola, O., Milton, W., Ayieko, A., Orawa, O., & Kimani, W. (2011). Analysis of fertiliser use in potato production in Nakuru district, Kenya. *Africa journal of Agriculture vol.6*

Olesen, J. E., & Bindi M. (2011). Consequences of climate change for European Agricultural Productivity, land use and Policy. *European Journal of Agronomy 16.*

Onyekwelu, J. C., Mosandl, R., & Stimm, B. (2006). Productivity, site evaluation and state of nutrition of Gmelina arborea plantations in Oluwa and Omo forest reserves, Nigeria. *Forest ecology and management*, *229*(1-3), 214-227.

Orre, S., Muriithi, B & Obondo, V. (2013) *Nyeri County 2013 Long Rains Food Seecurity Assessment Report.*

Osure, G. (2010). Agribusiness Forum – Uganda Inclusion of Small Scale Producers in Value Chains (Best Practices). *Syngenta Foundation for Sustainable Agriculture, Nairobi, Kenya.*

Parry J, Hammill A & Drexhage J. (2012). *Climate Change and Adaptation*. Manitoba, Canada. http://www.iisd.org.

Patt, A., P. Suarez & C. Gwata. (2012). E*ffects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe*. Proceedings of the National Academy of Sciences of the United States of America.

Rembold, F., Michele M., Ferdinando, U., Guido L., Herve, K., Ana P., and Gabor C. (2014). "ASAP - Anomaly Hot Spots of Agricultural Production, a New Early Warning Decision Support System Developed by the Joint Research Centre." Pp. 1–5 in *2014 9th International Workshop on the Analysis of Multitemporal Remote Sensing Images (MultiTemp)*. Brugge, Belgium: IEEE.

Republic of Kenya (2012). *Releasing our full potential. Sessional paper no. 8 of 2012 on national policy for the sustainable development of northern Kenya and other arid lands,* Ministry of State for Development of Northern Kenya and other Arid Lands. Nairobi, Kenya.

Salami, A., Kamara, A. B. & Brixiova, Z. (2010). Smallholder agriculture in East Africa:Trends, Constraints and Opportunities Development Bank. *African Development Bank Group: Ghana.*

Sayemuzzaman, M., Jha, M. K., Mekonnen, A. & Schimmel, K. A. (2014), "Sub-seasonal climate variability for North Carolina, United States", *Atmospheric Research*, Vol. 145– 146, pp. 69 –79.

Seitz, J. and Nyangena, W. (2009). *Economic impact of climate change in the East African community (EAC)*. Process in the EAC Region. Arusha, Tanzania.

Serigne, T. K., Kandji, L. V. and Jens M. (2006).*Climate Change and Variability in the Southern Africa: Impacts and Adaptation Strategies in the Agricultural Sector,* UNEP and ICRAF, Nairobi Kenya.

Starke, A. (2014), *Tomato Production Guideline*, Member of the Plennegy Group, www.starkeayres.co.za.

Statistical Abstract (2018). *Kenya National Bureau of Statistics (KNBS)*. Nairobi, Kenya.

Taiz, L. and Zeiger, E. (2010). *Plant Physiology* (5th edition). Los Angeles, Sinauer Associates, Inc.

The World Bank (2008). *Agriculture and Poverty*. Agriculture for Development Policy Brief (available at: siteresources. worldbank.org/ Southasiaext/ Resources.

Thornton, P., P. Jones, T. Owiyo, R. Kruska, M. Herrero, P. Kristjanson, A. Notenbaert, N. Bekele, & Omolo, A. (2006). *Mapping climate vulnerability and poverty in Africa*. Nairobi: International Livestock Research Institute.

Tshiala, M. F., & Olwoch, J. M. (2010). Impact of climate variability on tomato production in Limpopo Province, South Africa. *African Journal of Agricultural Research*, *5*(21), 2945-2951.

Tusiime, S. M. (2014). Evaluating Horticultural Practices for Sustainable Tomato Production in Kamuli, Uganda, *Iowa State University*.

United Nations Development Programme (UNDP) (2013). Combating Desertification in Kenya: Emerging Lessons from Empowering Local Communities.

Viet Nam *Assessment Report on Climate Change* (VARCC) (2009), Kim Do Publishing

Wachira, J. M., Mshenga, P. M. & Saidi, M. (2014). Comparison of the profitability of small-scale greenhouse and open-field tomato production systems in Nakuru-North District, Kenya. *Asian Journal of Agricultural Sciences*, *6*(2), 54-61.

Waliser, D. E., Moncrieff, M. W., Burridge, D., Fink, A. H., Gochis, D., Goswami, B. N. & Jakob, C. (2012). The "year" of tropical convection (May 2008–April 2010): Climate variability and weather highlights. *Bulletin of the American Meteorological Society*, *93*(8), 1189-1218.

Walthall, C. L., Hatfield, P. & Backlund, L. (2012). Climate change and agriculture United States; Effects and adaptation, USDA, Technical Bulletin , Washington DC

Willcox, J.K., G.I. Catignani & S. Lazarus, (2010). *Tomatoes and cardiovascular health. Critical Reviews in Food Science and Nutrient.*

World Meteorological Organization (WMO) (2009*). Living with Climate Variability and Change: Understanding the Uncertainties and Managing the Risks* Geneva, Switzerland.

World Wide Fund for Nature (2006). *Climate Change Impacts on East Africa. A review of Scientific Literature*. Gland, Switzerland.

Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M. & Smith, B. (2008). Climate change and adaptation in African agriculture. *Stockholm environment institute*, 17-19.

APPENDICES

Appendix 1: Letter of Introduction

February 11th , 2016

P.O. Box 720,

KISERIAN, 00206

Dear Respondent,

RE: LETTER OF INFORMED CONSENT

I am a postgraduate student at Karatina University taking a Masters of Arts Degree in Geography. Currently I am carrying out a research on **"**Influence of Rainfall Variability Trends on Tomato Farming in Kieni East Sub County of Nyeri County, Kenya".

Kindly respond honestly to the items in the questionnaire to generate data that will help in improving tomato farming in Kenya. All the risks and benefits arising from this research were explained to the participants. This research does not carry any risk. No benefits will accrue due to participation to the respondents. Your response will be confidential. Kindly do not write your name or other personal details on the questionnaire. Please complete all the items in the questionnaire.

Thanks.

Yours sincerely,

Karienye Macharia Joseph

Appendix 2: Questionnaire

QUESTIONNAIRE

I am carrying out a research on rainfall variability and tomato farming in Kieni East Sub County. To accomplish this task, I do hereby seek your assistance by answering the questions that follow. The information will only be used to devise adaptation strategies to mitigate the problem in the area. Your cooperation is highly appreciated.

Kindly do not write your details or name anywhere in this form.

Location..... Sub location.....Village.....

Section I: Demographic Data

1. Your gender Male ( ) Female ( )

2. Indicate your age: 15 – 24 years ( ) 25 – 34 years ( ) 35 - 44 years ( )

45 - 54 years ( ) above 54 years ( )

3. Level of Education Primary ( ) Secondary ( ) Graduate ( )

4. Occupation (i) Farming ( ) (ii) Business ( ) (iii) Professional employment ( ) any other? (Specify……

Section II: Land Tenure and Use

5. Size of the land holding? Less than 2 acres ( ) 2 – 4 acres ( ) over 4 acres ( )

6. Type of land ownership? Communal ( ) Leased ( ) owned ( )

If leased or communal, what is the acreage?.....

And why.....

……..

7. For how long have you been growing tomatoes?.....

8. How do you grow tomato? Rain fed ( ) Irrigation ( ) Greenhouse ( )

If irrigation, the source of water? .....

If rivers ( ) Name ……., …….....

Section III: Rainfall Variability and Tomato Farming

Kindly answer to the following statements according to your abilities and knowledge.

State your response by ticking ✓ the number that corresponds to your opinion on the **five-point scale** shown at the end of each statement.

5 – Strongly agree; **4** – Agree; **3** – I don't know; **2** – Disagree; **1** – Strongly disagree

		1	**2**	**3**	**4**	**5**
1	Rainfall shortages reduces tomato production					
2	Too much rainfall lowers tomato productions					
3	Tomato pests/ diseases increases with high rainfall					
4	Tomato diseases/ pests increases in dry periods					
6	Profits from tomatoes are low during rainy seasons					
7	Frequent dry periods lowers quantity and quality of tomato production					
8	During rainy season transport charges reduce profit margin in tomato sales					

9. What is your observation on rainfall amount for the last five years?

Year	**Excess**	**Adequate**	**Inadequate**	**No change**
2014				
2013				
2012				
2011				
2010				

10. What have you noted about seasonality for the last five years?

Regular ( ) Irregular ( )

If irregular, explain:……

……

Section IV: Production and Income Scale

11. What is the aim of growing tomatoes? Domestic consumption ( ) for sale ( )

12. Kindly state source of labour? Family members ( ) Hired labour ( ) Communal ( )

13. In the last 5 years, what have you done to tomato farming portion? Increase ( ) Decrease ( ) Same ( )

14. About how much income did you make per year from sale of tomatoes?

Year	2014	2013	2012	2011	2010	2009	2008
Number of seasons							
Income from tomato (Kshs)							

Explain the variations in seasons:……

.....

Explain variations in income:……

……

15. Where do you market your tomato produce? ……....

16. What is the mode transport your tomato produce to the markets?

Human ( ) Donkey/ cow carts ( ) Motor cycles ( ) Pick-ups ( ) Lorries ( ).

Explain your choice above:……

……

17. Do you access finances (loans)? No ( ) Yes( ). If yes;

From Banks ( ) From SACCO ( ) any other mention……..…….....

Why?.....

Which years?.....

Section V: Tomatoes' Farmers Adaptation to Rainfall Variability

18. In your opinion, what adaptations strategies on tomato farming are you putting in place against rainfall variations?

Use of certified seeds ( ) Use of manure ( ) Use of greenhouses (.....)

Follow advice from Agricultural officers ( )

Explain your choice(s)……..……...……

Other adaptation strategies:.....

Record your answer by ticking √ the number that corresponds to your opinion on the **five-point scale** shown at the end of each statement.

5 – Strongly agree; **4** – Agree; **3** – Not decided; **2** – Disagree; **1** – Strongly disagree

		1	**2**	**3**	**4**	**5**
1	Soil influence tomato yields.					
2	Seed influence tomato yields.					
3	Government Policies affect tomato prices in the market.					
4	Tomato yields affect its markets.					
5	High transport costs discourage tomato farming.					
6	Inadequate capital discourages tomato farming.					
7	High costs of labour discourages tomato farming					
8	Farming methods influence tomato. Yields					
9	Farming decisions influence tomato yields.					

Thanks for Your Precious Time.

Appendix 3: Interview Guide for Agricultural Officers

Please respond to the following statements in relation to your abilities and knowledge. Record your answer by ticking ✓ the number that corresponds to your opinion on the **five-point scale** shown at the end of each statement.

5 – Strongly agree; **4** – Agree; **3** – Not decided; **2** – Disagree; **1** – Strongly disagree

		1	**2**	**3**	**4**	**5**
1	You observed variability in rainfall in Kieni East Sub County for the past two decades.					
2	You have observed irregular trend in rainfall pattern over the past years.					
3	In your own opinion rainfall variability affects tomato production.					
4	There has been extreme climatic events (e.g. drought, flood etc.) affected tomato production in the area.					
5	There has been positive effect of rainfall variability on tomato production?					
6	Rainfall variability affects the livelihood of farmers in the district.					
7	You provide any assistance to farmers in times of crop failure due to extreme rainfall conditions / from KMD.					
8	Your office provides any training programmes to farmers to enhance their adaptive capacity in response to climate variability.					
9	Effective of your training to improves farmers‟ adaptive capacities?					

Where do the farmers sell their tomato yields?.....

Which assistances do you offer to tomato farmers?.....

……

State the challenges do you face as you address the tomato farmers issues?.....……

……

How are you addressing the challeges to ensure increase in tomato production?.....……

…….....……

Thank you for your precious time.

Appendix 4: Tomato Production and Income in Kieni East Sub County 2009 - 2014

COUNTY GOVERNMENT OF NYERI

DEPARTMENT OF AGRICULTURE, LIVESTOCK AND FISHERIES

Directorate of Agriculture

Telegrams: "MINAG", NYERI

SUB COUNTY AGRICULTURE OFFICE,

KIENI EAST,

NYERI,

Telephone: P.O. BOX 164,

Email:daonyerinorth@yahoo.com

KIGANJO. Date: 15th February, 2016

KIENI EAST FARMERS TOMATOES PRODUCTION

Year	Yields (MT)	Value 000 (Kshs)
2009	1,800	3,600
2010	5,250	10,500
2011	3,700	74,000
2012	3,520	105,600
2013	2,800	84,000
2014	3,200	75,000

Source: Kieni East Sub County Agriculture Office, 2014

Appendix 5: Farmers Growing Tomato in Kieni East Sub County

COUNTY GOVERNMENT OF NYERI

DEPARTMENT OF AGRICULTURE, LIVESTOCK AND FISHERIES

Directorate of Agriculture

Telegrams: "MINAG", NYERI

SUB COUNTY AGRICULTURE OFFICE,

KIENI EAST,

NYERI,

Telephone: P.O. BOX 164,

Email:daonyerinorth@yahoo.com

KIGANJO. Date: 15th February, 2016

KIENI EAST FARMERS GROWING TOMATOES

Below find the data for your information.

	Ward	**No. of tomato farmers**
1	Kabaru	35
2	Thegu	51
3	Naromoru /kiamathaga	39
4	Gakawa	17
	Total	**142**

J. W. Kibe **(**Sub County Agriculture Officer)

Kieni East Sub County Agriculture Office, 2014

Appendix 6: Research Clearance Permit

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No. A 9617

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. JOSEPH MACHARIA KARIENYE
of KARATINA UNIVERSITY, 0-206 KISERIAN,has been permitted to conduct research in *Nyeri County*

on the topic: *INFLUENCE OF RAINFALL VARIABILITY ON TOMATO FARMING IN KIENI EAST SUB COUNTY, MYERI COUNTY, KENYA*

for the period ending:
13th June,2017

Permit No : NACOSTI/P/16/92789/11087
Date Of Issue : 17th June,2016
Fee Recieved :ksh 1000

.....
Applicant's Signature

.....
Director General
National Commission for Science, Technology & Innovation

Appendix 7 : Introduction Letter

KARATINA UNIVERSITY

SCHOOL OF EDUCATION & SOCIAL SCIENCES
OFFICE OF THE DEAN

Tel. +254 – (0)729721200/0202176713
Email: sess@karu.ac.ke

P.O. Box 1957 – 10101
KARATINA, Kenya

Ref: KarU/RC/SESS/2016

Date: 20th April, 2016

National Council for Science and Technology.
Utalii House
P O Box 30623-00100
NAIROBI.

RE: KARIENYE MACHARIA JOSEPH-E226/2278P/2013

This is to certify that the above named is a student in the School of Education and Social Sciences, Karatina University pursuing Master of arts in Geography.

Mr. Joseph Macharia completed his course work and defended his proposal.

The student is expected to collect data to enable him complete his research project.

Any assistance given to him will be greatly appreciated. Please do not hesitate to contact us should you need any information about him.

Thank you,

KARATINA UNIVERSITY
Dean, School of Education & Social Sciences
29 APR 2016
P. O. Box 1957 - 10101,
KARATINA.

Prof. JOHN MWARUVIE
DEAN, SCHOOL OF EDUCATION AND SOCIAL SCIENCES

Appendix 8: Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.
NACOSTI/P/16/92789/11087

Date:
17th June, 2016

Joseph Macharia Karienye
Karatina University
P.O. Box 1957-10101
KARATINA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Influence of rainfall variability on tomato farming in Kieni East Sub County, Nyeri County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Nyeri County** for the period ending **13th June, 2017.**

You are advised to report to **the County Commissioner and the County Director of Education, Nyeri County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

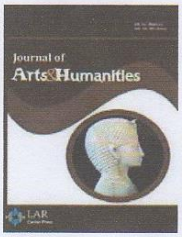
Copy to:

The County Commissioner
Nyeri County.

The County Director of Education
Nyeri County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

Appendix 9: Publications



Journal of Arts & Humanities

Volume 09, Issue 08, 2020: 18-33
Article Received: 02-07-2020
Accepted: 26-08-2020
Available Online: 29-01-2020
ISSN: 2167-9045 (Print), 2167-9053 (Online)
DOI: http://dx.doi.org/10.18533/journal.v9i8.1948

Assessment of Tomato Farming Systems and Rainfall Variability Related Implications in Semi-Arid Regions of Central Kenya

Joseph M. Karienye[1*], Tom Ouna[1], Hellen Kamiri[2]

ABSTRACT

The future of African agriculture depends on the outcome of climate and specifically on rainfall variability. In arid and semi-arid areas, the impacts of rainfall variability can be adverse especially where the main farming system is horticultural oriented. This study aimed at assessing tomato farming systems and how they were influenced by rainfall variability. The study focused mainly on examining the aspects of tomato farming practices and rainfall variability over a period of thirty four years (1980-2014). Data was collected from tomato farmers in four wards namely Kabaru, Thegu River, Narumoru/ Kiamathaga and Gakawa in Kieni East Sub-County, using face-to-face interviews and semi structured questionnaires. Rainfall data was obtained from Kenya Meteorological Department in Nairobi. Historical climatic data was analyzed to establish patterns and trends which were then correlated to production data. The study revealed that tomato farming system is determined by climate (rainfall), economic and social wellbeing of the farmers. The study further established the rainfall characteristics over the thirty four years under study varied both annually and seasonally. Farming practices applied by farmers in tomato production, included irrigation, crop rotation, and use of certified seeds, mulching, use of manure and use of greenhouse technology. These practices were however influenced by rainfall patterns and social economic status of the farmers. These findings show that there is need to develop policies that will enhance adoption of farming systems suited to the study area and therefore safeguard farmers from adverse effects of rainfall variability, and make tomato production a viable venture.

Keywords: Farming systems, tomato, rainfall variability, social factors.
This is an open access article under Creative Commons Attribution 4.0 License.

1. Introduction

Farming systems are dynamic and the components are site specific (Shaner, 2019). Thus a logical approach in evaluating a farming system is to identify integral components that can be

* corresponding author.Email: j.macaria.mj@gmail.com, j.macaria@yahoo.co.uk
1Department of Humanities and Languages, Karatina University, Kenya.
2 Department of Agricultural Sciences, Karatina University, Kenya.