EVALUATION OF CLIMATE VARIABILITY IMPACTS AND ADAPTATION STRATEGIES AS DRIVERS OF BANANA VALUE CHAIN DEVELOPMENT WITHIN MOUNT KENYA REGION

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DECLARATION

Declaration of the Candidate

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

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DEDICATION

Dedicated to my parents late Jackson Karienye and Gladys Mugure for sacrificing towards education, to my lovely wife Winnie and children Ian, Mitchell and Jewel.

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LIST OF ABBREVIATIONS AND ACROYNMS

AEZ	-	Agro Ecological Zone
BVC	-	Banana Value Chain
CEEPA	-	Centre for Environmental Economics and Policy in Africa
FAO	-	Food Agriculture Organization
FGDs	-	Focus Group Discussions
FFV	-	Fresh Fruits and Vegetables
GDP	-	Gross Domestic Product
GOK	-	Government of Kenya
GPS	-	Geographical Information Systems
GVC	-	Global Value Chain
HCD	-	Horticulture Crop Directorate
IPCC	-	Intergovernmental Panel on Climate Change
IFAD	-	International Fund for Agricultural Development
ILRI	-	International Livestock Research Institute
KShs.	-	Kenya Shillings
LH	-	Lower Highlands
LM	-	Lower Midlands
MAM	-	March April May
MOA	-	Ministry of Agriculture
NCCRS	-	National Climate Change Response Strategy
NCCAP	-	National Climate Change Action Plan
SSA	-	Sub -Saharan Africa
OND	-	October November December
UH	-	Upper Highlands
UM	-	Upper Midlands
UNEP	-	United Nation Environment Programme
UNIDO	-	United Nation Industrial Development Organization
UTM	-	Universal Transverse Mercator
VCD	-	Value Chain Development
WWF	-	World Wide Fund for Nature

^0C	-	Degrees Centigrade
KPHC	-	Kenya Population and Housing Census

ABSTRACT

Spatial and temporal dimensions of banana value chain processes globally have been impacted by past changes in climate. Research conducted on role played by climate variability on banana value chain has mainly focused on socio economic aspects of banana production with little concern on the effect of climate variability and adaptation strategies in banana value chain development. Hence, there is limited understanding of the relationship that exist between climate variability impacts and respective adaptation strategies in banana value chain, which this study sought to establish. The study purposed to evaluate how climate variability impacts and respective adaptation strategies drive banana value chain development within the Mt. Kenya region. The study specific objectives were to: establish trends and impacts of climate variability on banana value chain development within the Mt. Kenya region between 1980-2017; determine banana farmers' perceptions of climate variability impacts on respective banana value chain stages; establish how climate variability adaptation strategies influence banana production; and determine the extent to which rainfall and temperature trends affect developments in banana value chain. The study hypothesized that climate variability perceptions and adaptation strategies influence banana value chain development. The study was guided by the Action Theory of Adaptation to Climate Change. Triangulation research design was used to guide the study by integrating both qualitative and quantitative methods in data collection and analysis. The sites were purposively selected to include Imenti south and Mukurweini sub-counties where banana production has been practiced since the 1980s. A sample size of 381 respondents was identified using simple random sampling. Field survey techniques were used in the collection of data which was analysed using SPSS v21 statistical package. Study findings showed that rainfall and temperature had changed over the target study period. The annual change in temperature in Mukurweini sub-county for the study period was 0.02^0C while in Imenti South Sub County it was 0.016^0C. During this period, the study revealed that 43% of the farmers had changed the type of crop cultivated. Seventy nine percent of the respondents perceived climate variability in the region. Adverse effects of climate variability on banana value chain were reported as decline in yields, high transport cost, low market prices and limited value addition. Logit model was used to determine the socioeconomic factors influencing farmers' perception and choice of adaptation strategy to climate change. The model was significant at $p<0.01$ for adopters or non-adopters. Gender of household head, type of farming system and access to weather information were significant in explaining the farmers' perception to climate change. Irrigation and crop diversification were the most preferred adaptation strategies to climate variability. Banana acreage and production in both sub-counties have been increasing in the period between 2009 and 2017. The results of the study showed that improvement in banana value addition, access to credit facilities, irrigation facilities, information on weather information and market information is necessary for the smallholders' farmers in the region. The study recommends that county governments should develop and integrate value chain development concerns in reference to climate variability and adaptation in their agricultural and agribusiness policies. Farmers in the region should also be enlightened on best farming practices that are adaptive to climate variability. Moreover, further research on climate variability and banana value chain developments is required.

CHAPTER ONE

INTRODUCTION

This chapter introduces the study by highlighting the background of the research idea, the statement of the problem and the objectives of the study. It also introduces the spatial context and outlines the significance and the focus of the study.

1.1 Background to the Study

This section highlights the drivers of the agricultural processes and the relationship between climate variability and agricultural production.

1.1.1 Climate as a Driver of Agricultural Processes

Agriculture is a major occupational sector in many Sub-Saharan Africa (SSA) countries and a source of livelihood for the rural society (UNEP, 2011). Agricultural production in SSA is predominantly reliant on climate conditions with respect to its temperature and rainfall requirements. In this respect, scholars have noted that rural livelihoods that depend on agricultural production will continue being faced by challenges emanating from climate variability impacts (IPCC, 2007; Nhemachena, 2009). This results to changes in temperature and water availability. Temperature moderates the rate of nutrient absorption and crop growth rate, the evapotranspiration potential and hence the wilting points of a crop, which all determine the health of a crop and its production potential. Rainfall in turn is a crucial hydrological process that determines the water availability in the root zone of a crop. The levels of temperature and rainfall amounts develop a set of synergetic environmental conditions that spatially and temporal determine the potential of a crop's production, its yielding levels and its sustainability over space and time in a region.

In respect to feasible conditions, respective crops can only grow within certain Agro-Ecological Zones (AEZ), except with extra modifications enabled by technological advances as in the case where greenhouses and/or irrigation are used to enable crop production beyond their ecologically determined limits. These technological advancements go beyond production to other levels of the agricultural value chain such as transportation, harvesting, storage and trading which can be achieved through support from national and county governments to make banana value chain more competitive since it is a major form of livelihood to a significant number of the households within Mt. Kenya region (MOA, 2016).

1.1.2 Climate Variability Dynamics and Agricultural Production

Climate variability and agricultural productivity are interactive. Evidence from the increase in frequency of extreme climatological events specifically rainfall and temperature has become unequivocal, impacting water resources, agricultural and food systems (Bates, Kundzewicz, Wu., & Palutikof, 2008; Brown & Funk 2008; Hartmann *et al*., 2013). Agriculture is influenced either directly or indirectly by changes in climate leading to variations and seasonality in crop productivity. Dynamics in climatic variables specifically temperature and rainfall affect agricultural productivity by instigating physiological changes in crops (Chakraborty, Tiedemann & Teng, 2000). In addition, climate variability impacts on other factors of agricultural production such as water availability, soil fertility, pest and diseases (Porter *et al*, 2014). Amarnath and Ashok (2016) noted that climate variability affects food production negatively through decrease in food availability and limits food access to households (because of high food prices and inaccessibility to the farms during rainy seasons) for a significant segment of the population.

There has been a transformation of rural economies and agricultural food structures in the last 20 years due to the impacts of climate modifications (Oxfam, 2007). Climate variability is an influential spatial factor that contextualizes the production, processing, transportation and marketing of bananas globally. Understanding the influence of climate variables on various levels of the banana value chain is important since such knowledge enables stakeholders to make appropriate decisions regarding the value chain. The respective effects on banana chain are largely associated with frequent fluctuations in temperature and rainfall regimes over space and time globally.

Stern and Stern (2007) recognizes that the earth has already warmed by 0.7^0C since 1900 and based on current trends, average global temperatures could rise by 2– 3^0C within the next 50 years or 2-4^0C above pre-industrial levels. There is likelihood for global surface temperature to exceed 2.0^0C for many scenarios by the end of the 21^{st} century (Inter-Governmental Panel on Climate Change (IPCC), 2014). The IPCC (2014) attributes this to both natural internal developments and external forces or to the persistent man-made changes in the gaseous composition of the atmosphere and land usage. Successive assessments of the IPCC have brought out the role of Greenhouse Gases (GHGs) such as carbon dioxide, methane and nitrous oxide among others in promoting earth warming and climatic destabilization in micro and macro scale.

Scholars have recognized that developing countries are vulnerable to the effects of climate variability (Boko *et al.*, 2007). Boko *et al.*, (2007), further notes that most parts of Africa are experiencing high frequency and forceful extreme climatic events ranging from droughts to floods, which are predicted to continue intensifying. Temperature in Africa is predicted to rise faster than most parts of the world, which could exceed 2°C by mid-21st century and 4°C by the close of 21st period while future rainfall patterns are more uncertain (Niang *et al.*, 2014). The Fifth Assessment Report (AR5) presents strong evidence that warming over land across Africa has increased in the last 50–100 years. The surface temperature has already increased by 0.5–2^0C over the past hundred years (IPCC, 2014). Those regions that are relatively dry, such as the Mediterranean basin and parts of Southern Africa will experience further decreases in water availability due to climate variability. IPCC (2007) projected that by the close of 2020 approximately 75 and 250 million people in Africa are expected to experience water stress as a result of climate change linked impacts.

The Kenyan agricultural production has been affected negatively by the rising number of extreme event such as a droughts and floods due to climate variability, especially the subsistence sector and smallholders close to the equator (Wik, Pingali & Brocai, 2008). Wik *et al.*, (2008), further outline that agriculture is specifically delicate to variations in climate variability hence crop yields depend mainly on meteorological variables which includes temperature levels and rainfall amounts and patterns. IPCC (2014) notes that climate related impacts will lead to food insecurity as well as breakdown of food arrangements in the rural areas. However, it is not scientifically clear when, how and where the effects of climate variability on agriculture production and food insecurity.

Nelson, Kokic, Crimp, Meinke, and Howden (2010) points that the results of climate variability will damage on agricultural production, food availability and the overall economic development, particularly in the emerging and developing countries. The rural smallholder farmers in Africa will be the most susceptible to the vagaries of climate over the next 50 years and the effect will be on agriculture productivity and food availability to the small holders farmers (IPCC, 2007; Muamba & Kraybill, 2010). The most vulnerable region to climate effects will be the Sub Saharan Africa due to limited capacity, knowledge and skills to respond to climate variability and high poverty level (Bryan, Ringler, Okoba, Roncoli, Silvestri, & Herrero, 2010).

Hassan and Nhemachena (2008) noted that Sub-Saharan Africa will be severely affected by climate variability resulting to reduced agricultural yields due to extreme weather events like persistent droughts and recurring floods. Arumugam, Ashok, Kulshreshtha, Vellangany and Govindasamy (2014) points out that agriculture is more sensitive to climate conditions and inter-temporal variability in crop yields is dependent on the climatic variables. Climate change and associated variability affects food security with respect to food: availability, accessibility, utilization, systems stability and the entire livelihood (FAO, 2008). This will be through food production and supply networks and changing purchasing power of the people due to associated changes along their respective crop's value chains.

In SSA, the impacts of climate variability is due to the region's level of poverty, the geographical location, weak transport and communication channels, poor skills in natural resources management and over dependence on rain-fed agriculture (IFAD, 2010). Small holders' farmers in the region that are vulnerable to climate related impacts are likely to experience losses and reduction in crop productivity. This results from extreme climatic events like low, unreliable and unpredictable precipitation and exceeding temperatures levels. In East Africa, the link between climate influence and livelihood is very strong because majority of households rely heavily on rain-fed agriculture (WWF, 2006; IPCC, 2001). Impacts of temperature increase in the region and precipitation decrease have been observed and documented, for instance the (WWF, 2006), reported that the years between 1996 to 2003, there was a reduction of rainfall amounts of between 50 and 150 mm per season during long rains March to May (MAM) within East Africa leading to decline in yields. Progressive moisture deficit results to reduced crop yields, thereby impacting the availability of food supply among smallholders. In some areas in East Africa, rainfall is likely to increase but this will not guarantee increased production due to poor timing as well as seasonal variations.

According to NCCRS Report by GOK (2010), Kenya will not be exceptional to the impacts of climate variability; more specifically warming trends have been noted from early 1960s. Mutimba, Mayieko, Olum and Wanyama, (2010) notes that temperature levels have risen by 0.7–2.0^{0}C in Kenya during the last 40 years, coupled with irregular and unpredictable rainfall, leading to poor timing of agricultural events. IISD (2012) projects future increases in mean annual temperature (average monthly temperatures) of broadly 1 to 3.5^{0}C over the range of models by the 2050s (2046-2065). The IISD (2012) further notes a strong link between climate risk and vulnerability in Kenya where poverty is at 52% and 74% of the population depends on labour income from agricultural production for their livelihood (FAOSTAT, 2010). Water deficiency coupled with high temperature has put the smallholder farmers to be more susceptible to climate variability related impacts. Kamau, Olwande and Githuku (2011) note that approximately 10% of the Kenyans are food insecure and up to 30% of the food insecure persons live in urban and peri-urban centers.

Smallholder farmers in the Mt. Kenya region are faced with several challenges due to the impacts of climate variability where the farmers possess few physical and natural resources such as access to land, water or irrigation systems; they often have very little technical skills and low managerial capacity. They often have limited access to markets, inputs, finances and credit services. These constraints pose a huge challenge for them to ably participate in value chains and when they participate, high operation costs are often involved due to the small and dispersed nature of their farming enterprises.

1.1.3 Climate Variability Dynamics and Agricultural Value Chains

Agricultural value chain perspective captures the sequence of related activities required to bring a produce from material inputs to production, harvesting, storage, transportation and distribution, final consumption and recycling (Norman & Kebe, 2006). This entails a combination of physical transformation and the participation of various actors within the chain. Climate variability will have profound effect on the value chain component of agricultural production and also delivery of the final produce to consumers. These will include impacts on production, transportation and marketing of farm produce. Climate variability has impacts that can complicate the uncertainty and the stability of crop production, more so around the tropical regions (ILRI, 2007).

Africa Harvest Biotechnology Foundation International (AHBFI), (2015) has identified the major challenges affecting the banana value-chain in Mt. Kenya region as inadequate access to hygienic planting materials, poor agronomic practices, disorganized marketing, and high incidence of pests' infestations and diseases in the orchards. The smallholder farmers' vulnerability is worsened by limited access to land due to the traditional land tenure systems, lack of adequate water, low levels of know-how and education and institutional mismanagement (Nhemachena, Rashid & Pradeep, 2010). This calls for clear response strategies to climate variability in terms of adaptation in order to deal with the threats posed by climate variability to the low resourced endowed small-scale farmers in Kenya whose coping mechanism is limited. This has increased their risk of food insecurity.

The worth of the global trade of food and agricultural commodities has increased fivefold in the last 50 years and it is projected to keep rising (FAOSTAT, 2010). Although agriculture in the powerful USA, Europe, Brazil, Argentina and Australia still lead the markets, there are other many emerging economies that are also net exporters. A minority of large farms/plantations and a huge multitude of smallholders are involved in the production of high value crops including bananas (Bruni & Santucci, 2016). According to GOK (2010), Kenyan economy is dependent on agriculture being the main source of livelihood and contributing 30% to the GDP, 60% of the export earnings and accounts approximately 80% of the employment. Agriculture is among the basis of achieving food security, economic growth, employment creation and foreign exchange generation in Kenya. There are a variety of agricultural practices across the country, with some being subsistence production systems and others being for income generation such as cash crops. A great majority of small-scale farmers intermix the two perspectives. One of the more specialized cash crop production system in Kenya focus on horticulture.

HCDA (2008) noted that horticulture farming is the fastest growing industry within the agricultural sector in Kenya, recording an average growth of between 15% and 20% per annum. It contributes positively to wealth creation, poverty alleviation and gender equity especially among the rural poor. The sector contributes to the Kenyan economy through generation of income, creation of employment opportunities for rural people and foreign exchange earnings. In terms of sectoral linkages, agriculture supplies raw materials as well as final consumer goods to other sectors (UNECA, 2009).

Banana is an important fruit (GOK, 2012) which is among the top three most valuable crops grown (AHBFI, 2012) in Kenya. Banana is a both source of food and income for millions of smallholders in Africa and developing countries worldwide (Arias, Dankers, Liu & Pililkauskas, 2003). Banana production as a horticultural crop and mainly as a cash crop is a new venture in the Mt Kenya region, where previously coffee farming was dominating until 1990. The smallholder farmers dominate the fresh fruits and vegetables domestic market globally (Splisbury, Jagwe, Wanda & Nkuba, 2003). Karanja and Nyoro (2002) points out that since the colonial era, Kenya’s economy, in the Mt. Kenya region depended on coffee production until 1990. Nevertheless, the coffee industry worldwide has been facing various crises due frequent and unfavorable price fluctuations. The frequent and often drastic drops in prices have severely affected Kenya and especially the Mt. Kenya region, which forced the smallholder farmers that relied heavily on coffee production as the only main basis of income and livelihoods to rethink their livelihood and economic options.

Banana growing is usually rain-fed with little irrigation in some parts of Kenya. According to AHBFI (2012) there are approximately 390,000 banana farmers in Kenya, most of whom (84%) are smallholders cultivating <0.2 hectares. Majority of the smallholder producers have become more reliant on the income generated from banana sales, especially in areas that were negatively affected by declining incomes from traditional cash crops such as coffee (Wambugu & Kiome, 2001).

The growth of Global Value Chains (GVCs) in a range of industries has been a salient feature of the world economy over recent years (Miroudot, Lanz & Ragoussis, 2009). De Backer and Yamano (2012) points that GVCs are branded by the functional and spatial fragmentation of activities in a firm value chain, including production, distribution, sales and marketing, research and development, innovation and other functions. Lack of well-established banana value addition activities within the chain has been reported to constrain smallholders in other banana activities in Africa (for example, Mwangi & Mbaka, 2010; Ouma & Jagwe, 2010) recommended that maximizing banana value through improving cleaning, packaging and labelling to differentiate products would promote competition.

Smallholder farmers generally face challenges within the value chain to access all factors that are required for the products to respond to market demand competitively. Poor market organization leads to exploitation of farmers by middlemen (brokers) who dominate the marketing of agricultural produce. This acts as a disincentive to farmers and affects returns in the agricultural sector. They often face strong economic, social and physical disadvantages: in some areas the infrastructure is poor to access markets, while in other areas up to-date market information is not always available to everyone due to poorly coordinated and unstructured market. Other challenge include difficulty in accessing technical advisory services, agricultural inputs; lack of post-harvest facilities making it difficult to deliver consistent supply of good quality produce and lack of financial services (Ellen & Bart, 2010). Limited agro-processing opportunities hinder horticultural value chains forcing farmers to sell their produce at ridiculously low prices to avoid substantial post-harvest losses due to the perishability nature.

Value chain has potential on agricultural transformations especially in developing countries by linking local producers to consumers. Agriculture value chain helps producers in moving from primary production towards processing and trading with the aim of increasing value of the produce. The key condition for banana farmers to participate fairly in the value chains is the access to market information and the ability to translate it to market intelligence (Trienekens, 2011). In this aspect the developing country smallholder farmers may diversify their production portfolio and capture larger added value market channels. To achieve this supporting infrastructure, skills, resources including knowledge and competences are key conditions for these chains to be successful and help the small farmer achieve the desired goals.

1.2 Statement of the Problem

Banana production in Mt. Kenya region before 1990s was mainly for household consumption. It occupied only about 20% of the farms while the rest of the portion was occupied by other cash crops mainly coffee and tea as well as subsistence crops like maize and beans, which were the main sources of income for small scale farmers in the region. Due to challenges associated with price fluctuations, delayed payments and general declines in coffee proceeds as well as uncertainties associated with changing climatic regimes, farmers in the area opted for banana production and agribusiness as alternative sources of income. This led to increased acreage of banana production, and with time banana business has evolved to become a major cash crop, which provides farmers with both food and a steady source of income. Rapid urbanization and high population growth in the recent past have also increased banana demand as one of the staple foods. In this respect, banana farming has continued to gain ground as a preferred crop for both subsistence and commercial reasons. Most of the studies conducted on banana production have focused on socio-economic issues and agribusinesses prospects. However, little attention has been made with respect to the extent of climate variability effects and the associated adaptation measures in driving banana in value chain developments within the Mt. Kenya region. The impacts of climate fluctuations on banana value chain development are not well understood. Temporal and spatial adaptation measures that are implemented to regulate effects of climate variability in the Mt Kenya region are not well understood.

Hence, the relationship between climate variability and moderating adaptation measures remains largely unknown. This knowledge gap disadvantages farmers, planners and other actors in the banana industry who need clear information for enhanced banana production and respective agribusinesses. It is these gaps in knowledge that this study sought to address by evaluating the trends of climate variability and its impacts on adaptation strategies as the main drivers of banana value chain developments in the study region. This study therefore offers more concrete information and data on the best practices while bridging the existing gap in order to strengthen the link between facilitators and other actors.

1.3 Objectives of the Study

The purpose of the study has been outlined.

1.3.1 The Purpose of the Study

The researcher purposed to evaluate how impacts of climate variability and respective adaptation strategies drive banana value chain developments within the Mt. Kenya region.

1.3.2 Specific Objectives

The specific objectives of the study were;

i. To examine the trends and impacts of climate variability on banana value chain development in Mt Kenya region from 1980 to 2017.

ii. To determine banana farmers' perceptions of climate variability impact on respective banana value chain stages in Mt Kenya region.

iii. To establish how banana farmers adaptation strategies to climate variability affect banana production within Mt Kenya region.

iv. To evaluate the extent to which rainfall and temperature trends impact on banana value chain development within Mt Kenya region.

1.4 Research Questions

The research questions of the study were;

i. How has climate variability impacted banana value chain in Mt. Kenya region from 1980 to 2017?

ii. How do banana farmers' perception of climate variability impacts on banana value chain stages in Mt Kenya region?

iii. Which are the banana farmers' adaptation strategies to climate variability and how do they influence banana production in Mt Kenya region?

iv. To what extent does rainfall and temperature impact on banana value chain developments in Mt Kenya region?

1.5 Hypotheses

The study hypotheses were as follows;

i) H_0. There is no significant relationship between rainfall changes and banana transport in Mt Kenya region.

ii) H_0. There is no significant relationship between banana farmers' perception and socioeconomic characteristics of the households on banana value development in Mt Kenya region.

iii) H_0. There is no significant relationship between adaptation strategies and socioeconomic characteristics of the households on banana value development in Mt Kenya region.

1.6 Spatial Context of the Study Region

The study was carried within Mt. Kenya region focusing on selected areas located in Meru and Nyeri Counties. According to UTM projection, Meru County falls within approximately between longitudes 37^0 0’ 00” East and 38^0 30’ 00” East and latitude 00 20’ 00” North and 00 40’ 0” South. Nyeri County is located between Longitudes 36^0 and 38^0 East and along the equator at Latitude 00 38´ South.

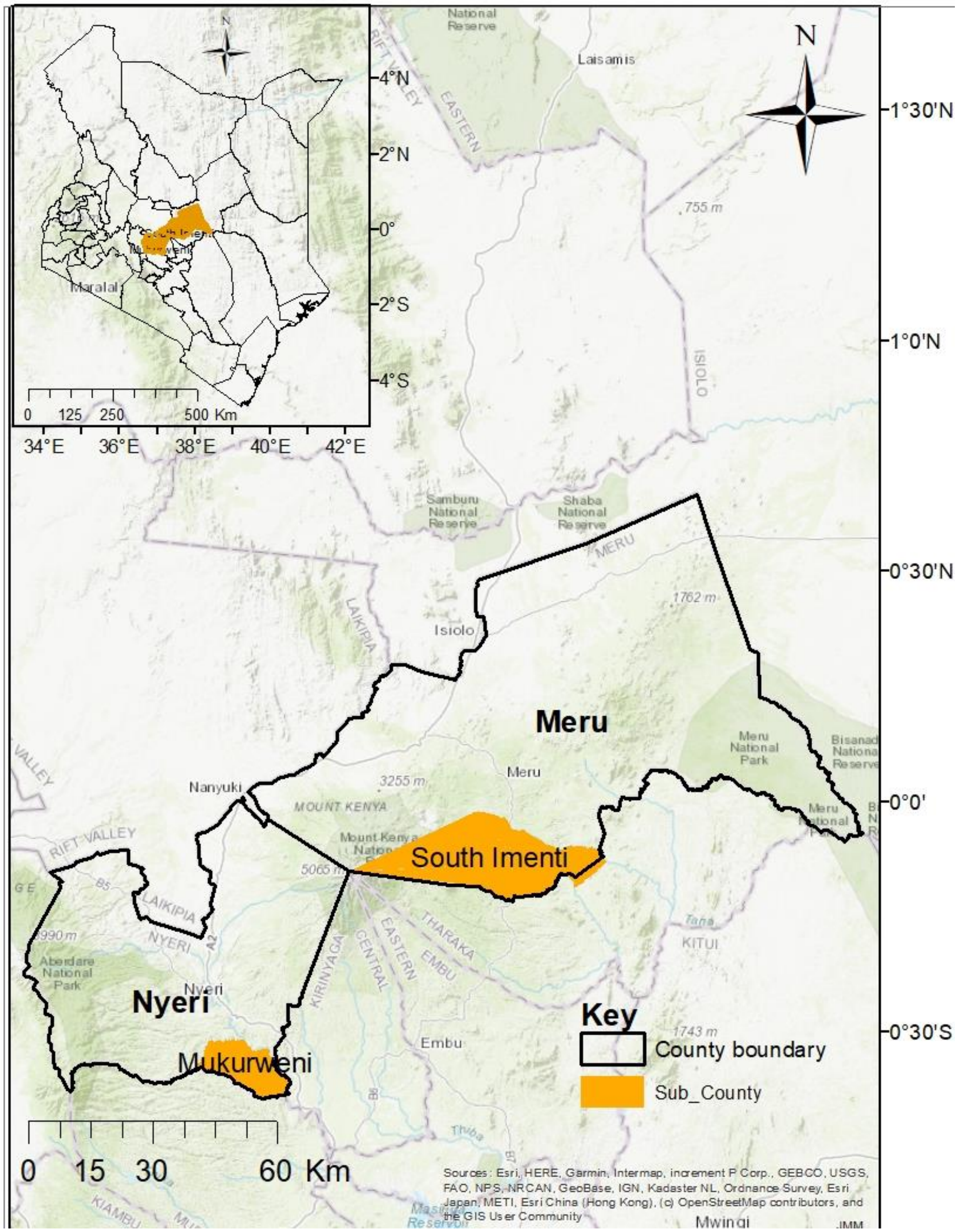

Figure 1.1. Map of Kenya showing the location of the study areas in Imenti South (Meru County and Mukurweini (Nyeri County)

1.6.1 Climate

The region receives bi-modal rainfall pattern with long rains (LR) season falling from March to May (MAM) and short rains (SR) season falling between October and December (OND). According to Jaetzold, Schmidt, Hornez and Shisanya (2006), the climate in Meru County can be described as cool. Temperatures in the highlands range between 14^0C to 17^0C while those of the lowlands, between 22^0C to 27^0C. The region receives an average rainfall of between 1250mm annually (GOK, 2015a).

Nyeri County experiences equatorial rainfall due to its location within the highland zone of Kenya. The monthly mean temperature ranges from 20^0C to 20.8^0C. The region receives an average rainfall of between 1200mm annually (Nyeri statistical abstract, 2015). Banana plants thrive in tropical regions where the annual average temperature is 17° C and the yearly rainfall is between 1300 mm (Bose, Mithra & Sanyal, 1996) making Mt Kenya region ideal for banana production.

1.6.2 Relief

Meru County lies between altitude from 1300 and 5199 meters above sea level at the peak of Mt. Kenya (GOK, 2015a). The water catchment area is Mt Kenya forest where rivers and streams have sources. The rivers transect the hilly terrain on the upper zones to the lower zones and drain as tributaries to form Tana River, which discharge its water into the Indian Ocean. The existence of permanent rivers in the region provides water for domestic and crop production. Nyeri County lies from 1100 to 3,076 meters above sea level. The western part of the County is flat, whereas further southwards face Aberdare ranges and the topography is characterized by steep ridges and valleys (GOK, 2015b). According to Bose, Mithra and Sanyal, (1996), the best altitude for banana farming of 1500 meters, making the Mt. Kenya an appropriate region for banana farming.

1.6.3 Geology and Soils

The geology of Mt. Kenya region is categorized by volcanic soils in western part and basement rock system on the eastern part. The volcanic part has ridges on the middle and lower slopes of Mt. Kenya with uplands and scattered plateaus. The basement system shows several different landforms such as hills and valleys. The soil of the ridges is derived from volcanic parent material and has very deep red clay (Nitisols and Andosols) while the soils of the volcanic plateau are moderately deep to shallow with various textures. The soils derived from the basement system rocks are predominantly moderately deep to shallow with loam to clay textures (Cambisols and Luvisols). The soils on the hills are very shallow and rocky (Leptosols) (WRB, 2014). The distribution of natural vegetation reflects changes in soil, altitude, relief and climate of the region.

Mt Kenya region is therefore suitable for banana production since it possesses deep red highly fertile soils with pH between 6 - 7.5 which is ideal for banana production. This type of soil has good drainage, adequate fertility and moisture and is most preferred for banana cultivation. Mulching of banana fields is recommended as a traditional agronomic practice since it suppresses weeds, enhances moisture conservation and organic matter retention hence improving soil fertility.

1.6.4 Socio-economic Characteristics

Meru County has a population of 1,356,301 persons (GOK, 2009). According to Kenya Population and Housing Census (GOK 2009), 98.2% of households in the county engage in crop farming. The major economic activities which the local community engage in include agriculture and livestock production specifically dairy, fresh fruits, vegetables, bananas, coffee tea and food crops farming (GOK, 2015a). This has great contribution to the regional economic development. Poverty in the county is manifested in various parts, which can be defined both in monetary and human capability terms.

Nyeri County has a population of 693,558 persons (GOK, 2009). The major economic activities which the local community engage in include agriculture and livestock production specifically dairy, bananas, coffee and tea farming (GOK, 2015b). The average land size in Nyeri County is 1.8 ha for majority of households while for the large-scale farmers, average land holding is 18.25 ha (GOK, 2015b). The socio-economic characteristics of the households in this region give them an advantage to engage in banana production. The small land sizes make them engage in farming production which can generate both income and offer food, thus banana production becomes one of the key options. Banana production in particular requires small capital unlike other agricultural enterprises. Due to high unemployment rate in the region most of the persons are forced to engage in agricultural production hence making banana production popular and the better option.

1.7 Justification of the Study

The study evaluated impacts of climate variability and adaptation trends on banana value chain in Mt. Kenya region. The findings are of great significance to county governments and policy makers when formulating agricultural production and trade related policies with implications on food security and nutrition in the region. The farmers shall benefit from the study findings through provision of the best ways to manage climate variability in reference to banana production, transportation and trade. Moreover, the data acquired constitutes significant knowledge to academia on banana value chain and other players in the agricultural industry on respective aspects of the value chain. This knowledge forms the basis for information regarding further research in the study area. This information aids in establishment of the agro-industries in the study region to make the supply and the related demand of banana hence achieving long-term economic growth.

The study is justified by Sustainable Development Goals (SDG 1, no poverty; SDG 2, on zero hunger; SDG 3, on good health; SDG 8, on economic growth; and SDG 9, on industry and infrastructure); Kenya Vision 2030 (Economic pillar on food security and attainment of economic growth of 10%), Kenya Big 4 Agenda (agenda 1 on food security and agenda 4 on manufacturing industries more so cottage industries) and Rome declaration on food security. The study will contribute on County Integrated and Development Plan (CIDP) (on provision of water in dry lands, promotion of agriculture, food security, employment and manufacturing sector) in respect to increasing food production to meet the demand of Africa and Kenya fast growing population.

1.8 Research Focus

The study focused on evaluation of climate variability; impacts of climate variability, on perceptions and adaptation strategies in banana value chain developments among smallholder farmers in Mt. Kenya region. Due to time, geographical extent and financial constraints, the study emphasized on banana value chain developments in two sub-counties *i.e*. Imenti South and Mukurweini which are within Mt Kenya region. The two sub-counties were representatives of the major banana production zones in Mt. Kenya in terms of climate and economic activities.

1.9 Limitations of the Study

Time factor and financial constraints, restrained the study to be carried within the Mt. Kenya region. Two climatic elements that is temperature and rainfall were analyzed and assumed to influence banana value chain within the region while other biophysical factors were held constant during the study period 1980 to 2017. Banana production data were only available for the period between 2009 and 2017, hence disregarding the rest of the study period.

1.10 Operational Definitions of Terms

Adaptations – Refers to responses by farmers while adjusting to banana farming systems due to changes in rainfall amounts and temperature levels.

Agro-Ecological Zone (AEZ) - Refers to the division of an area of land into smaller units, which have similar characteristics related to land suitability and potential production. The zone groups are defined according to the maximum temperature limits within which the main crops can flourish.

Banana - A tropical fruit which form staple food within the region and can be consumed either raw when ripe or cooked.

Banana Value Chain - Involve numerous interlinked activities and stakeholders operating at full range of activities of banana fruit which comprises production, harvesting, storage, transport and trade different levels.

Climate Variability – means what we experience when the normal climatic conditions fluctuate temporarily or permanently above or below a long-term average value. Events of climate variability are like drought and floods.

Climate - refers to the average weather in terms of the mean and its variability over a time-span of more than 30 years. In this study climate refers to rainfall and temperature variables.

Drivers- Key factors and activities that influence operation or performance in an organization.

Extreme weather Event – An event that is very rare in a particular geographical region and period of year and affects agricultural production.

Impact of climate variability - refer to the consequences arising due to climate variability (rainfall or temperature variations) on human livelihood, specifically on banana production.

Farm gate Prices - Is the price paid to the farmer at the farm level and hence excludes margins on transport.

Horticulture - Fruits, vegetables, flowers or crops which are highly perishable with short shelf life when harvested. Banana is a horticulture crop and a fruit.

Mt. Kenya Region - Counties that are neighbouring to Mount Kenya. This study sampled Nyeri and Meru Counties within the region.

Perception - Process of receiving information from the environment in particular meteorological and forming some psychological reactions about the environment.

Sub-County - Refers to both administrative units of national government and county government and in most areas, it coincides with the constituency area**.** Mukurweini and Imenti south constitute sub counties within Nyeri and Meru Counties respectively.

Seasons - Describes the bimodal rainfall, long rains occur from March to May (MAM) while the short rains come in October to December (OND).

Smallholder farm - the farm size within the Mt. Kenya region possessed by banana farmers and is usually less than 2.5 hectares.

Triangulation - Application and combination of several research methods or techniques in the study.

Value Chain Development - Approach that looks at market dynamics and interaction between different actors and levels in production with the aim of removing obstacles in order to increase the value of a given commodity.

Vulnerability - the level to which banana farmers are susceptible to climate variability and its effects due to their socio-economic characteristics.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter critically reviews the relevant literature concerning the banana value chain and climate variability. The following literature was reviewed; climate variability on agricultural production, farmers' perception on climate variability trends and its effect on value chain. Literature on agricultural value chain in relation to the dynamics of banana value chain and the impacts and adaptations of climate variability on banana value chain was also reviewed. Climatic requirements for banana production are discussed and lastly both conceptual and theoretical framework has been presented.

2.2 Climate Variability on Agricultural Production

Climate variability directly impacts on the four dimensions of food security which includes food availability, utilization, accessibility and stability. Climatic variations directly affect crop productivity hence food insecurity given that majority of the rural households rely on crop production for their livelihoods (Ochieng, Kirimi & Mathenge, 2016). Agriculture as an economic activity is exposed to various forms of menace ranging from weather variability, pests' infestations and diseases attack, to price fluctuations in the markets. Moreover, poor agricultural households that depend on rainfall for agriculture face imperfect market conditions and are particularly exposed to the climate variability related risks. Agricultural production in Africa is vulnerable to climatic related impacts due to a number of reasons: firstly, most parts of the continent are already experiencing very high temperatures, secondly, most farmers depend on the quality of rain and production is mainly subsistence; and lastly water stress is affecting vast regions within the continent (IPCC, 2001).

According to the United Nations Framework Convention on Climate Change (UNFCCC, 2009), climate variability is "*change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods*". Climate variability is experienced whenever the climatic situations fluctuate either ways about the statistical mean. The date the rainfall season commences and ends, the seasonal duration, the specific numbers of days rained, duration and magnitude of dry spells, or variations in the sum total of the seasonal rainfall can also indicate climate variability. Hence climate variability is not always an alteration in the average climatic conditions, but can be exhibited by a variation in the strength and occurrence of such extreme climate experiences such as dry spell, floods, hurricanes, and robust winds among others events.

Agriculture continues to dominate in majority of the countries as the key to economic development and hence it remains a key contributor towards economic empowerment among the poor in Sub Saharan countries. Despite agriculture accounting for almost 72% of the labour force, over 25% of GDP and 20% of agribusinesses in majority of the countries, it remains to be given low priority with imminent climatic challenges. Agriculture has a high multiplier effect, which means that agricultural investment can generate high economic and social returns among the rural communities and enhance economic diversification as well as social development. According to FAO (2008), agriculture is crucial for food security in two ways: it produces the food we consume; and remains the principal source of mainstay for 36% of the world's total workforce as an income generating activity. Productivity of this sector is at risk of impacts of climate variability which are expected to lessen the agricultural yield dependent on rainfed system. The effects of global climate variability on food structures are likely to be widespread, complex, geographically and temporal varied and prone to preexisting and emerging socioeconomic situations (Vermeulen, Campbell & Ingram, 2012).

Kenya is an agriculture-based country, with only 12% of land being high potential for farming or intensive livestock production while 5.5% is classified as medium potential (Mohajan, 2013). Only 60% of this high and medium potential land is devoted to crops (maize, coffee, tea, horticultural crops) and the rest is used for grazing and forests (CEEPA, 2006). Crop production is limited in the regions which receive adequate and reliable rainfall coupled with favorable temperatures. The GOK (2012), reports placed horticultural production third in the country. The total domestic value in the horticulture sector in 2012 totaled to Ksh 217 billion with area under production being 662,835 hectares with a total production of 12.6 million tones. According to GOK (2012), the total value area and production of horticulture have been increasing by 6%, 9%, and 38% respectively. This is elucidated by improved farming technologies, high value of the produce and increasing demand for both urbanites and export. The challenges that face this sector are the uncertainties resulting from climate variations.

As the area under horticultural production increase, Kenyan rural population continue to rely on it for food sustenance and source of income with 80% of population residing in the rural areas and depends on agriculture for their livelihoods (HCDA, 2008). About 56% of the Kenyan population lives below poverty line and 53% of which are economically active population. Agriculture related ventures employ 74% while 80% of all people working in agriculture are smallholders' farmers who rely heavily on rainfed agriculture. This calls for revitalization of agricultural activities to make Kenya a food secure country and build strong economic bases among the rural communities. This can be achieved through value chain systems of the agricultural production. The agri-food value chain system includes primary production (farming), post-farm (transportation marketing) and distribution services (domestic and international). These industries are important for providing food but also for income and job creation in agriculture, manufacturing and services industries. These industries add value to the produce hence earning more market prices.

Agricultural growth is the primary basis of poverty reduction in most agriculture-based economies Kenya being unexceptional. The expansion of smallholder farming can lead to faster rate of poverty alleviation by raising the incomes of rural smallholders and reducing food expenditure and thus reduces income inequality (World Bank, 2010). HCDA (2008) reports that the horticultural sector employs about 2.5 million people in Kenya directly in production, processing and marketing while another 3.5 million people indirectly benefit through trade and other related activities. In terms of generation of income in domestic and export earnings it is ranked among the top and contributes to 36% of agriculture GDP therefore a significant contributor to national economy (HCDA, 2008). However, agriculture sector needs to be unified with value additions components in order to control the adverse impacts related to climate variability in order to address poverty and household's inequality. Meteorological extremes like droughts, floods and strong winds have far reaching impacts on Kenya economic growth. They have implications in a range of sectors such as agriculture, water resources, health, energy and disaster management among others (Gitau, Githui, Mutua & Bauwens, 2009).

According to Nyagena and Seitz, (2009), droughts result in sharp reductions in agricultural output, related to productive activity and employment. This will lead to lower agricultural export earnings and other losses associated with decline in rural income, reduced consumption and investment. East Africa have recorded major droughts in 1970, 1975, 1979-80, 1989-90, 1999/2000 and 2005. When weighted by impact on GDP, it appears that drought poses a substantially higher risk to human livelihood especially the smallholder farmers. Prolonged drought affects agriculture, water supplies and ecosystems. If drought becomes more persistent farmers will have difficulty in sustaining viable agricultural systems leading to food insecurity (Zinyowera Moss & Watson, 1998). Fluctuations in rainfall may lead to reduced productivity and price volatility hence periodic risk of famine. Climate variability will pose risk to agriculture-based livelihood systems due to increased crop failure, new forms of pests and diseases, lack of appropriate seeds and planting material. The vulnerable smallholder farmers face immediate risk of food insecurity (FAO, 2008).

Kenya is prone to cyclical droughts with major ones occurring every ten years and slight ones after every three to five years (UNEP & GOK, 2000). Since the early 1990s, Kenya has been affected by the droughts of 1991/2, 1992/3, 1995/6, 1998/2000 and 2004, the El-Ni˜no rains that resulted in the floods of 1997–1998 (Orindi, 2005) and the drought of 2008/9. It is anticipated that increase in strength and occurrence of droughts, as a result of climate variability will affect smallholder farmers negatively. The prolonged drought of 2008/9 was partially attributed to climate variability and placed an estimated 10 million Kenyans or one fourth of the whole population at menace of malnutrition, hunger and starvation (GOK, 2010). In the last 100 years, Kenya has experienced 28 key droughts and the magnitude of the droughts has been increasing (Fund, 2012).

An analysis of trends in temperature, rainfall, sea levels and extreme events point presence of climate variability in Kenya. Studies indicate that temperatures have generally increased throughout the country (King'uyu, Ogallo & Anyamba, 2000; GOK, 2010). Mayieko, Olum and Wanyama (2010), further notes that temperature has increased by 0.7–2.0°C during the previous 40 years, coupled with unpredictable rainfall, leading to poor timing of farming activities while other projections tend to predict steady increase in the average annual temperature levels of 1 to 3.5^{0} C by the end of 2050s (SEI, 2009). According to National Climate Change Action Plan (NCCAP) 2013-2017 the Kenyan annual rainfall patterns exhibit either unbiased or slightly negative trends to a general decline during the long rains that ranges starting from March, April and May (GOK, 2013). The positive trend can be attributed to season extending to January and February during the recent times perhaps due to more frequent El Niño events, and sometimes coupled with moderately warmer to cool surface temperatures levels on the west sides of the Indian Ocean (Stige *et al.*, 2006). This prolonged season affect the farmers timing on planting dates and affect the harvesting period leading to post harvest losses.

The Meru County Strategic Plan (2012-2017), has documented presence of extreme climate variability incidences such as drought and floods in Meru County arising from effects of climate variability. Effects of climate variability within the region have led to the depletion of glaciers on Mt. Kenya (IPCC, 2007). Further observations have shown that temperature has increased during the day and night from 1960 to 2006 in Mt Kenya region (GOK, 2010). Brown and Funk, (2008) argues that Mt. Kenya which has traditionally been central to crop production will experience climate variability related impacts. The impacts will be through drop in crop yields mainly due to climate induced conditions such as a lack of sufficient rainfall, high temperatures and high incidences of pest and diseases. This will have a direct relationship with the market food prices. The concerns will be on how much the rainfall will decrease and the resultant net effect on production. Unusual climate change incidences arising from climate variability were evident during the 1997 *Elnino* rains and the 2001 drought, leading to flooding, landslides, and high levels of erosion which resulted to damage of infrastructure (GOK, 2015a). The roads to market and farms were cut and therefore agricultural produce could not reach to the market. Whereas during the dry period food production declined due to water scarcity leading to food insecurity.

GOK (2012) highlighted that in 2012, the total value of horticultural export was 87 billion which was a decline compared with 91 billion for 2011, which represented a 4% drop. The decline was attributed to effects related to extreme weather events, pest and diseases. The subsector is highly regarded as the major contributor towards food security with regard to increasing economic access to food for majority of smallholder farmers in Kenya (GOK, 2011). Horticultural production provides raw material for fruit as well as vegetables agro-processing industries and also income generating enterprise to the rural households who rely on crop production for their livelihood. Communities in the rural settings rely heavily on rainfed agriculture especially for the high value crops. Mbaka, Mwangi and Mwangi (2008), notes that with availability of water for irrigation, banana farming as a fruit can significantly reduce poverty and hunger.

2.3 Farmers' Perception on Climate Variability

"Perceptions shapes knowledge and knowledge shapes perception" (Ansari *et al*, 2018). Slight information is known regarding farmers' perceptions on the impact of climate variability and adaptation choice as a result of climate information. Therefore, farmers' perception of climate variability effects is a precondition for the adaptation choice and strategy (Alam, Alam & Mushtaq, 2017; Tripathi & Mishra, 2017). Smallholder farmers perceive climate variability to have a substantial impact on crop productivity due to increased temperature levels and unpredictable and unreliable rainfall patterns. Yet, there is significant uncertainty on rainfall amount and distribution; an indication of regional variation in terms of location (Herrero, Van de Steeg, Thornton, Zhu, Bryan & Notenbaert, 2010). Reduced rainfall amounts coupled with unpredictable rainfall pattern as well as increased temperatures and variations is the farmers' perception to climate variability. Bryan *et al.*, (2010) assert that increased temperature levels have detrimental effects on availability of water leading to prolonged dry spell. The farmers' definition of perception on climate variability is water availability, temperatures levels and amount of precipitation. Farmers place greater emphasis on rainfall pattern when making farming decision concerning planting and harvesting. Extended period with low rainfall amounts is based on farmers' knowledge on rainfall variations and particularly on changes of timing and rainfall distribution rather than average quantity of rainfall (Bryan *et al.*, 2010).

Van den Ban and Hawkins, (2000) defined perception as the process of getting information and provocations from the surroundings or environment and translating them into psychological actions. Farmers perception to climate variability is extremely a hard idea, has restricted boundaries as the person's perception varies with the previous and current environmental situation (Saarinen, 1976). According to Ogutu, Piepho, Dublin, Bhola and Reid (2008), perception has been influenced by the recent climate trends more so the prolonged extreme events such as drought. Farmers are concerned with the great variability in rainfall hindering their ability to predict rainfall patterns and plan their farming activities such as planting dates. Short rainy season leads to longer dry period, while between the seasons there are low food supplies hence high market prices. Perceptions of climate variability appear to be mainly based on farmers' experience on agricultural production depending on the period engaged in farming practices (Bryan, *et al.*, 2013). The more the number of years, the more the farmer is likely to perceive long-term changes in temperature, precipitation and rainfall variability. Perceptions of farmers on climate variability are in line with the observed trends in climatic variables.

Perceptions strongly influence how farmers dealt with climate induced risks and opportunities. The precise nature of their behavioural responses to the impacts will shape adaptation options, the process involved and adaptation outcomes (Adger *et al*., 2009; Pauw, 2013). Misconception about impacts of climate variability and its associated menace may result in no adaptation or maladaptation thus increasing the negative impact of climate variability (Grothmann & Patt, 2005). Therefore, information on the impacts and coping mechanisms to climate variability effects is crucial to small holder farmers in order to get the best, affordable and sustainable adaptation strategies.

2.4 Agricultural Value Chains

An agricultural value chain is defined as the people and activities that bring a basic agricultural product such as banana, maize or vegetables from obtaining inputs and production in the farm to the consumer, through stages such as processing, packaging, and distribution. According to UNECA (2009), African agriculture is weakly integrated with other sectors such as the industrial sector. By promoting greater sectorial linkages, value chain development can greatly enhance job creation, agricultural transformation and broad-based growth on the continent. Africa should take the necessary measures to confront its challenges in this sector with the rise of unpredictable climate. Processing of agricultural produce is essential for expanding agricultural markets nationally and regionally because raw products are characterized by high perishability, which means a short shelf life; bulkiness as water constitutes a high percentage of agricultural products; quality change and hence the need for quality standards. This leads to seasonal variability in production and lack of market information. Value chain linkages with the production sector would increase demand for the produce and increase market price leading to competitiveness.

This calls for a transformational process within the agricultural value chain to integrate the value chain actors (Jaffee & Morton, 1995).

Value chains comprise of numerous inter-linked activities which are complex and involves several actors and stakeholders operating at various stages. Value chain analysis is the process of breaking the chain into its constituent parts in order to better understand its structure and functioning in different conditions (Usman, Abate, Belete, Wegi, Legese & Duncan, 2012). The analysis consists of identifying chain actors at each stage and discerning their functions and relationships; determining the chain governance, or leadership, to facilitate chain formation and strengthening; and identifying value adding activities in the chain and assigning costs and added value to each of those activities. Agricultural value chain involves examination resulting from the functioning of every stage within the chain due the climate related impacts. Tucker, Mohamed, Johnston, McFallan and Hampson (2001), argues that the flows of goods and information through the various stages of the chain are evaluated in order to detect constraints and identify opportunities to improve the contribution of specific actors and the overall performance of the chain with the changing climate.

Agriculture being the mainstay of the Kenyan economy should embrace transformations of agricultural value chain. Kenya is a key producer of horticultural produce and the major fruits produced in Kenya in order of volume are bananas, pineapples, mangoes, citrus and avocadoes (GOK, 2008). Most of the horticultural crops are produced by small scale farmers throughout the country. Marketing of fresh fruits and vegetables (FFV) is characterized by many actors who operate at different levels who include producers, transporters and brokers (GOK, 2008). It therefore means that FFV produce follows different channel and actors before getting the final consumer. The marketing system poses a lot of challenges to small scale farmers due to lack of market information, perishability nature of the produce and changing climate making producers get exploited by the middlemen. The problem is worsened by the lack of cold storage facilities, poor post-harvest handling techniques and congested market. Furthermore, the farmers lack skills to enable them do farming as a business. Hence it is paramount to enlighten farmers on the potential and envisaged impact related to climate variability within the chain.

Climate variability risks will have effect on transportation depending on severity and seasonality as a result of extreme meteorological abnormalities like high precipitation making the access weather road to farms impassable thus making transportation of banana produce to market or collection centers difficult hence high transport cost (FAO, 2016). According to GOK (2008), there is a great challenge in the development of rural roads so that produce can easily have access to the market. According to FAO (2010), the effects of weather on transportation are visible, but they have not been incorporated at either local or national levels. During high rainfall sessions, there is destruction and loss of infrastructure and roads. In countries with inadequate infrastructure (roads and bridges) there is higher risk of floods which is likely to pose significant threats in rural transport (Vermeulen, *et al*., 2012).

Poor roads during peak harvest periods have continued to contribute to high post-harvest loss and increased transportation cost where most of the feeder roads are earth roads to the farms. Some production regions are not accessible during bad weather and buyers avoid those areas hence post-harvest losses. In Kenya like any other developing countries, transport infrastructure limits effectiveness of the value chain and impacts are expected to be intensified by climate variations (FAO, 2008). Similarly, highly sophisticated, low-inventory food chains that work to a just-in-time mode of delivery are highly susceptible to disruption by weather (UNIDO, 2009). On the other hand, high temperatures affect the perishability and safety of fresh produce. Bacterial growth rates approximately double with every 10^0C rise in temperature above 10^0C and below 10^0C, temperature change has a stronger effect, with storage life halved for each 2–3^0C rise in temperature (James & James, 2010). This affects availability of produce in the market, quality of produce as well as prices volatility at the farm level.

UNIDO (2009) points out that agri-food industries provide, promote entrepreneurship, raise demand for agricultural products and connect farmers with various consumers through processing, marketing, distribution and retail of agricultural products. They have strong backward and forward linkages with other parts of the economy. The progress in agri-food industries is transferred to other sectors through higher demand for inputs, technology, such as packaging materials, transport, communication and quality infrastructure. Agri-business industries should promote value chain development interventions through operational partnerships with existing value chain actors and agents, including the private sector, existing programmes, government agencies and civil society organizations. Effort should be made to ensure that smallholders' farmers participate in the value chains in order to make banana production competitive.

The banana value chain comprises of the following major stages in the distribution channel: production, harvesting and storage, ripening, whole selling and retailing while transport occurs between these stages. Brokers' acts as the middlemen and dominate banana operations in the trading process, they collect and deliver produce on behalf of different urban-based wholesalers and vendors in various geographical locations. The constant interaction of the brokers and other players in the banana distribution chain enables them have good price information from urban centers unlike the producers who are farmers (Technoserve, 2004). This prior knowledge on market information makes them exploit the small holder's farmer who do not have bargaining power. Providing market information on banana farmers will permit them make informed decision regarding the prices. The constraint faced by the small-scale farmers in an attempt to market their produce impedes their growth as the incomes of farm keep on fluctuating (Irungu & Odingo, 2005).

Scholarly studies conducted indicated that smallholder farmers' involvement in the trading can be enhanced through communal action (Catacun, Bertomeu, Arbes, Duque, & Butra, 2006; Irungu & Odingo, 2005; Obare, Bekele & Muricho, 2005; Technoserve, 2004). Collective action can enable the farmers' access to farm inputs, access market information and more important have a strong voice to lobby for production support. The interaction aspect of value chain forms a critical dimension in achieving food security in developing countries. Climate variables mainly rainfall and temperature are important drivers of food system and availability from the farm to the consumer affecting the quantities, types of food produced and the adequacy of income generated (FAO, 2008).

2.5 Climate Variability Impacts on Value Chains

Climate variability is a key factor affecting banana production globally (Trienekens, 2011). In addition to the distinctive variation of climatic variables comprising of temperature and precipitation regimes, there is a collective need for farmers to address the effects of climate variability on banana value chain. Value chain comprises of all value-generating activities required to produce, deliver and dispose off a commodity (Schmitz, 2005). More specifically, it "describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformations that is value addition and the input of various producer services), to delivery to the final consumer and final disposal after use" (Kaplinsky & Morris, 2000). According to Trienekens (2011), the main objective of a value chain is to produce value added products or services for a competitive market, by transforming resources and by the use of infrastructures within the opportunities and constraints of its institutional environment. Therefore, constraints for value chain development are related to market access (local, regional, international) with the recent trends on climate variability and market orientation (Grunert *et al.*, 2005), available resources and physical infrastructures (Porter, 1990) and institutions (Scott, 1995).

Extreme weather events interfere with transport and distribution systems thus affecting other components of the value chain. High temperatures coupled with declining rainfall, is projected to raise water demand, by 12–15% (Dione, 2007). Higher temperatures encourage pests and disease infections among the banana crop. Colder dry seasons, on the other hand, will delay the ripening of the fruit taking longer time than expected. Agricultural production is inherently delicate to climate variability owing the close natural connections and dependencies that exist between climatic weather conditions and plant growth (GOK, 2013). High temperatures reduce crop yields and, at the same time introduce new pests and disease strains. Conversely, variations in precipitation patterns increase the likelihood of short-term produce failure and ultimately long-term decrease in crop productivity. Most of the agricultural activities in the rural settings are rain fed and dominates the horticultural and staple food production. This poses climatic risk to the subsistence farmer’s hence great risk to food provision.

Global warming is another factor that adversely affects agricultural production. Projections show that it may cause losses of over 25 % of crop productivity in Southern and West Africa (APN, 2008). Countries in East and Central Africa are also projected to experience losses of 5 to 25 %. Dione (2007) predicts on reduced productivity due to climate related impacts. Climate scenario projects that rise in world temperatures levels, will have negative results in yields both regionally and globally by 2080s (Parry, Rosenzweig, Iglesias, Livermor & Fischer, 2004). World food system depends on climate variability and is directly related to world food prices, availability and accessibility to population more so in Sub Saharan countries (Parry *et al*, 2004). In turn food availability will depend on household income and price level, thereby affecting the poor who cannot be able to purchase.

The projected increases in mean temperatures levels and precipitation will not manifest through constant gradual changes, but will be experienced as increased incidence, period and intensity of dry seasons with changes in precipitation patterns. According to FAO (2008), the annual manifestation of numbers of hot days and increased temperature levels are expected to rise in vast parts of the continent while the statistical average of the global precipitation is not expected rise uniformly throughout the world. Basically, it is predicted that wet regions will become wetter while dry regions dryer. Rainfall amounts are also expected to rise with many models indicating an escalation of substantial rainfall specifically during the wet periods, and an associated flood risk (Stige *et al.*, 2006). Seasonal rainfall trends are mixed, with some locations indicating increasing trends while others show no significant changes.

When infrastructure is affected by extreme climate, particularly frequency of flood events that cut down communication lines, there are impacts on food distribution, influencing people's access to markets to sell or purchase food (Abdulai & CroleRees, 2001). Seasonal rainfall trends will affect infrastructures in developing countries hence high transportation cost and lack of access to market. The solution is to improve rural infrastructure and trade-related capacities for market access (UNECA 2002, 2005). Fresh produce will last longer, taste better and be more nutritious hence fetch high market prices. Over time, bruises and pest damage become more apparent and water loss lead to shriveling of produce, hence loss in quality and in price (FAO, 2005). The most noticeable loss occurs when produce has to be thrown away.

Climatic conditions, especially humidity level, temperature levels and light intensity, are closely related to the nutritional quality of Fresh, Fruits and Vegetables (FFV) (Gustavsson, Cederberg, Sonesson, Van Otterdijk, & Meybeck, 2011). According to Lee and Kader (2000), the magnitude of FFV losses increase with exposure to temperatures, relative humidity, and/or concentrations of oxygen, carbon dioxide and ethylene outside the ranges that are optimum for each commodity during the entire post-harvest handling system. All these are catalyzed by extreme weather events. Environmental factors have several effects on FFV such as low yields, shorter cropping period, low produce quality and determines the harvesting period (FAO, 2005). However, as the frequency and intensity of weather-related events increase, there is an upward risk of storm damage to transport networks and distribution infrastructure which consequently disrupt food supply chains. This makes the small holders have difficult in embracing the new urban and international markets opportunities (Swinnen, 2007).

Dynamic relations between and within the bio geophysical and human environments has impact on production, processing, distribution and consumption of food, resulting in food systems that support food security (Gregory, Ingram & Brklacich, 2005). Food system embraces food availability (production, distribution and exchange), food access (affordability, allocation and preference) and food utilization (nutritional and societal values and safety). Food security is, therefore, diminished when food systems are stressed due to a range of factors more so climate variability and/or other agents of environmental change. Climate variability impacts such as increase in rainfall will make transportation and trading of FFV challenging from the farms to the market due to lack of road networks

(Swinnen, 2007). The poor infrastructure in the country also increases the risks and susceptibilities to climate related impacts among small holders where high percentages of Kenya's roads are earth roads. Extreme climatic event such as flooding cuts off links and destroys the limited infrastructure (GOK, 2013). This will affect the overall value chain of the production. Two mechanisms which are critical for smallholders are provision of physical resources (technological developments, road and storage facilities) and market information that will link smallholders' farmers to market (Swinnen, 2007). This will reduce market risks and operation cost that are incurred as a result of effects of climate variations.

According to FAO (2008), changes in agricultural production trends and performance arising from climate variability will affect food supply at the global and local levels. Globally, higher yields in temperate regions could offset lower yields in tropical regions while in tropics food insecurity will be felt due to frequent droughts. This will lead to reduced agricultural production hence affecting livelihoods and access to food at the global and local levels. Producers that are less able to deal with climate impacts, such as the rural poor in developing countries, risk having their safety and welfare compromised due to food insecurity (Vermeulen, *et al*., 2012). Other value chain developments, like transportation, post-harvest handlings, distribution and food processing are inflicted by climate related impacts.

According to GOK (2012), temperature management and gaseous exchange technologies are known to significantly reduce water loss and respiration rate and they determine the shelf life of fresh produces. Increased temperature is likely to affect the growing of major crops in the country which banana is not exceptional (Otto, 1999). Ideally, harvesting should take place when the crop and the climate are coolest and the plant has the highest moisture content. This is in the early morning but other issues have to be taken into consideration (FAO, 2005). For instance, labour and transport may not be available early in the morning. If rainy, weather will hinder transport of the harvest and rescheduled to avoid produce being left standing in the field for too long. Storage infrastructure can be damaged or destroyed completely by extreme weather events, but there appears to be little research to date on the impacts of increasing climate variability and longer-term climatic trends. The FAO (2008) notes that increasing temperatures lead to strains on electricity grids, air conditioning, refrigeration hence high storage costs. Higher temperatures will affect the perishability and safety of FFV (Vermeulen *et al*., 2012).

Access to markets is not the only prerequisite condition for the produce but supporting infrastructures such as good road network and storage facilities that can withstand all weather, resources including knowledge and capabilities are conditional for the produce to realize high market values. According to Porter (1990), factor conditions relate to the nation's endowment with resources such as physical, human, knowledge, technology and infrastructure enable or constrain value chain. These physical resources such as road network and storage facilities are affected by the extreme weather events and connect farmers to market (Vermeulen *et al*., 2012). Weak infrastructures hamper efficient flows of produce laterally on the chain hence constraining the flow and exchange of market information along the chains (Trienekens, 2011).

Low levels of available physical infrastructure in form of input materials for production and other related input (e.g., energy and water) constrain value chain upgrading. Vermeulen *et al.*, (2012) outlines four factors that constrain value chains. First, high energy costs as a result of varying weather events. Secondly, the geographic position of the region provides its competitive position to the market. Thirdly, availability of educated labor and knowledge on production, distribution, and marketing are important conditions for innovative behavior of value chain actors. A fourth category is the level and availability of technology that can be used for production and distribution activities in the value chain. Besides availability of resources, the presence of an adequate distribution and communication infrastructure is a basic condition for value chain development and upgrading (Trienekens, 2011).

In conclusion various studies conducted on effect of climate variability on crop production indicated negative trends. For instance, Runge (1968) reported that high temperature leads to decline in maize production, while Wardlaw, Hulme & Stuck (1989), noted a declining wheat yields when temperature increase above 15^0C. Further studies by Karafyllidis, Stavropoulos and Georgakis (1996), showed that water stress reduces potato yield by reducing amount and size of the potato harvest. Therefore, it is conclusive to note that climate variability leads to declining yield on most of the crops. This calls for the adaptation strategies aimed at addressing the declining crop yield in order to address food insecurity which is among the UN Sustainable Development Goals (SDGs), Kenya Big 4 agenda and Vision 2030 in Kenyan setting.

2.6 Adaptation Strategies to Climate Variability

Climate variability adaptations refer to responses or changes within the production system to reduce the negative effects and enhance the positive influences of climate variability. The severity of environmental impacts due to climate related experiences can be reduced by adaptation strategies. Hence adaptation strategies reduce the state of damages arising or could have occurred. The achievement of adaptation strategies depends solely on the provision of necessary resources. These resources include but are not only limited to financial and environmental resources, but knowledge, skills, technical competence, and institutional capital (PCGCC, 2004). Adaptation to the effects of climate variability is a prerequisite in both short and long-term (Adger, Huq, Brown, Conway & Hulme, 2003). In addition, social, monetary, technical and environmental trends shape the ability of small holders' farmers to perceive and readily adapt as a response to the impacts. It has been recognized that adaptation strategies can minimize the adverse impacts of climate variability on crop production (Kabubo-Mariara & Karanja, 2007). Adaptation can be grouped in different echelons for instance regional, state level, sub-state and at local levels. Adaptation at the lowest level makes up the most critical component, as local community understand and realize the harshness of the climate variability (UNFCCC, 2009).

Adaptation comprise of a two-point process. Firstly, farmers have to note and perceive climate variability within the settings and recognize associated risks; secondly take actions as response in order to minimize the hostile effects. In order to have successful adaptations, farmers perception need be accurate, otherwise if the process is based on erroneous perception could result to negative effect. Accurate perception depends on three aspects, the knowledge, technical know-how and information access to the farmers. However, knowledge and technical know-how depends largely on educational level and persons experience (Amarnath & Ashok, 2016). Adaptation to certain climate variability is the best response option for small holders' farmers in order to minimize the harmful impacts of climate variability since it can transmit the result of the farmer's perception (Füssel & Klein, 2006).

Climate variability adaptations are fundamental for the realization of human development in Kenya. Kenya has a National Climate Change Response Strategy (NCCRS) which identifies crop production as the most exposed sector to climate variability (GOK, 2010). The NCCRS identifies a number of priorities in the sector. Crop production in the country heavily relies on weather and, it is important to have a robust adaptation mechanism which will address the climate variability related vulnerabilities and risks which are being experienced and those expected in future by small holder farmers. Heavy dependence on rainfed crop production increases the susceptibility of the small holders' farmers in the rural setting to the harmful effects of climate variability globally (David, Thomas Twyman, Osbahr & Hewitson, 2007; Mertz, Mbow, Reenberg & Diouf, 2009). Smallholder farmers in African countries are believed to be among those adversely affected by climate variability (IPCC, 2007) and are assumed to have inadequate knowledge and resources regarding response mechanisms. This calls for responsive measures to curb and reduced the associated effects to climate variability. Adaptation to climate related impacts seems the most suitable and responsive way for small holder farmers to lessen the impacts, as it provides the means of transmitting the outcome of the small holders' farmers' perception (Füssel & Klein, 2006).

Adaptation approaches to climate related risk are of two categories change autonomous or self-regulating and planned or public adaptation measures. Private adaptation strategies comprise of action engaged by non-state for instance farmers, societies or organizations as a response to climate effects. Bruin (2011), highlights the adaptation measures that include crops diversification, changing crop planting calendar, introducing new management practices, introducing irrigation system and choosing different cropping know-hows. Public adaptation includes activities taken by different actors within the organization at local, county and or national administration to offer resources and institutions with the aim of minimizing the undesirable impact of the environment. Public adaptation measures include construction of irrigation systems, provision of transport and storage facilities, land use changes and access to property rights and water shed supervision (World Bank, 2010).

Bruin (2011) reported that adaptation approaches can take proactive or anticipatory dimensions depending on when it happens either beforehand or after the impacts. Reactive adaptation measures are responses to address effects after having been experienced within the environment, whereas the proactive adaptation policies are involved when climate variability is expected. In agriculture**,** reactive adaptation measures consist of improving soil richness, introduction of new breeds, changing planting and reaping time. Anticipatory adaptation measures on the other side involve the introduction of tolerant breeds, research development, strategic measures such as taxation and use of incentives. The best way for smallholder farmers to adjust to climate related risks is through varying planting dates as well as crop diversifying (Gbetibouo, 2009). Government supports is required if this is to be realized by providing the required resources in the value chain. Soil conservation measures, planting trees and water management are some of the recommended adaptation measures among small holders' farmers (Yesuf, Falco, Deressa, Ringler & Kohlin, 2008).

Data on the drivers of adaptation strategies of climate variability in diverse ecological zones is lacking and there is need to recognize the capacity and drivers of adaptation to climate variability in order to find the suitable and proper policy that can strengthen the accessibility of the different adaptation methods. Scholarly studies done in Sri Lanka, pointed that adverse effects of climate risks on crop production can be minimized by applying suitable adaptation strategies like the introduction of micro irrigation, shifting planting dates and crop diversification (Esham & Garforth, 2013).

Many countries in sub-Saharan region are highly susceptible to climate risks. These countries are vulnerability due to weak economic power, lack of institutional capacity, inadequate engagement in conservation and adaptation matters, and absence of validated data on local knowledge (Adams, Hurd, Lenhart & Leary, 1998). Experience has revealed that acknowledged adaptation strategies do not necessarily interpret into changes, adaptation approaches to climate risks and physiological hindrances to adaptation are locally defined (IPCC, 2007). In this regard local knowhow of climate is critical when developing proper adaptation approaches that can mitigate the hostile consequences of climate variability. The acquaintance to the adaptation choices and socioeconomic factors touching the adaptation approaches to climate variations are crucial while tackling the climate challenge.

2.7 Determinants of Adaptation Strategies to Climate Variability

Adaptation to climate variability requires households to appreciate that there exist climate variability and recognize useful adaptation options, by choosing among a wide range of adaptation approaches available at their disposal. This explains why households within the same geographical location are using different adaptation strategies in response to climate variability due to their ability and competence (Shongwe, Masuku & Manyatsi, 2014).

Yesuf *et al.*, (2008) highlighted farmers' adaptations strategies is inclined to accurate weather data from meteorological departments, formal and informal organizations, provision to credit and extension information, seasonal rainfall amounts, geographical location and settings, household size, age and level of literacy of the household head. Hassan and Nhemachena (2008) further found that access to markets, provision to electricity, land ownership rights and gender of the household head suggestively influenced household choice to adaptation strategies to climate variability. Gbetibouo (2009) further cited poverty, lack of secure property rights, lack of savings, farm size, lack of technical skills and off-farm employment as additional barriers to adoption of climate variability adaptation strategies. Information of the adaptation strategies and factors influencing farmers' choices towards tackling the challenges imposed by climate variability on small holders' farmers is paramount (Deressa, Hassan, Ringler, Tekie & Mahmud, 2009). Agricultural activities namely improved crop breeds, afforestation practices, soil conservation, shifting planting dates, and irrigation are the most widely used adaptation strategies whereas several environmental, institutional factors and the economic structure are key drivers influencing farmer' choice to specific adaptation methods (Bryan *et al.*, 2013). Deressa *et al.,* (2009) concluded that farmers education, access to extension services, provision of credits facilities, climate information, and agro-ecological zone have great influence on farmers' choice of adaptation strategy to climate risks while financial constraints and limited information and knowledge about adaptation methods hinders the farmers to take up adaptation strategies.

2.8 Overview of Banana Production Globally

Banana (*Musa spp*.) is ranked 4^{th}, as the most treasured fruit and staple food crop in developing world, after rice followed by wheat and then maize and originated from Asia (Frison, Escalant & Sharrock, 2004; FAO, 2004; Ramirez, J., Jarvis, Van den Bergh, Staver, & Turner, 2011). Price (1994) in his studies traced the first documentations of banana crop and their probable production in the Middle East region to 327 BC. They are native to south East Asia and the Indian subcontinent, and are currently grown in more than 110 countries (Heslop-Harrison & Schwarzacher 2007; FAOSTAT, 2015). At a global level, the majority (20%) of world banana production is based in India, followed by Brazil (Deuter, White & Putland, 2012). Banana subsistence production is the most common way of bananas and plantains production in the tropics and accounts for over 87% of world banana production (INIBAP, 1996). Banana is perennial crop, low-input with small farm size (0.25- 5 ha) and practiced in rural areas of Africa and India. *Musa* fruits vary in size, shape and color but mostly when raw are green and when ripe is yellow. They are elongated cylindrical, straight to strongly curved, 7-35 cm long, and 2-7 cm in diameter. The fruit peak is an important characteristic in variety identification.

The main varieties grown include: Desert banana cultivators-Grandnian, Gross Mitchell, Williams hybrid, lactan, Valery, Chinese Cavendish, Dwarf Cavendish and apple banana. Out of the world banana annual production, 25.6% is produced in Eastern and Southern Africa which is approximately over 20 million tonnes of bananas (Karamura, Frison, Karamura & Sharrock, 1998). The same region is among the world's principal consumer of banana with yearly per capita consumption volume of 400-600 kg. It provides key source of dietary carbohydrate, minerals and vitamins to an estimated 30 million households. It has for long been regarded as an ideal baby food. Banana occupies 30% of the cultivated land of the East African highlands (Mbaka *et al.*, 2008). Majority of the producers are small-scale holders' farmers whom the cultivation forms all-year-round enterprise. In high density regions where land is limited bananas is intercropped with other crops as way of maximizing the farm production and offer households balance diet. Bananas provide food for zero grazed animals' production which provides manure for the farm in order to maintain soil fertility.

In many developing countries, bananas serve as a fruit and food crop. It offers an important basis of fibre (for example Abaca hemp in the Philippines) and among other uses, can be fermented to yield wine. Bananas have also been considered as a useful tool to deliver edible vaccines. The fruit can be eaten uncooked, it is sterile before peeling, and it is often the first solid food eaten by babies (Sharrock, 1997). They are popular and multipurpose and can be processed into food products, beverages (soft and alcoholic), snacks, animal feed, industrial spirits, crafts and medicines. Some varieties are sweet and tasty for desserts while plantains can be cooked or roasted. Non-food products include handcraft such as table-mats, handbags, envelopes, postcards, wall pictures and hats. There is also increasing demand for banana by-products such as peels for livestock feed. Such by-products are opening new market opportunities for smallholder banana producers thereby improving their economic status. The constant availability of harvestable bunches from a banana stool contributes to the year-round food security, and source of income of banana cultivators.

2.9 Banana Production in Kenya

The enactment of the new Kenya Coffee Act (2015) section 4, gave the small holder farmers leeway to uproot coffee plants. This gave farmers opportunity to replace coffee plants with banana crop in the tradition coffee production region of Mt Kenya region (Karanja & Nyoro, 2002). This change offered farmers with hope and freedom to diversify from coffee production to other crops and in particular bananas, which can fetch more prices (with immediate payments, which was more preferable than coffee). Due to this reason many coffee farmers opted to engage in banana production after long periods of low coffee returns, poor management of co-operative societies, rising cost of farm inputs and low yields (GOK, 2002). With the positive developments in banana production most of the small-scale farmers took up banana production but produce small, inconsistent quantities of varying quality (Splisbury *et al.*, 2003). Bananas farming has emerged as the major income earner and food item among the rural small holder’s population of Kenya (GOK, 2011). Smallholder farmers owning less than 2.5 hectares of land produce nearly 84% of the entire banana output in Kenya **(**AHBFI, 2008**).** In 2012, banana production constituted 38% of the total value of fruits produced in Kenya (GOK, 2012).

Banana is primarily produced in Central, Nyanza, Western, Eastern and Coast regions being the key economic enterprise in Mt. Kenya environs it provides food and source of income to cater for health care, households school fees, procurement of food and home improvement (Mbaka *et al*., 2008; USAID, 2013). According to GOK Report (2012), the leading counties in banana production in Kenya are Meru (40%), Kirinyaga (21%), Tharaka Nithi (19%). Banana is a key livelihood source for Meru’s population and is grown on 2.2% of the County’s total agricultural land. In 2015, a total of 382,390 metric tonnes were produced earning the farmers approximately KES 3,700 million. It accounts for nearly half the annual total tonnage of fruits produced in Kenya (GOK, 2008). Banana grows in various climatic conditions and produce harvestable fruit all seasons, thus providing energy during the 'hungry period' between the harvests of supplementary food crops. Banana production is ideal for intercropping and mixed farming with livestock. Due to their suitability for production in backyard systems, banana form an important element of peri urban agriculture where land is limited.

2.10 Post Harvest Strategies in Banana Culture and its Impact on Banana Value Chain.

Unlike other major cash crops produced in Kenya for which cooperative marketing exists, banana trading in Kenya is dominated by middlemen who buy bananas from the farms at the gate prices. The banana are then transported to the collection centres where they can be transported to major towns on hired trucks (Nzioka, 2009). Currently, this situation has changed and some farmers are taking their bananas to collection points and some have formed cooperative societies. Bananas are transported by motorcycles and shoulder carrier to the nearby collection centres depending on seasons. The collection sites are carefully selected to ensure that they are along major roads for easy access to both farmers and produce buyers especially during rainy seasons (AHBFI, 2012). Trucks are used to transport to distant city markets. During loading and unloading about 20-30% fruits are damaged due to heavy pressure of bunches and rough handling (Islam & Hoque, 2003). This affects the banana quality and market pricing.

Banana are consumed raw as staple food or ripen as a fruit. Natural ripening of banana is done for home consumption only. Heat treatment is the common method for ripening banana for commercial purposes. In this system, the firmness or texture of banana is damaged partially due to high temperature created inside the polyethylene cover or closed room. When the heating period is longer with no cooling system after heat treatment, about 10-15% of bananas are damaged within a day due to overheating (Hossain, 2014). Fruit colour also change to pale. Some businessmen use Ethel to accelerate ripening due to market demands. Others usually spray ethel on overall bunch before loading truck for shipment to distant market (Islam & Hoque, 2003).

Banana being a perishable crop with limited shelf life, requires proper storage. Post-harvest banana loss is a major constrain in the value chain. Generally, the primary factors causing post-harvest losses in fresh produce are of mechanical, physiological and environmental nature (Kader & Rolle, 2004). Post-harvest losses are mainly incurred from inadequate infrastructure and technology. In Africa, high post-harvest losses caused by inadequate post-harvest handling limits the expansion of banana production (Olorunda, 2000). Likewise, lack of suitable infrastructure for packaging, storage, distribution and post-harvest treatment, along with production constraints, result to low productivity and post-harvest losses in most banana-producing countries (Gabre-Mariam, 1999). Considerable great number of bananas are damaged, or lost altogether before getting to the urban markets or the designed collection points (Gabre-Mariam, 1999).

2.11 Banana Farming Requirements

Morton, (1987) describes the best conditions for banana farming globally. Banana does best in areas with an optimal mean monthly temperature of 27^0C. The lowest mean annual temperature for growth is 12^0C and temperatures beyond 37^0C can cause leaf scorching and if temperatures fall below 10^0C the crop maturity period extends and reduces the bunch weight. Low temperature for about two months causes injury to banana (Islam & Hoque, 2003). Temperature is very central in different phases of banana growth; about 27°C is optimal for growth and production (Figure 2.1).

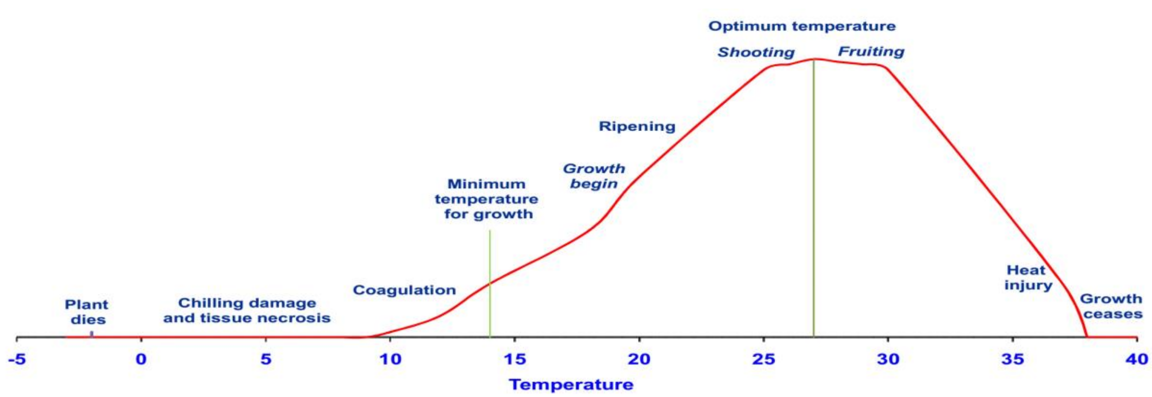

Figure 2.1: Relationship between temperature and growth processes in banana culture. (Source: Samson (1980) cited in Sastry (1988)

Banana has high water demand due to its vegetative nature, with approximately 25 mm per week being the minimum for optimum growth. An average annual rainfall of 1500-2500mm, which is well distributed, is considered the most optimal. However, with good management of available water, bananas can even grow in areas with mean annual rainfall lower than 1200 mm (Robinson & Saúco, 2010). Bananas require a deep, well-drained loam soil with high humus content and a pH range of 5.6 - 7.5. Bananas require considerable amounts of Nitrogen, and Potassium (NK) to maintain high yields. Drought, water logging condition and inadequate sun light cause crop damage and low yield. The recommended spacing is 3m between and 3m within the row (3m x 3m). Rows should be straight in flat fields to allow plants to receive maximum amount of sunlight. Holes should be 45cm deep and 45cm wide. Generally, planting holes size ranges from 30 - 60 cm deep and wide **(**Morton, 1987**).** The deep and large holes provide water retention during the rainy season.

Banana contains important nutrients such as potassium, carbohydrate phosphorus, calcium and magnesium (Archibald, 1949) and various vitamins, (Sampath, Debjit, Duraivel & Umadevi (2013) useful for human growth and development). For example, banana and plantain are required by about 70 million for 25% of their energy demands in developing countries (Consultative Group for International Research for Development (CGIAR), 2015). In Kenya and other Sub Saharan countries ripe banana with yellowish cover can be peeled and eaten directly while those with green cover are regarded raw and could be cooked. Ripe plantain can be roasted or fried in presence of oil before eating (FAO, 2015; Akubor, Obio, Nwandomere & Obiomah, 2003).

Banana offer medication and treatment of various illness such as bronchitis, ulcers and diabetes while banana flowers have been described as astringent plant sap used in hysteria, fever, epilepsy, leprosy, and acute dysentery (Sampath *et al*., 2013). The peels of ripe bananas contain antifungal and antibiotic ingredients against mycobacteria while better mood of persons with depression has been observed when the body converts tryptophan present in bananas to serotonin (Sampath *et al*., 2013). Despite the role banana play within the society, its productivity is declining in recent decades a situation which has been attributed to deficiency in soil nutrient (Clifford, Eldad, Andrew, Fred & Agnes, 1999), pests and associated diseases (Mlot, 2004) and fluctuations in weather pattern in the region where banana production is being practiced. Therefore, banana peels, sap and the fruit are important components in banana crop that are consumed by persons. In addition to this banana stem, leaves can be fed to animals during dry spell.

2.12 Pest and Diseases in Banana Production

Banana production globally is being faced with severe challenges emanating from diseases and pest infestations thereby reducing the production (Clifford *et al*., 1999; Mlot, 2004). Some of the main pests and disease that cause damages to banana crop include:

i) Nematodes

The most notorious pest on bananas and plantains production is nematodes. Nematodes are of different kinds which are of worm-like animals. They are found mostly in the environment setting as parasites and as living organisms which are normally microscopic (Viljoen *et al*, 2016). They cause substantial damage to the banana plants, and are prevalent. Since they are invisible their damage is associated to other diseases. The types of nematodes associated to banana production include the spiral nematodes: *Scutellonema* *brachyurum*, *Helicotylenchus multicinctus* and *H. nannus*; banana root-lesion nematode, *Pratylenchus coffaea*; *musicola*; and the burrowing nematode, *Radopholus similis* less than 1 mm long (Morton, 1987). Nematodes enter through lesions in the roots causing banana rotting providing entry for the fungus *Fusarium oxysporum* (Gowen & Queneherve, 1990). The resulting effects on production include bearing of small bunches, shortened shelf life of the production unit and tumbling of the crop.

To protect the crop from nematode, nematicides need to be properly applied. Alternatively, the soil must be cleared, cultivated and exposed to direct sunlight before planting (Morton, 1987). Sun destroys nematodes at least in the upper several inches of earth. Means of controlling nematodes include crop rotation with legumes, leaving the land idle for more three years, soaking the tubers in hot water (50-55°C) for 15 minutes after trimming all the roots, disinfecting planting material (tubers, or parts of tubers, or the bases of suckers) can help in protecting against the nematodes (Viljoen *et al*., 2016). Viljoen *et al* (2016), highlighted other factors that contribute to nematode infestation to a lesser extent, include climatic factors, water availability, soil situations and fertility, and the existence of other pests and diseases in the environment.

ii) Black weevil

The black weevil *Cosmopolites sordidus*, also known as banana stalk borer, is a destructive pest of bananas and plantains causing heavy loss to the production hence low yields (Ostmark, 1974). Weevil has a long lifespan of adults (lives up to 6 months) and endophytic behavior of the larvae. Conventional method of control, especially chemical control has proved to be less effective (Padmanaban, Sundaraju, Velayudhan & Sathiamoorthy, 2001). It attacks the base of the stool and tunnels upward while producing jelly like fluid discharge from the point of entrance. If the grub damage occurs during bearing stage of the banana crop, the yield loss may go up to 85 % (Rukazambuga, Gold, & Gowen, 1998). According to Morton, (1987) the associated effects of banana weevil attack include destroy the existing roots, limit nutrient uptake, interruption of flowering and increase in vulnerability to other pests and diseases. Yield reductions are caused by plant loss (plant death, rhizome snapping, collapsing) and lower bunch weights. Toppling, are commonly attributed to nematodes and has been observed under conditions of high weevil attacks in the absence of nematodes. Notably the egg development occurs when temperature is above 12°C; this temperature range threshold explains why the weevil is hardly encountered in the region above 1600 m above sea level mainly the highlands.

iii) Thrips

The banana thrips, *Hercinothrips bicintus*, causes silvery patches on the peel and dots them with shiny black specks of excrement. Damage caused by thrips is through feeding on very young, succulent, immature fruits, flowers and foliage (Arnold, Ronald, Ronald, Christopher & Ruth, 2002). The injury to the fruit is not significant but affects the harvest quality. To control weevils, all infested material should be trimmed first. This includes trimming all roots, small suckers and all necrotic tissues until only white, clean tissues remain (Scot, Randy, Ploetz, & Angela, 2006). Afterward soak the trimmed suckers in 10% household bleach solution, let them air-dry for a few days and plant in a new spot.

iv) Sigatoka

Sigatoka, also referred to as leaf spot, is caused by the fungus *Mycosphaerella musicola* (Viljoen *et al*, 2006). It is documented among the most serious constraints to banana farming (Carlier, Zapater, Lapeyre, Jones & Mourichon,, 1996). Loss caused by Sigatoka fungus is displayed as necrotic leaf lesions. This reduce the functional leaf part and reduces photosynthetic ability, resulting in declining crop yield. This can result to banana losses ranging from 20-50% (Stover, 1991; Crous & Mourichon, 2002). The pathogen causes early ripening which seriously affects quality (Stover, 1991). Disease dispersal and growth is accelerated by climatic factors such as moist environment and high humidity. The disease is most prevalent on shallow, poorly drained soil and in areas where there is heavy dew (Morton, 1987).

v) Panama Disease

Panama Disease or Banana Wilt, is caused by the fungus, *Fusarium oxysporum* is a soil-borne disease of bananas present in Africa (Viljoen *et al*, 2006). Banana crop infected with Banana wilt can be recognized by the visible yellowing and wilting of mature leaves and latter attack the youngest and sprouting leaves till the affected crop dies (Morton, 1987). Highly spread by infected soil and contaminated root systems. Planting clean material is the remedy to the disease.

In conclusion, climatic conditions are closely related to pest and diseases infestation on banana production. Moist and rainy environments favor fungal and bacterial diseases to thrive well while dry climate encourages insect outbreaks (e.g., mites) and banana virus diseases. Disease and pest outbreaks are more common in monoculture system of banana production. The severity of the pest and diseases infections depends upon the environment.

2.13 Climate Variability and Banana Production

Climate is particularly an important driver of food availability at the farm and at the end of the value chain, affecting the quantities and quality of banana produced and the adequacy of production related income (FAO, 2008). Rainfall and temperature affect banana production in terms of fruit quality, yield, size and crop cycle length (Turner, Fortescue & Thomas, 2007). These are the most important traits for market supply, food security and producers' income for small holders in the rural areas. Predicted climatic conditions using Global Climate Models (GCMs) indicate that recent and predicted increases in climatic variables (temperature levels and rainfall amount and patterns) has put pressure on banana cropping systems (IPCC 2007; Hawkins, Sharrock & Havens, 2008).

Rainfall and temperature affect immensely growth and production of bananas. Rates of photosynthesis and leaf emergence are reduced by prolonged dry seasons, very high temperatures or low light availability (Turner, 1998). High temperatures lead to losses due to increased sun burnt fruits and it has impact on fruit size and bunch emergence. During hot days the size of the banana fruit reduce and also the bunch size. Flying fox damage in plantations increase due to reduced nectar flows in native forests, particularly during dry period. Decreased rainfall and prolonged dry season results is critical since bananas have a rapid physiological response to soil water deficit, which slows and eventually stops leaf emergence leading to reduced production. Bunch emergence is affected by low temperatures (at altitudes above 500 mm and in the subtropics) (Simmonds, 1966). To resolve the over dependency on rain-fed production of bananas, irrigation is the remedy.

Change in pest/predator ratios is influenced by varying temperature levels resulting from new tropical zone pests moving further south. Cottin, Melin and Ganry (1987), argues that low temperatures reduce growth cycle and the seasonality of production thus affecting the timing of produce supply to markets. There is increased disease incidence due to extended leaf wetness and saturated soils. This is severe during high rainfall seasons. Frequency and intensity of storms during maturing period cause damage and losses in production. This leads to banana "blow downs" during intense storms and also increased leaf tearing from high winds hence reducing photosynthetic ability and possibly inducing more disease (Ortiz & Vuylsteke, 1995). Whereas, there are opportunities associated with climate variability such as an increase in areas climatically suited to bananas farming as a result of increased temperatures and reduced incidence of frost in certain locations. These affect the amount of yields and quality of the produce and finally the market prices.

Increases in daily minimum temperatures above 14^0C, and in the mean daily temperatures in the range 13–22^0C accelerate fruit development and shorten the crop cycle (Turner & Barkus, 1982). Brat, Yahia, Chillet, Bugard and Bakry (2004), notes that fruit quality is significantly affected by environmental factors, particularly temperature. With high production at farm level, the availability of the produce on the market will be determined by climatic conditions such as transportation and post-harvest time of the region especially in developing countries.

Banana value chains should provide maximum potential for the achievement of food security while at the same time generating income among households in Mt. Kenya region. Gereffi, Humphrey, Kaplinnsky and Sturgeon (2001) argues that value chain should shift the focus from production alone to the whole range of activities from production to marketing. This should aim at removing inefficiencies, and enhance a strong ‘end market’ to pull and sustain the chain earning high quality produce that generate best prices. Some of the inefficiencies within the chain are brought by climate variability.

2.14 Theoretical Review

Various climate adaptation theories were examined in the development of this study. They included Cultural Theory of Risk for Climate Change Adaptation, Climate Adaptation and Theory of Change and Action Theory of Adaptation. The Action Theory of Adaptation was more relevant and valid to this study. According to Eisenack and Rebecca (2011), the Action Theory of Adaptation to climate variability maintains that socio-economic factors have effect on crop productivity. The theory focuses on the challenges linking biophysical factors and agricultural production. Its emphasis is on the changes and contribution of meteorological variables such as temperature and rainfall. These variables change or vary from statistical average in term of intensity or rate of occurrence. The climate parameters (rainfall and temperature) are supported by the Koeppen climate classification system. Actions must be `actual´ but stimuli may be potential or actual. Stimuli refer to a sudden or unusual event on the earth surface. There exists discrepancy between meteorological impacts comprising of temperature levels and precipitation trends and more or less subsidiary effects like drought or greater incidence of extreme weather events such as *Elnino* or *Lanina* due to socio economic factors (Philander, 1985). The focus of this study is based on action theory of adaptation to climate change and focuses on the impacts and adaptations. The scope of the study will go beyond the former and focus on socioeconomic factors influencing household perception to climate and choice of the adaptation strategy.

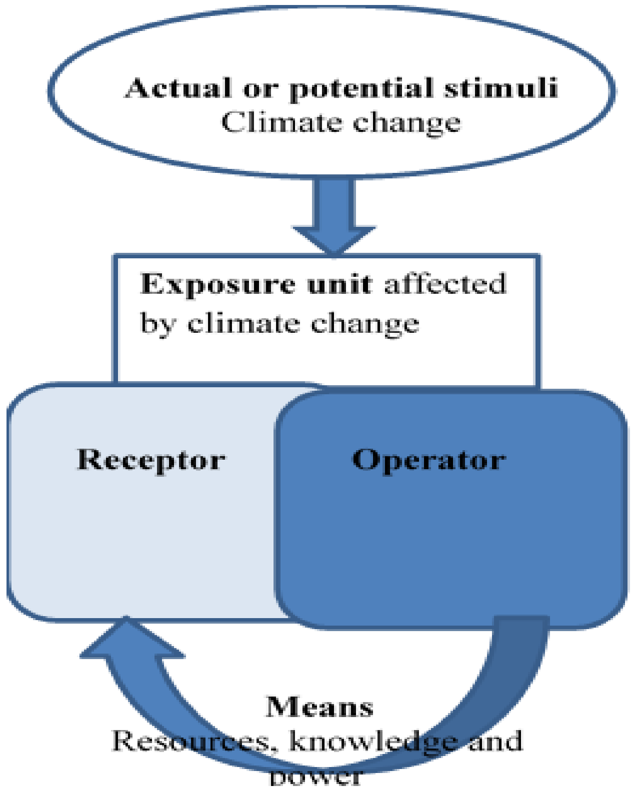

Figure 2.2: Schematic representation of core concepts of the Action Theory of Adaptation (Source: Eisenack and Rebecca, 2011*)*

As indicated in Figure 2.2, the term exposure unit generally refers to all actors that directly depend on climatic conditions (Stimuli) such as social, technical or non-human systems. Exposure unit are susceptible to climate risks and for this study the unit is banana production which is affected by stimuli while operators are the persons or individual households that engage in farming and are small holder banana farmers within Mt Kenya region. The system that is susceptible to climate variations is referred to as the receptor. Receptors for this study refer to both biophysical entities (banana crops) and social systems (small scale banana farmers). To implement the operator (individual household) need resources referred to as means in order to adapt to impacts of climate variability. The means include access to monetary resources, market information, technical know-how, innovations and access to information. Constraints shape the action further that cannot be influenced by the operator and are so-called conditions.

This theory is used in evaluation of climate variability impacts and adaptation strategies on banana farmers in the banana value chain. The stimulus for this study is temperature and rainfall. The exposure unit is directly affected by climate variability. It comprises of banana farmers and their livelihood aspects, weather forecast stations and extension agents. Meteorological department provide the weather forecast information available. Farmers' application of information on adaptation is dependent on their knowledge on theme under study and presence of resources at hand. Absence of credit and loan facilities may hinder or constrain the farmers from coping with the suitable production strategies. Means of transmitting data to receptors (farmers practicing banana farming) is dependent on the resources available to the operators (County and National government, Research organization and Kenya Metrological Department).

This theory is directed towards climate variability hence applicable to this study. It deals with adaptation strategies due to climate variability effects mainly rainfall and varying temperature levels. These conditions lead to extreme weather events such as drought and floods. In order for the households to adapt there must be presence of the resources, knowledge and skills. This theory was used to study poverty and vulnerability reduction related to climate risks in Kenya (Eriksen & O'brien, 2007)

2.15 Conceptual Framework

The study was guided by the conceptual framework presented in Figure 2.3. The independent variables of the study are rainfall and temperature variations while the dependent variables are the Banana Value Chain (BVC) comprising the production, transport, trading and consumption. The climatic variables (rainfall and temperatures variation) affect BVC dynamics over time and space due to climate variations. This study assumed that only two climatic variables (temperature and rainfall) influence the BVC. The moderating variables include the socioeconomic factors (Gender of HHH, Age of HHH, Level of education of HHH, Farm Land size, Access to market information, Farming system, Group membership, Agro-Ecological Zone, Farming practice, Access to weather information and Land under banana production) and biophysical factors. From Figure 2.3, rainfall and temperature fluctuations together with moderating variables affect the BVC thereby influencing the adaptation strategies to climate variability and farmers perception. Socioeconomics factors determine the ability of the farmers to respond to climate variability and actions towards banana production system. If the farmers prefer to adapt to climate variability, will translate to increased production at farm level and hence high income will be realized. Actions will lead to behavioral change among the farmers in relation to banana value chain.

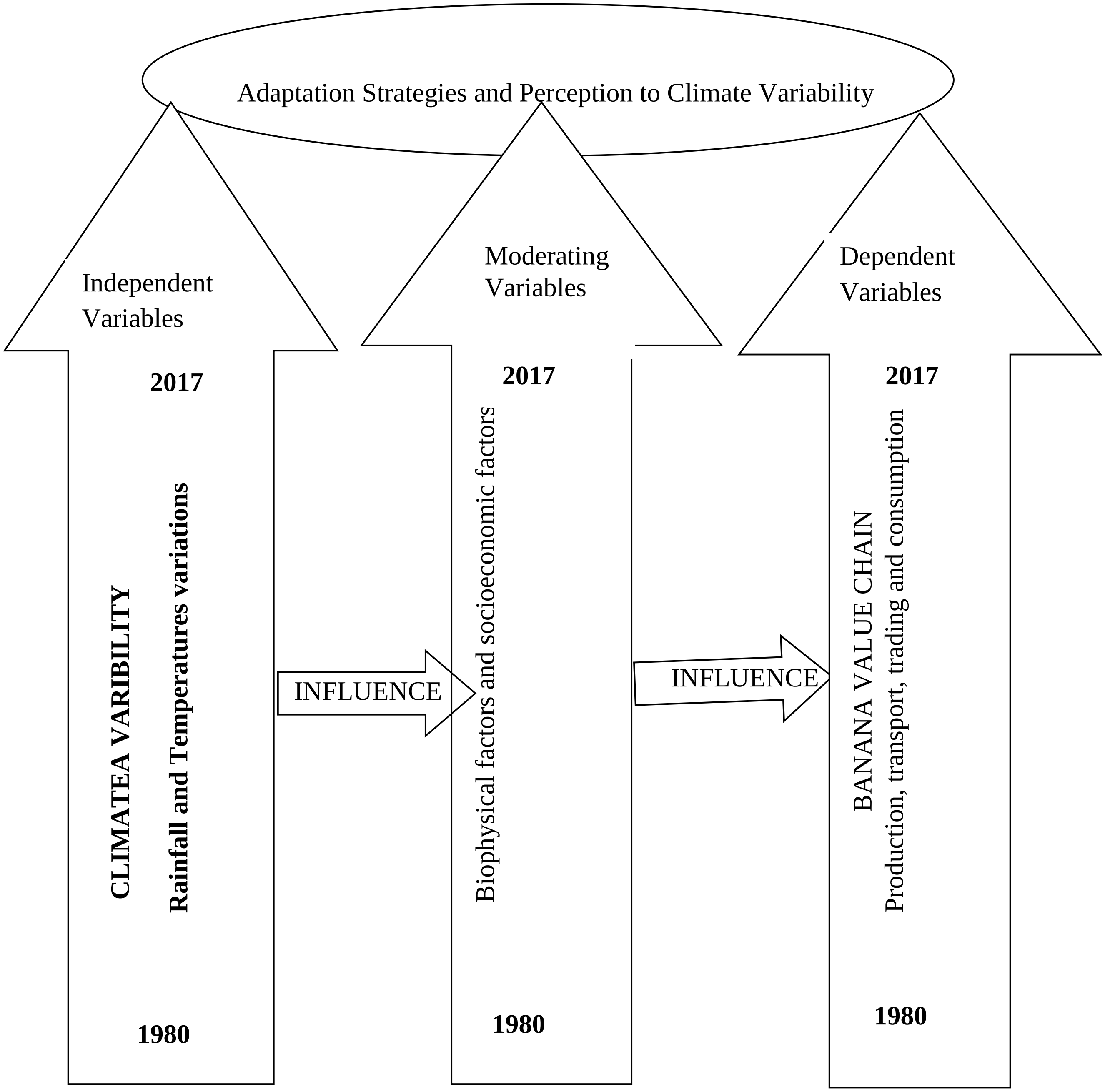

Figure 2.3: Conceptual framework showing the interaction between climate variability and banana value chain (*Authors own conceptualization, 2018*).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter highlights the research methods used in the study. It presents the research design, research instruments, sampling procedures, methods of data collection (both qualitative and quantitative) and data analyses. The chapter concludes by highlighting the research ethical dimensions observed.

3.2 Research Design

The study adopted mixed research design to evaluate impacts of climate variability and adaptation trends in banana value chain in Meru (Imenti South Sub County) and Nyeri (Mukurweini Sub County) within the Mt. Kenya region. The study involved use of triangulation method whereby both qualitative and quantitative techniques were adopted to collect data using structured questionnaires administered to smallholder farmers; Focus Group Discussions (FGDs); in-depth interview of key informants and visual observations of land use systems. Historical data on meteorological variables (rainfall amounts in millimeters and temperature levels in degree centigrade) and banana yield in tonnes were acquired from Kenya Meteorological Department (KMD) and Horticultural Crops Directorate (HCD) respectively.

3.3 Selection of Study Area and Sites

The study area was purposively selected to include diverse locations where banana has been grown for the target period from 1980-2017 within Mt Kenya region (Fig 1). Areas with similar Agro Ecological Zones and availability of climatic data were considered in the selection of study areas. In Meru County, six sites were selected in Imenti South sub-county (Mitunguu, Igoji East, Igoji West, Abogeta West, Abogeta East and Nkuene (Appendix 5) while the sites in Nyeri County comprised of Ruigi, Mukurweini Central, Gikondi and Mukurweini West in Mukurweini Sub-County (Appendix 4). The average land size in Nyeri County is 1.8 ha for majority of households while for the large-scale farmers, average land holding is 18.25 ha (GOK, 2015b). The selected study sites are located in three Agro Ecological Zones as described in Table 3.2.

3.4 Selection of the Respondents

Simple random sampling method was used to choose the respondents for the study. The sampling method was ideal because it ensured a high level of representation by providing the respondents with equal opportunity of being selected to participate in the study. The sampling frame for the study consisted of smallholder's banana farmers. According to GOK (2009) population statistics, the population of Imenti-South was approximately 179,604 with 47,197 households while that of Mukurweini Sub-County 83,932 with 24,083 households.

The sample size was thus calculated following Krejcie and Morgan, (1970) as follows: -

$S = X^2 NP (1-P) \div d^2 (N-1) + X^2 P (1-P)$

Where

S = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom with the desired confidence level (3.841).

N = Population size.

P = the population proportion that would provide the maximum sample size for the study.

d = the degree of accuracy expressed as a proportion

Thus, a sample size of 382 respondents was obtained from a total population of 71,280 households. This sample estimate corresponds with Gay (2003) who showed that a sample size of 400 is adequate for a population of over 5,000. Further to determine the sample size per each study area, proportionate method was used and actual sample size per site attained as shown in Table 3.1. The respondents also included key informants from Agricultural Extension and Horticultural Crops Directorate (HCD) officers in both study locations. A total of 381 (99.73%) questionnaires were fully filled and returned after the study. This number was adequate according to Mugenda and Mugenda, (2003) who stated that 50% response is adequate, 60% is good and 70% is very good. Hence the response rate of 99.73% was therefore considered very good and adequate for this study.

3.5 Validity and Reliability of Research Instruments

3.5.1 Validity

Validity is defined as the accuracy and meaningfulness of data collection tools. It is the level to which results obtained from the analysed data actually represent the truthfulness of the study (Mugenda & Mugenda, 2003). The researcher validated the research instruments in terms of content and face validity. The validation of the questionnaires and interview guides were done through the pretest of the questionnaires and expert review of the tools. The validity of the instruments was tested through pretesting done in the study sites which were similar with the study region. Pre testing was done in the study sites where

5 questionnaires were administered per site totaling to 50 questionnaires. The instruments were improved after pretesting in accordance to recommendations from experts.

3.5.2 Reliability

Reliability focuses out the degree of internal consistency over time of a research instrument. A research instrument must be reliable to yield consistent and stable results when applied more than one instances in data collection or when gathering information from two samples drawn randomly from the same population (Mugenda and Mugenda, 2003). Reliability of the instruments was computed using SPSS version 21 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, Geoffry & Peter, 2009). An Alpha index of 0.7 or higher is considered a sign of acceptable internal consistency (Nichols, Nichols, & Mitchell, 2004).

3.5.3 Normality

This test was carried to determine whether sample size was drawn from normal distributed population. The Shapiro-Wilk test is one of the most popular tests for normality assumption diagnostics which has good properties of power and it based on correlation within given observations and associated normal scores (Keya & Rahmatullah, 2016). Shapiro wilk test (w - value) greater than 0.05 was considered acceptable for the study.

3.6 Data Collection

3.6.1 Methods and Procedures

Data collected comprised of primary and secondary data which included individual interviews, Focus Group Discussions (FGDs), data mining from records and researcher observations. Quantitative and qualitative data collection methods and acquisition were used. Studies that combine the two methods have been proven to be more inclusive than those that employ one type of methodology (Creswell & Plano, 2011). Adopting a triangulation of methods was informed by the research problem under investigation, which required the researcher to collect data, analyze and make inferences.

Table 3.1: Tabulated sample size per study area based on number of households according to GOK (2009) KPHC data

Study Location (sub county)	Number of Households	% Proportion	Tabulated sample size
Imenti south	47,197	66.2	253
Mukurweini	24,083	33.8	129
Total	71,280	100	382

Table 3.2: Biophysical characteristics of the study sites in Meru and Nyeri Counties

Study Area (County/Sub county	Study site	AEZ[¶]	Temperature range ^{0}C	Altitude (Masl)	Rainfall range (mm)	Major agricultural activity
Meru County (Imenti South)	Mitunguu	LM3	22.9-20.6	910-1280	800-1200	Cotton, Maize, banana, Asian vegetables
	Igoji East	LH1	17.4-14.9	1830-2200	1500-2000	Tea, banana, Maize
	Igoji West	UM1	19.2-17.0	1830-2200	1500-1800	Coffee, Tea, banana, Maize, beans and horticulture
	Abogeta West	UM2	20.6-18.2	1280-1680	1200-1800	Coffee, bananas, Maize, beans, avocado, dairy
	Abogeta East	UM3	20.6-19.2	1280-1520	1200-1500	Coffee, bananas, Maize, beans and horticulture
	Nkuene	UM2	20.6-18.2	1280-1680	1200-1800	Coffee, bananas, Maize, beans and avocado
Nyeri county (Mukurweini)	Ruigi	UM3	20.8-17.5	1220-1780	870-1000	Coffee, banana, maize and beans
	Mukurweini Central	UM2	19.3-17.8	1460-1710	950-1500	Coffee, banana, maize, avocadoes and beans
	Gikondi	UM2	19.3-17.8	1460-1710	950-1500	Coffee, banana, maize, avocadoes and beans
	Mukurweini West	UM1	17.8-17.5	1710-1780	1100-1600	Coffee, banana, maize, avocadoes and beans

[¶]AEZ (Agro ecological zones as described by Sombroek, Braun & Van der Pouw. (1982) and FAO (1996). Agro-ecological zones (AEZs) are land units defined on the basis of combinations of soil, land form and climatic characteristics. LH-Lower Highland zone, UM-Upper Midland zone, LM-Lower Midland zone.

a) Primary Methods

Quantitative methods included the use of surveys to collect data on banana production, yields and trends in the value chain. Close ended questionnaires were used to capture indicators of climate variability, key factors determining farmers' perception and adaptations strategies. Qualitative methods employed for the study included interviews of key informants and Focus Group Discussions (FGDs). In addition, researcher observations were conducted to enrich primary data. Key issues of the climate variability effects and adaptations on banana value chain were captured by in-depth interviews from key informants. FGDs were undertaken to validate data collected from individual households. The FGDs have several advantages over individual interviews as they save time and money and provide an opportunity to collect diverse information on a particular topic (Morgan, 1988).

b) **Secondary Sources**

Historical data was used to examine climatic trends (temperature and rainfall) and production data. Documented banana production (in tonnes) and acreage data (hectares) were collected from the HCD offices in Nkubu and Mukurweini sub counties from 2009 to 2017. Monthly climatic data obtained from Kenya Metrological Department (KMD), Nairobi included temperature (^{0}C) and rainfall (mm) from 1980 to 2017 for the adjacent stations in Imenti south and Mukurweini Sub-Counties. These two parameters have the longest and widest data coverage in the country and are the most common climatic variables considered by many studies in Sub-Saharan Africa. Temperature and rainfall were used for respective yearly data and their long-term values to capture climate variability and estimate the short and long-term effects of climate on banana value chain.

A similar approach has been followed in previous studies (Kabubo-Mariara & Karanja, 2007; Lobell, Burke, Tebaldi, Mastrandrea, Falcon, & Naylor, 2008; Sarker, Alam, & Gow, 2012). Other sources of data included journal articles, government reports, County strategic plans, County abstracts and books which gave background information on climate and production.

3.6.2 Research Instruments/ Equipment

The study used structured questionnaires for the purpose of gathering information from the smallholder farmers. In-depth interviews were administered to key informants who included agricultural extension officers and HCD officers. Field observations were used to enrich the collected data.

3.7 Data Analyses

a) **Qualitative Analysis**

Survey data from the questionnaires were coded and entered in SPPS Version 21 (SPSS, 2012) for analysis. Chi square was used to establish associations that existed between variables while correlation established the direction and strength of the relationships of the variables. These cross-tabulations were done to respective research objective/questions and to test the hypotheses. Respondents (Farmers) perceptions on climate variability related issues and adaptation strategies were analyzed using binary models. A binary model was preferred to establish the factors influencing farmers' perceptions on climate and preferred adaptation strategies. Binary logit models were employed when the number of choices available were two. The dependent variables in this study were perception and adaptation.

Thus,

Regarding farmers' perception:

$R^*_i = X_i \alpha + \varepsilon_i$

Where

R* is the latent variable,

ε is the error term,

X set of explanatory variables or socioeconomic factors influencing farmers' perceptions.

The binary outcome is equal to one ($P_i = 1$) if farmer *i* perceives climate variability over the past 10 years and ($P_i = 0$) if a farmer does not; then 0 is the intercept. Perceptions regarding long-term change on the average temperature and rainfall fell under two categories (perception, and no perception).

For Farmers households' characteristics influencing adaptation strategies of climate variability

$R^*i = Xi\alpha + \varepsilon i$

Where

R* is the latent variable,

ε is the error term, and

X denotes the set of explanatory variables or factors that influence households' choice on adaptation strategy.

Five adaptation strategies were identified which farmers choose from. These strategies were; drought tolerant varieties; shifting planting dates; no adaptation; crop diversification; and irrigation. The farmers were assumed to adopt only one strategy for instance (adaptation strategies=1, while no adaptation =0).

Multinomial Logistic Model (MNL) was preferred for the analysis of socioeconomic factors influencing perception and adaptation strategies. MNL was used to analyze the socioeconomic factors influencing the farmers' perception and adaptation strategies to climate variability by individual households while descriptive statistics was used to analyse adaptation strategies used by households. The strength of MNL is the ability to specify the relationship between the probability of choosing an adaptation option and the set of explanatory variables (Magombo, Kantlini, Phiri, Kachulu & Kabuli, 2011).

The MNL model is described below;

$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots\ldots\ldots\ldots \beta_n X_n + e_i$

Where Y_i = adaptation strategy such as (drought tolerant varieties; shifting planting dates; irrigation; crop diversification).

X_i, where i = 1, 2, 3, 4………n, are explanatory variables.

β_0: is the intercept,

$\beta_1 \ldots\ldots \beta_n$.: are slopes of the equation in the model.

The dependent variable was regressed on a set of explanatories. Preceding to the approximation of the logistic regression model, the explanatory variable were checked for the presence of multi collinearity. To aid analysis of the binary data of factors influencing farmers' perception and adaptations, a definition table showing independent variables is appended (Table 3.3) exploring farmers of the Mt Kenya region.

b) Quantitative Data Analysis

Quantitative data was analysed using both descriptive and inferential statistics (correlation and regression). Graphical methods including charts, tables and graphs were used for data presentation. Sample means were computed and analysed for respective areas for comparison purposes. Chi square index was used to determine existence of association between variables. To determine the strength and direction of respective relationships between banana production, transport and trading trends on the one hand and climate variability trends on the other, a coefficient statistic was applied. Hypotheses were tested at a P-level of 0.05. Excel 2016 was used to analyse rainfall and temperature variability from two meteorological stations to come up with annual means of rainfall and temperatures.

3.8 Ethical Dimension

For ethical reasons, prior to the research process, the researcher and the participants signed an agreement that clarified obligations and responsibilities through informed consent. Each respondent was enlightened on the objectives of the study, need for them to participate, and associated risks, envisioned benefits and confidentiality measures adopted by the research team. Research permit was obtained from National Commission for Science Technology Innovation at national level (Appendix 6). At County and university levels, an authorization letters to undertake the research were also issued.

Table 3.3: Variables used in the logistic regression models

Variable	Definition
Dependent Variable	
Adaptation strategy to climate variability	1 = Adaptation
	0 = No Adaptation
Perception to climate variability	1 = Perceived
	0 = Not perceived
Household characteristics (Independent variables)	
Gender of household head	1 = Male
	0 = Female
Age of household head	1 = <20yrs
	2 = 21-30years
	3 = 31-40years
	4 = 41-50years
	5 = 51-60 years
	6 = >60years
Education level of the household head (HHH)	1 = No formal education
	2 = Primary
	3 = Secondary
	4 = Tertiary
Type of farming practice	1 = Subsistence
	2 = Cash-crop farming
	3 = Mixed farming
Type of farming system	1 = Rainfed
	2 = Irrigation
	3 = Both rainfed and irrigation
Member of social group	1 = Yes,
	0 = No
Land ownership	1 = Own land,
	2 = Rented land
Agro- Ecological Zone	1 = LM
	2 = UM
	3 = LH
Access to credit	1 = Access to credit,
	2 = No credit
Access to extension services and training	1 = Access to extension services,
	2 = No extension services
Access to market information	1= Yes
	0 = No
Information on weather	1 = Yes
	0 = No
Land size	Acreage
Perceptions of households towards climate variability	1= Yes
	0 = No

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter presents an analysis of research findings per specific study objectives. The chapter first addresses the social landscape of the respondents and a synthesis of the banana value chains in Mt Kenya. The chapter further presents the finding of the specific objectives which are to determine (a) the trends of climate variability and related impacts on banana value chain from 1980 to 2017; (b) the perception of banana farmers towards the effects of climate variability on production, post handling activities, transport and trade: (c) the climate variability adaptation strategies on banana production: (d) the extent to which rainfall amounts and temperature levels impact on banana value chain from 2009 to 2017.

4.2 Demographic Characteristics of the Respondents in the Study Area

The demographic characteristics of the respondents in the study area are discussed in regard to gender, age distribution and highest level of education as shown in Table 4.1. In the two sites, majority of respondents were females representing 56.2% in Mukurweini Sub County and 51% in Imenti south Sub County. This shows that there were more females involved in the banana production than their male counterparts. This can be attributed to the fact that females are more engaged in household food provision in most parts of rural settings in Kenya and other developing countries.

Table 4.1. Gender, Highest Level of Education and Age Distribution of the Respondents in the Study Area (Mukurweini and Imenti South Sub Counties)

		Mukurweini (N=130)	Imenti South (N=251)
Variable	**Specific variable**	**Frequency and percentage**	
Gender of the respondents	Male	57 (43.8%)	123 (49%)
	Female	73 (56.2%)	128 (51.0%)
Level of education among the respondents	No schooling	9 (7.0%)	12(4.8%)
	Primary	53(41.1%)	130 (51.8%)
	Secondary	58 (44.2%)	82 (32.7%)
	Tertiary	10 (7.8%)	27 (10.8%)
Age distribution of the respondents	Less than 20yrs	1 (0.8%)	4 (1.6%)
	21 - 30 years	17 (13.1%)	21 (8.4%)
	31 - 40 years	15 (11.5%)	87 (34.7%)
	41- 50 years	31 (23.8%)	79 (31.5%)
	51- 60 years	33 (25.4%)	34 (13.5%)
	More 60 years	33 (25.4%)	26 (10.4%)

Values in parentheses are the percentages

In Mukurweini south sub county, majority (44.2%) had secondary level of education while in Imenti south sub county 51.8% had primary level of education. Those who never attended any schooling represented 7.0% in Mukurweini and 4.8% in Imenti south. Majority (25.4%) of the respondents in Mukurweini were between the ages of 41-50 and more than 60 years while 34.7% of the respondent in Imenti south were between the ages 31 - 40 years.

4.3 Observed Banana Value Chain and Actors in Mt. Kenya Region

Banana value chain in the region is considered to be dynamic due to internal factors (relationships between actors) and external factors (climate). According to findings from the respondent's and Focus Group Discussions (Plate 1), the banana value chain commences from the smallholder's farmers who are the main producers (Figure 4.1). In between production and consumption there is harvesting and storage of the produce then transportation to the consumer. The role of harvesting depends on the agreement between the farmer and buyer because it's associated with extra cost in form of labour. Storage is solely the role of the buyer/trader. The consumers include all those who directly consume the bananas while in between the producers and consumers; there were other actors who facilitated the movements of the produce. Brokers or middlemen play an important role in the chain through connecting producers to the consumers. Most of the produce is sold to brokers/middlemen and few farmers deliver them to the market where buyers from urban centers directly buy the produce. Many smallholder farmers are unorganized and rely on middlemen who collect their produce at the farm gate (Trienekens, 2011). Thus, the brokers are seen to negatively influence banana pricing for their personal gain as explained by respondents during Focus Group Discussions.

The main banana value chain actors and their roles were identified during the study in FGDs (Plate 1) including farmers or the producers, transporters, traders (micro-traders, bulk traders and retailers), processors facilitators (both state and non-state actors) and consumers (Table 4.2). The major role played by each actor is a pointer of their status in the existing banana value chain development in the Mt Kenya region.

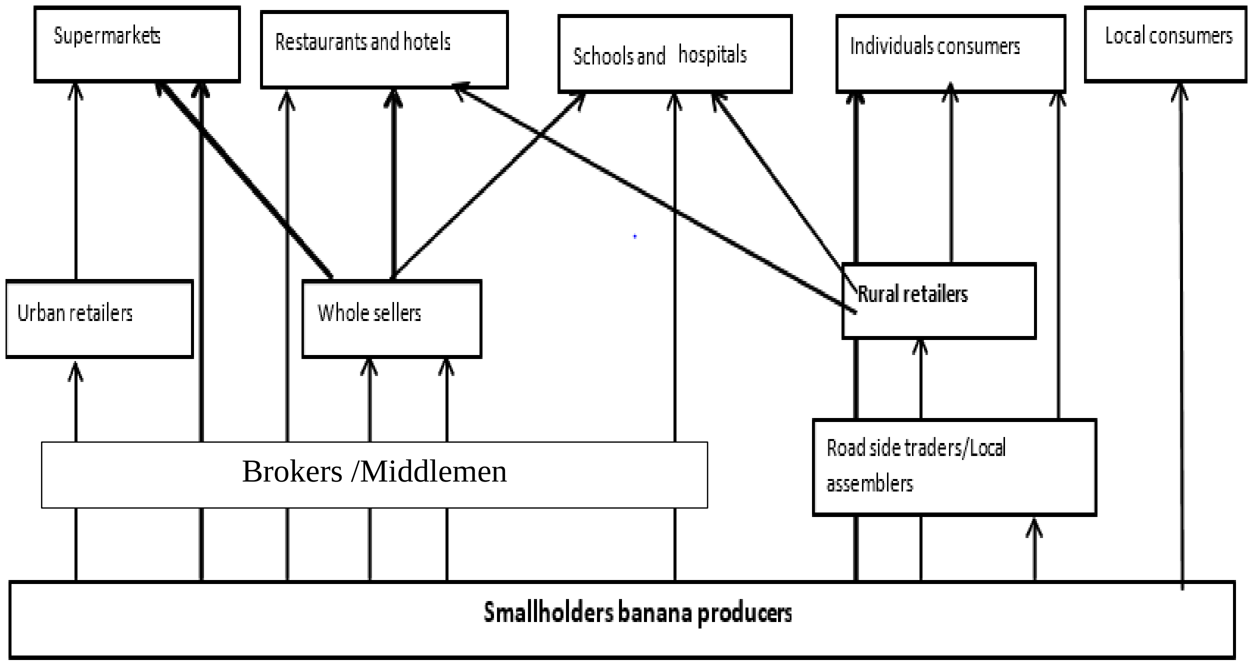

Figure 4.1: Observed banana value chain in the study location

The principal player in the Banana Value Chain (BVC), are smallholder rural farmers with farm acreage less than 2.5 hectares. They acquire the planting materials from older plantation farmers or neighbors. The market approach is through farm gate sale of small quantities of bananas to small scale traders (bicycle traders). In the upstream segments of the value chain, particularly at farm level, post-harvest losses occur and are often associated with physical losses such as theft and selling of immature bananas fruits which form economic losses (Trienekens, 2011).

Plate 1: Focus Group Discussion session during data collection in Imenti south.

Traders include local traders whose mode of transport to the market or collection is motorcycle and also human porterage. These traders move from one farm to another in pursuit of banana fruits to purchase either through random farm visits checks or referral. They are preferred by farmers since they offer the transport to village markets hence no cost incurred during transport. These traders mainly bridge the collective purpose for non-existing or non-functional producers on the marketing groups. Market vendors on the other hand operate on a higher level than local traders. Their market points are village markets where they buy bananas from individual farmers and motorcycle traders and transport them to bigger market or collection points where bulk traders collect them to major urban centers like Nairobi and Nakuru. They have an established link with bulk urban traders which ease their functionality.

Transporters offer their services and hence act as a key link between rural banana production points and urban consumers. Transporters in the BVC have an important part in moving banana produce to urban or city markets. Transporters deliver bananas to organizations such as schools, hospitals and hotels. Loaders are connected to transporters whose role is to carry and pack banana in crates, cartons, sacks and or in the vehicles. Once bulk traders get to urban centers, they supply to retailers selling at village and urban markets. Urban retailers sell banana produce to small consumers inform of fingers or cluster at ago.

The mode of communication between the farmers and traders or consumers or brokers is through mobile phones. The communication helps them locate where bananas are available and to negotiate on the prices. Sometimes there exist other traders or middle men who move from one farm to another in search of the produce once they locate enough produce, they communicate to the main buyer or transporter in order to come and collect the produce.

Urban retailers operate in residential neighborhoods within the urban setting to help banana consumer reach the produce nearby. Banana processors add value to the produce and operate on a small scale in the rural setting with the aim of transforming banana produce and other banana parts to more valuable products like flour, wine and crisp to boost the market demands, reduce waste, increase the price as well as increase the shelf life.

Table 4.2: Major Banana Value Chain Actors and their Roles in Mt Kenya Region.

BVC Actors	Major role(s)	Characteristics
Small holders' farmers	• Banana farming; • Farm gate and trading at village level • Offer human portage or motorcycle transport to local markets; • source of food to a significant portion of their banana produce	• Smallholders with acreage less than 2.5ha • Use ordinary farm implements and traditional methods in plant management; • Borrow suckers from neighbours farms or use own as a means of maintenance their farm • Sell produce to micro traders or bicycle vendors
Local traders	• Involved in micro-collection of bananas produce from farm gates to collection points or market centres • Connect farmers to markets	• They function on a small scale (transport and trade less than 5 banana bunches at a time)
Market sellers	• Commence the collection of bananas from motorcycle traders • Collect on behalf of bulk traders	• Operate on higher level than local traders but less than bulk traders • Have an established connection with bulk urban traders
Transporter providers	• Provide transport services • Involved in long distance and bulky transport of bananas from rural areas to urban centres	• Operate in large with lorries • Provide connection between urban consumers and rural farmers or local traders
Urban Retailers	• Buy from large traders and sell to consumers • Sell bananas to consumers at required quantities	• Operate on small scale in urban setting • Operate mini shops grocery while selling other goods other than bananas; • Operate in major markets and also next-door kiosks in residential areas
Brokers/Middlemen	• Connect the farmers to buyers or traders • They determine the banana prices at farm gate or collection centres	• They function on bulkiness. • They communicate to farmers by mobile phone or move randomly from one farm to another

Processors	• Transformation of fresh bananas or banana plant parts to value added products • Create consumer awareness on processed banana products	• Operate on a small scale due to market bureaucracy
Value chain facilitators	• Provision of extension services; • Value chain development; • Provide funding of value chain activities	• They incorporate banana promotion in their activities • Conduct research and training on banana breeding for climate resilient banana cultivars
Consumers	• Provide ready market for banana produce and produce	• Varies from small individuals and households to large organizations such as restaurants and hospitals

The facilitators offer their services to the BVC actors which include provision of advisory and technical services such as extension and training, financial services and research. Within the existing banana value chain operations in the region, the facilitators are weakly connected to BVC actors. The main banana consumers are individual households, hospitals, hotels and learning institutions which are spread within the region and outside the region.

4.4 Climate Variability effect on Banana Value Chain in Mt Kenya Region between 1980 - 2017

This section highlights the findings of data analysis on climate variables and their effects on banana value chain. The data is presented in the order of climate variables (rainfall and temperature trends, their seasonality, effect on production, transport of banana to the market, value addition, trade and marketing. Other factors affecting the banana value chain include land use changes; production systems which have compounding effect on production are also presented.

4.4.1 Temperature Trends in Imenti South and Mukurweini Sub-County between 1980 and 2017

Analysis of temperature and rainfall was done for a period of 37 years (1980-2017). This is supported by the World Meteorological Organization (WMO) that requires the calculation of averages for consecutive periods of 30 years, in order to exhaustively understand the climate trends (FAO, 2008). This period is adequate to eliminate year-to-year variations. In order to understand the changes in temperature levels and rainfall amounts during the study period (37 years), the monthly statistics for every year were reduced to single annual value.

Table 4.3: Temperature Characteristics in the Study Area

Location	Average temp(^{0}C) 1980-2017	R^2	Highest temp (^{0}C)	Lowest temp (^{0}C)	Annual change in Temp(^{0}C)
Mukurweini	18.6	0.3314	18.8	17.3	0.02
Imenti South	18.9	0.3341	18.8	17.6	0.016

The study revealed that Imenti South Sub-county was slightly warmer than Mukurweini Sub-county with mean average temperature of 18.9^{0}C and 18.6^{0}C respectively (Table 4.3). There was a gradual increase in temperature in the two locations from an average of 17.7^{0}C in Mukurweini and 18.1 ^{0}C in Imenti South in 1980 and rising gradually to 18.2^{0}C and 18.6^{0}C in 2017 in Mukurweini and Imenti South respectively. The highest recorded mean temperature for Mukurweini Sub-County was in 2009 at 18.7^{0}C while in Imenti south Sub-County in 2015, it was at 18.9^{0}C. The lowest recorded mean temperatures for Imenti South Sub-County was in 1982 at 17.6^{0}C while in Mukurweini Sub-County were in 1985 and 1998 at 17.3^{0}C.

As indicated in the Figure 4.2, the two study areas display increasing linear trends of temperature as denoted by positive slopes in the trend line equations. The yearly trend line analysis of Mukurweini sub-county presented R^2 = 0.3314 which translated to 33.14% change while in Imenti South, R^2= 0.3441 translated to 34.41% (Figure 4.2). Positive slope on the trend line indicated the temperature was increasing in the study areas. The temperature change was gradual with a peak year being after every 4 years in the study area. This is supported by Rarieya, and Fortun (2010); Karienye, Mwangi, Kaguai, Waweru and Muthoni, (2013) who noted that temperature reached peak values after every four to five years and this resulted to drought incidences in the region. This also concurs with National Environment Management Authority (NEMA) (2014) who noted that drought is a frequent phenomenon occurring after every 4 years, thus impeding agricultural investments, case in points in the recent times having occurred in 1991/92, 1995/96, 1998/2000, 2004/2005, and 2008/11.

Mukurweini sub-county trend line indicated average temperature in 1980 as 17.7^{o}C and in 2017 as 18.5^{0}C. The overall change for 37 years (1980-2017) was 0.8 ^{0}C translating to 0.02^{0}C annually. In Imenti South sub-county, the average temperature in 1980 was round 18.1^{0}C and 18.7^{0}C in 2017. The overall temperature change for 37 years was 0.6^{0}C translating to 0.016^{0}C annually. This indicated that temperature was increasing in both counties during the said period. This is supported by the IPCC (2001), which indicates that temperatures levels were anticipated to increase by around 0.4°C in East Africa per decade while Naresh and Diptimayee (2013) in their study conducted in Odisha, India revealed that the annual average temperature was increasing with about 0.03^{0}C. The temperature increase could vary between 0.4°C and 1.8°C by 2020, being more severe in tropical locations. High temperatures (particularly >3°C) are reported to dramatically affect agricultural productivity, farm incomes, and food security (Rodomiro, 2012). This concurs with Niang *et al*., (2014) who reported that climate variability is expected to increase temperature levels and precipitation variations in East Africa. Temperature levels in Africa is likely to rise faster than other parts of the world, which could exceed 2°C by mid- 21st century and 4°C by the end of 21st century (Hansen, Sato, Ruedy, Lo, Lea, & Medina-Elizade, 2006).

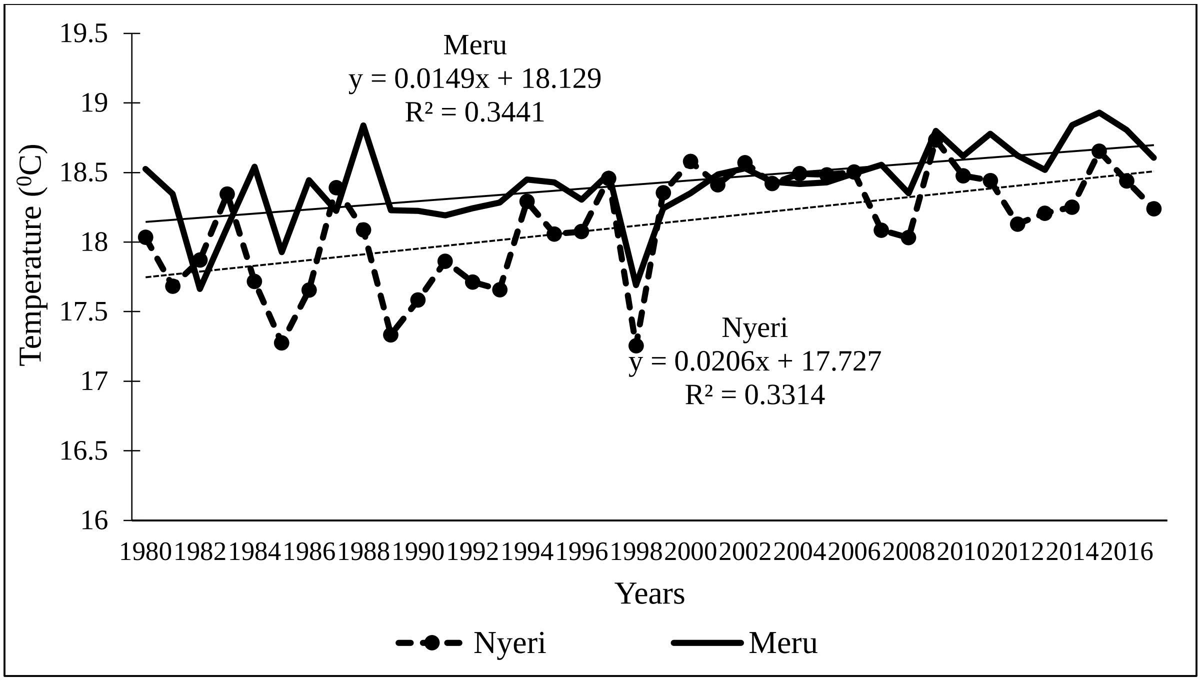

Figure 4.2: Time series of annual temperature data for Meru (Imenti South Sub-county) and Nyeri (Mukurweini Sub-county) and their respective linear trend lines.

4.4.2 Rainfall Trends in Imenti South and Mukurweini Sub-County during the Period 1980 to 2017

The average annual rainfall for Mukurweini and Imenti South sub-counties were 949mm and 1286mm respectively (Table 4.4). High rainfall amounts were recorded in Imenti South in the year 1986, 1997 and 2002 amounting to more than 1800mm annually while in the year 2000, 2004 and 2015 lowest amount of rainfall were recorded below 1000mm annually (Figure 4.3). In Mukurweini Sub-County the rainfall had been moderately below 1500mm annually except in the year 1997 which recorded 1620mm. Rainfall amount below 600mm was recorded in the year 1987, 1999, 2000 and 2005 in the study areas.

Table 4.4: Rainfall characteristics of the study area

Location	Average amount of rainfall (mm) 1980-2017	R^2
Mukurweini	949	0.1064
Imenti South	1286	0.1014

As indicated in Figure 4.3, the rainfall decreased in both study locations and rainfall peaks occurred after every four to seven years as observed in the graphs. The study findings reveal a decreasing trend of annual rainfall in Mt. Kenya region, which is represented by negative slope in the corresponding trend line equations. The same trends have been documented by (IPCC, 2001) who noted that precipitation in Africa is likely to decline at a rate of between 10 and 20% in Southern Africa and 10 to 50% in Eastern and Northern parts of Africa.

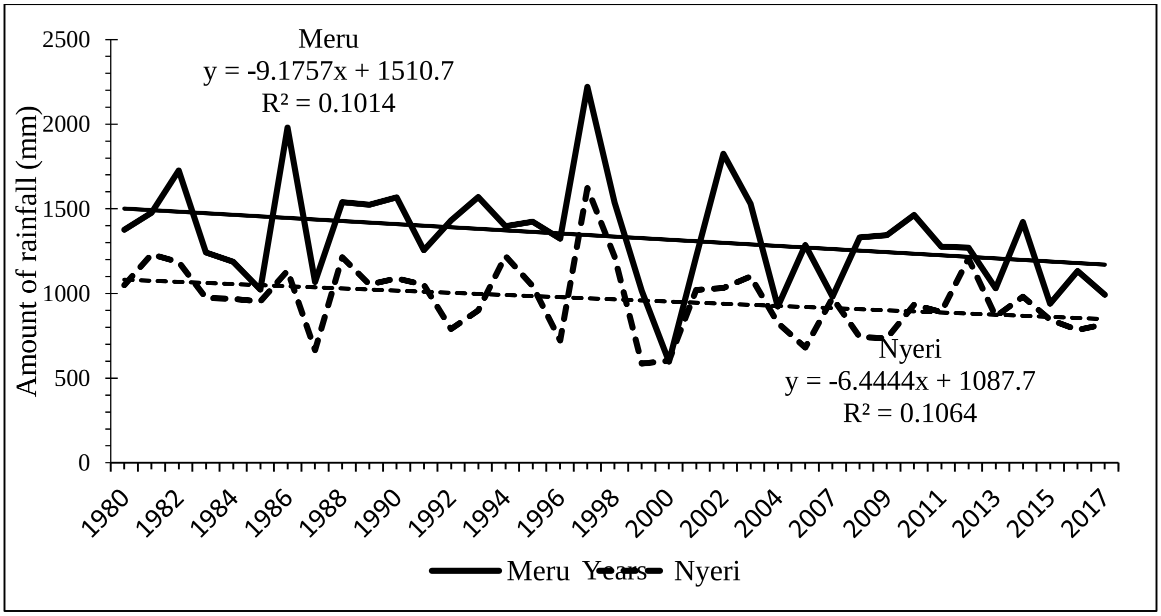

Figure 4.3: Time series of annual Rainfall data for Meru (Imenti South Sub-county) and Nyeri (Mukurweini Sub-county) and their linear trend lines.

4.4.3 Banana Production in the Study Region between the Period 1980-2017

Banana farming in the study region was primarily for income generation (53.0%) and provision of food (47.0%) as shown in Table 4.5. In Imenti South and Mukurweini Sub counties, bananas were mainly grown for income generation. This is supported by Stephen, Jorge, John and Simon (2015) (2015) and MOA (2016) found that banana serves as food security and rural income for the small holders. Income from banana was used towards paying school fees; catering for medical expenses etc. and therefore variation on production or market price have a serious effect on farmer's livelihood.

Table 4.5: Significance of banana production in the study regions

Location	Income	Food	Total
Mukurweini	66(50.8%)	64(49.2%)	130(100%)
Imenti South	135(53.8%)	116 (46.2%)	251(100%)
Total	**201(53.0%)**	**180(47.0%)**	**381(100%)**

Farmers' response regarding seasonality of banana production is shown in Figure 4.4. Majority of the respondents in Mukurweini Sub-county reported that banana production was highest during the April-June quarter (41.2%) while in Imenti South Sub-County the production was at highest in (Jan-March) (43.6%) quarter. A great number of the respondents (63.0%) in Mukurweini Sub-County indicated that low banana production period was January to March while majority of respondents in Imenti South Sub-County (54.2%) identified July-September as the period when banana production was at lowest. Banana farming within the study region comprised of irrigation, rainfed and a combination of irrigation and rainfed systems. From the study it was realized that the method of banana farming in the region was mainly through combination of irrigation and rainfed (45.4%) production system (Table 4.6).

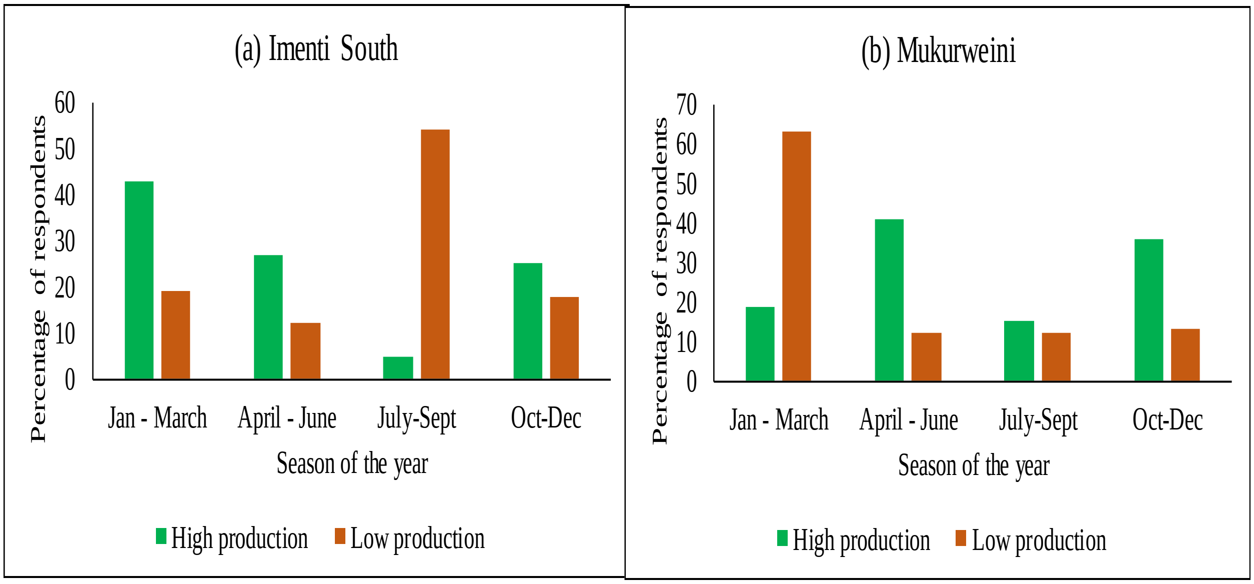

Figure 4.4: Seasonality of banana production as reported by farmers in the study region

Majority of the farmers in Mukurweini Sub-County practiced banana production by rainfed system (95.4%), while in Imenti South sub county farmers practiced both irrigation and rainfed system (67.7%). This is supported by studies conducted by MOA (2016) which found that most farmers in Meru County irrigated their banana stems due to availability of water and this was much more in the drier parts of Imenti South such as Mitunguu which lies in the lowland side of the Sub County.

Table 4.6: System of banana production in the study locations

Location	Proportion of farmers practicing banana production			
	Rainfed	Irrigation	Rainfed and Irrigation	Total
Mukurweini	124(95.4%)	3(2.3%)	3(2.3%)	130(100%)
Imenti South	34(13.5%)	47(18.7%)	170(67.7%)	251(100%)
Total	**158(41.5%)**	**50(13.1%)**	**173(45.4%)**	**381(100%)**

4.4.4 Effect of Rainfall and Temperature on Banana yields (2009-2017)

To evaluate the effect of climatic variables on banana production, rainfall and temperature data was reduced to a single annual value while the productivity data was calculated in form of production per acreage for the study period (2009-2017). Production data for previous years (1980-2008) was not available for the study area. Banana production is an all-year round enterprise in the study areas while the quantity of banana produced varied depending on the period of the year. In Imenti south, banana production increased as rainfall decreased from 2009 until 2013 when rainfall reached 1500mm (Figure 4.5a).

These findings concur with Rodomiro (2012) who found that climate variability may affect banana and plantain yields. Studies conducted in some of the Feed the Future (FtF) countries revealed that drought stress is either the most important or the second most important constraint in banana production in the region (Van Asten, Fermont & Taulya, 2011). The reduction in banana yields as a result of long periods of water stress, hence low soil moisture and extended exposure to extreme temperatures (above 28^0C). Meanwhile, highland bananas are projected to observe significant yield loss due to increased risk of pest and diseases if the temperature increases by 2^0C (Thornton & Cramer, 2012).

From 2015 the production increased as rainfall decreased perhaps due to irrigation input. An exceptional trend was noted in the year 2014 when banana production increased and rainfall decreased. In Mukurweini Sub-County the annual banana production was steady with amount of rainfall.

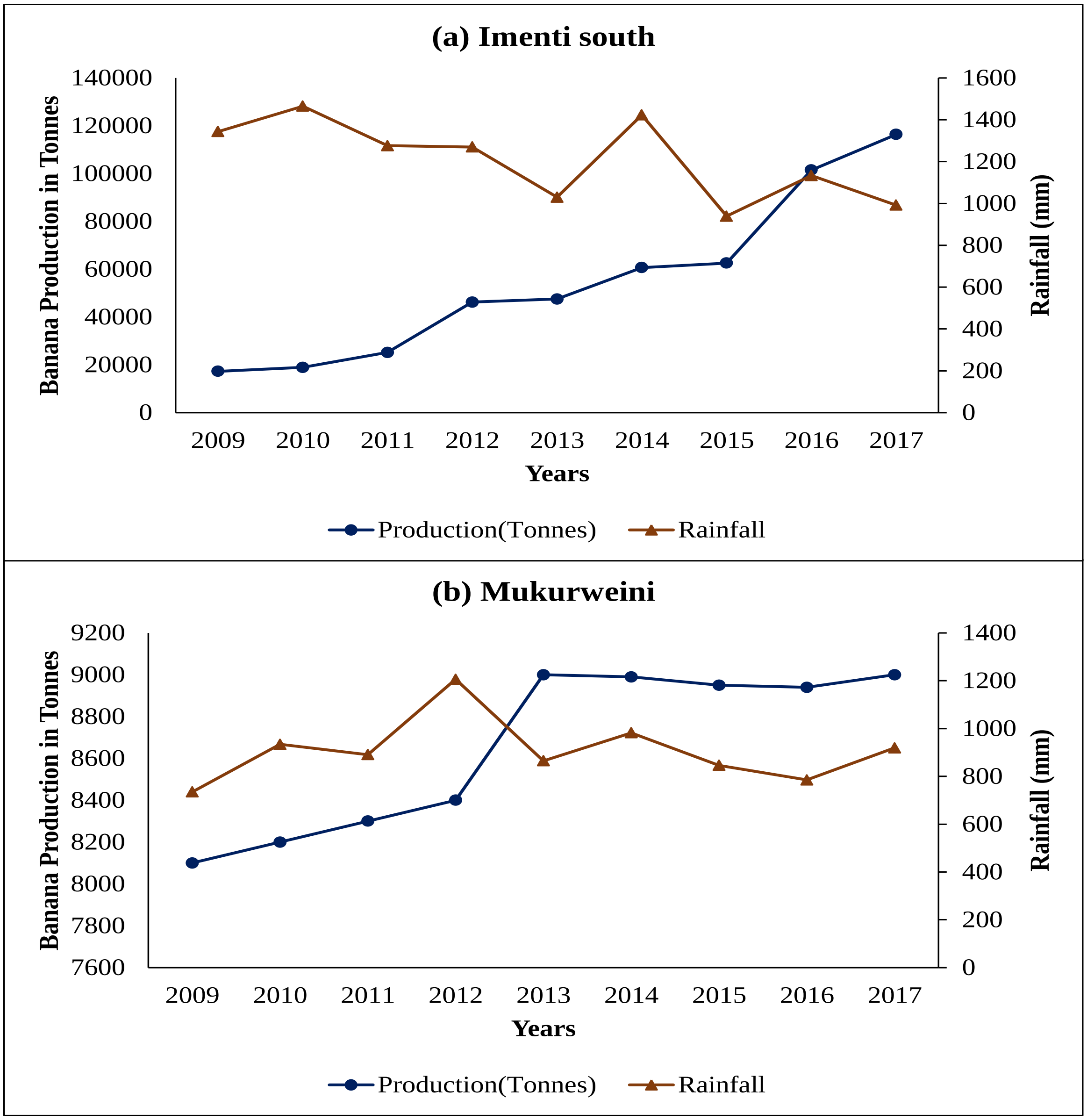

Figure 4.5: Time series of banana production and Rainfall trends (a) Imenti South and (b) Mukurweini sub counties for the period 2009-2017

Figure 4.5(b) reveals that in year 2012 as the rainfall increased the banana production dropped while in the year 2013 the production rose slightly as rainfall dropped which was a unique observation. Rainfall amount does not necessary translate to high production. This is supported by Opeyemi, Marvelous, Oluwatosin and Rufus (2016) who found that strong wind destroys the banana stool, resulting to an overall reduction in the banana productivity. This inter-annual unpredictability in precipitation is already having negative consequences on rural livelihoods due to reduced crop productivity.

Figure 4.6 (a) shows banana production trends in relation to temperature in Imenti South Sub County. In the year 2009, the temperature recorded was highest at 18.7^0C which corresponded to lowest banana production. From the year 2012 to 2015, as the temperature dropped, banana production increased. In Mukurweini Sub-County, as temperature decreased there was corresponding increase in banana production from 2009 to 2012 while increase in temperature led to decrease in production from 2012-2015 as shown in Figure 4.6 (b).

The decrease in production with decrease in rainfall has been supported by National Climate Change Action Plan 2013-2017, (GOK, 2013) which noted that changes in precipitation patterns are likely to directly increase short-term crop failures and long-term production declines for rain-fed agriculture.

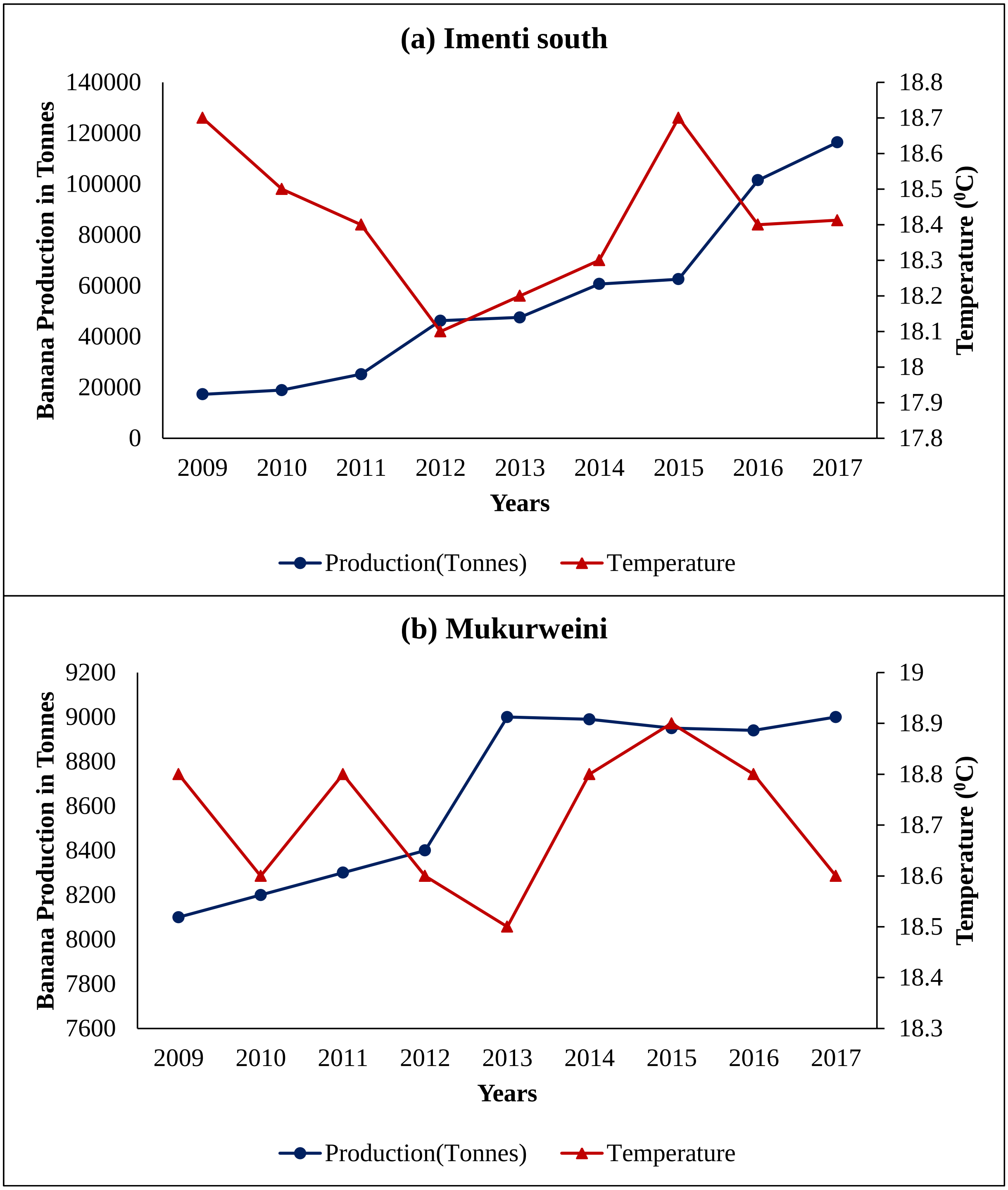

Figure 4.6: Time series of banana production and Temperature trends (a) Imenti South and (b) Mukurweini sub counties for the period 2009-2017

4.4.5 Seasonal Variations of Climate (Temperature and Rainfall) and its Effects on Banana Production

The rainfall data was further analysed based on two main seasons comprising of short rains from October to December (OND) and long rains from March to May (MAM). In Imenti South, the OND season recorded the highest amounts of rainfall except in the year 1981, 1985, 1998 and 2010 (Figure 4.7a). In the year 1986 and 1997, the highest amount of rainfall recorded was 435 and 534mm respectively during the season. The lowest rainfall amount recorded during the OND was in the year 2000 of about 40mm. The MAM season received the highest rainfall totals during the study period in Imenti south. Mukurweini Sub-County seasonal time series indicated that MAM received the highest amount of rainfall during the entire period of study except in the year 1984, 2009, 2011 and 2015 (Figure 4.7b). In 1997 (*El nino*), the highest amount of rainfall was recorded during OND season during the entire period of study of about 329mm.

The year 2005 Mukurweini Sub County received the lowest amount of rainfall during OND. This is contrary to KNCCAP report (2013-2017), which noted a decline in annual rainfall trends during the long rains season that extend from March to May (MAM) (GOK, 2013). This is supported by Ericksen *et al.*, (2011) who documented that high temperatures directly reduce yields of desirable crops in the long-term. He further gave example of the South West Kenya where temperature decrease has potential of reducing the number of suitable crops in the area. Peng, Sivasithamparam and Turner (1999), further notes that *Fusarium wilt* severity is positively correlated with soil temperature leading to decline in yields during dry spell. He further observed that temperature increase from 24 to 34 °C significantly increased disease severity in a pot experimental with banana plants. High soil temperature allows the spread of banana disease in the soil hence affecting the banana production. Land that persisted on banana production for more than 10 years before abandonment had more disease losses (Mazzola, 2002).

Controlling soil temperature for banana is difficult due to its perennial growth and large land coverage. Unlike short-season crops, whose growing season can be shifted to align with optimum seasonal temperature, banana is cultivated year-round. Soil temperature can be reduced by shading, with a denser planting or cultivation of ground cover (Ryan & Paul, 2018). Opeyemi *et al.* (2016) further noted that, low rainfall, excessive rainfall and low temperature or very high temperature affect the productivity level of banana as banana tends to produce less under these climatic conditions in a study conducted in Ondo State, Nigeria. Pests such as aphids (which are virus vectors), flower thrips, and mites may increase their damage in the host plants during dry spell hence reducing productivity (Rodomiro, 2012).

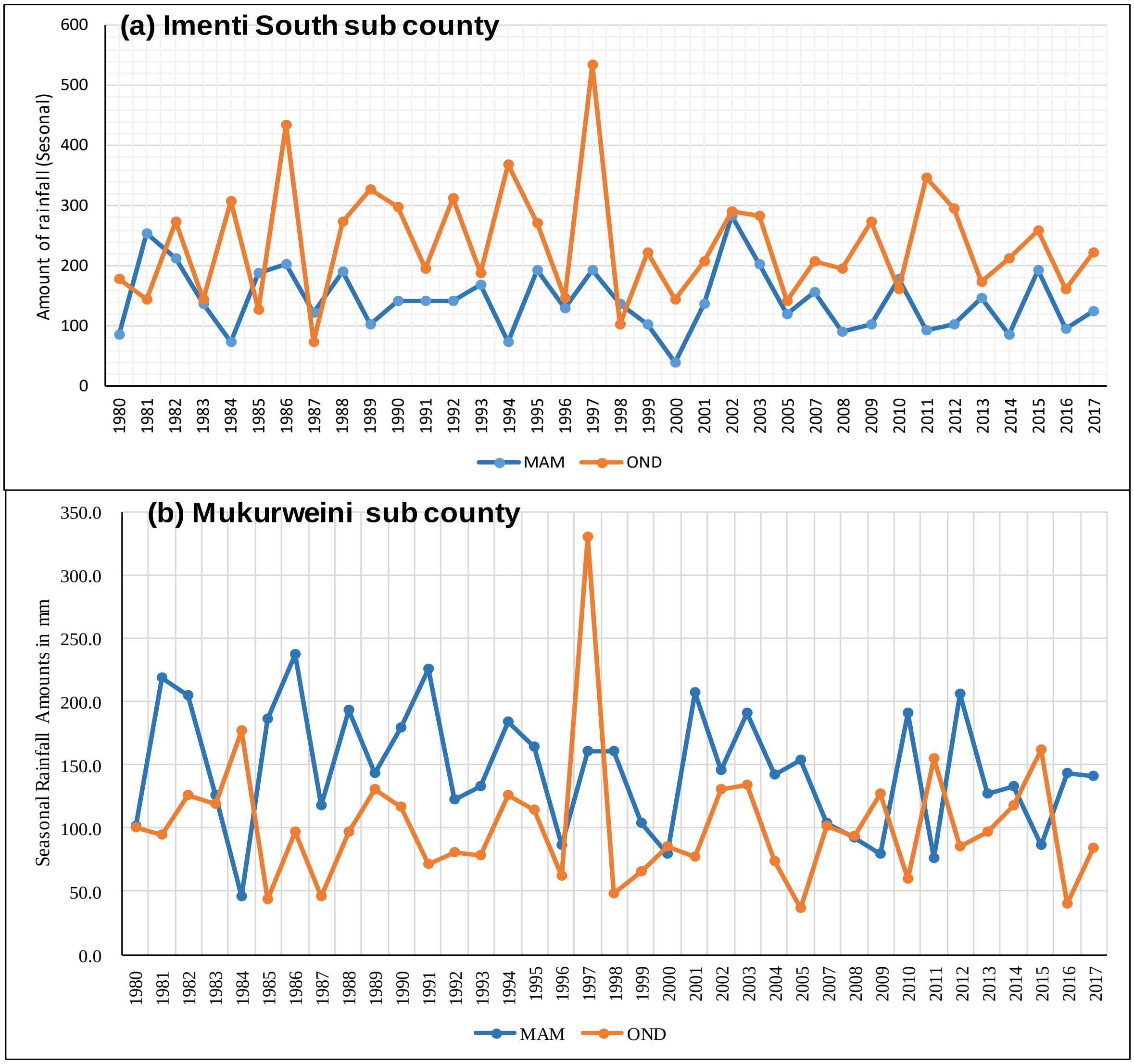

Figure 4.7: Time series of Seasonal Rainfall (mm) data for (a) Imenti south and (b) Mukurweini Sub-County (1980-2017)

4.4.6 Other Factors Affecting Banana Production in the Region

The study also revealed that apart from temperature and rainfall parameters, there were other factors that influenced banana production. These included land use changes, soil fertility, pests and diseases, fluctuating labour costs and soil water retention. Approximately (73.2%) of the total respondents specified that soil fertility had an antagonistic effect on banana yields (Table 4.7) while soil water retention (18.6%) was the second most important factor affecting banana production in the region. This concurs with studies conducted by Van Asten *et al*., (2011) which suggested that soil nutrient deficiencies, poor/inefficient nutrient cycling and retention of adequate soil moisture is a major obstacle to enhancing banana production. Sustainable increase in banana productivity is directly related to crop nutrient requirements.

Table 4.7: Other factors affecting banana production in the study areas

Location sub county	Water retention in the soil	Soil fertility	Labour costs	Pest and diseases infestation	Total
Mukurweini	7(5.4%)	115(88.5%)	3(2.3%)	5(3.8%)	130(100%)
Imenti South	64(25.5%)	164(65.3%)	6(2.4%)	17(6.8%)	251(100%)
Total	**71(18.6%)**	**279(73.2%)**	**9(2.4%)**	**22(5.8%)**	**381(100%)**

Water retention is related to rainfall amount and temperature levels and therefore could explain why it was an important factor in banana production. However, from the study findings, labour costs were well managed and therefore did not have a significant effect of banana production (2.4%).

The study findings also revealed that land area under banana production increased during the period under study as farmers opted to convert most of their crop land to banana production. It was reported that the trends of banana production have been changing since 1990 in the study region (Table 4.8). Majority of the respondents (42.8%) in the study region admitted to have changed the land use and type of crops they have been farming in the last 27 years with the highest number of respondents recorded in Imenti Sub County at (53.7%). This can be explained by Wambugu and Kiome (2001), who noted many smallholder farmers who depended on the cash income generated from banana sales had to change to other crops, due to the declining incomes from traditional cash crops such as coffee. Out of those who reported changes in land use, 20% had changed from coffee farming to other crops, 4.7% changed from banana farming to others crops whereas 30% changed from other crops to banana farming with only 0.8% changing to coffee farming. Majority of respondents (40.2%) changed to banana farming in Imenti South Sub-County and 9.2% from Mukurweini Sub-County. This concurs with GOK (2014) which found that 47% of the total households in Meru County had changed crops grown as a response to climate variability. Some respondents preferred farming food crops mainly beans and maize with 2.4% and 5.5% respectively in the study areas.

Farmers prefer banana as source of steady income and food for the household due to its perennial nature, the possibility of year-round harvest, and the fact that banana yield can be obtained without purchased inputs making it a typical security crop in the local context. This is supported by studies conducted by Dubois, Coyne, Kahangi, Turoop and Nsubuga (2006); Kahangi, (2010); Njuguna, Wambugu, Acharya and Mackey (2010) who noted that strong fluctuations in coffee and tea prices led to banana popularity as a cash crop in some regions. This was further observed by Oxford Business Group (2014) which noted that coffee production slumped because of a variety of factors that adversely impacted growers, including unpredictable global prices, erratic weather, expensive farm inputs, payment delays and poor sector management.

Table 4.8: Proportion of land use change under Banana production in relation to other crops in the study region (2000-2010). Values in parentheses are the percentages

Study Location	Changed from						Changed to					
	No Changed	**Banana**	**Beans**	**Coffee**	**Maize**	**Others**	**Total changed**	**Banana**	**Beans**	**Coffee**	**Maize**	**Others**
Mukurweini	102 (78.5%)	3 (2.3%)	2 (1.5%)	8 (6.2%)	7 (5.4%)	8 (6.2%)	28 (22%)	12 (9.2%)	0 (0%)	1 (0.8%)	8 (6.2%)	7 (5.4%)
Imenti South	115 (45.8%)	15 (5.9%)	11 (4.4%)	68 (27.1%)	26 (10.3%)	15 (5.9%)	135 (53.7%)	101 (40.2%)	(3.6%)	2 (0.8%)	13 (5.2%)	10 (4.0%)
Total	**217 (57.0%)**	**18 (4.7%)**	**13 (3.4%)**	**76 (20.0%)**	**33 (8.7%)**	**23 (6.0%)**	**163 (42.8%)**	**113 (30.0%)**	**9 (2.4%)**	**3 (0.8%)**	**21 (5.5%)**	**17 (4.5%)**

4.4.7 Effects of Rainfall variability on Transportation of Banana Produce

Rainfall variability had profound effects on banana transportation from the farm to the collection point whether at farm gate or at the market. The study revealed that there exist a significant association between rainfall and banana transport in the study location (X^2=7.89 p=0.001) (Table 4.9).

Table 4.9: Chi square tabulation for variables affecting banana value chain

Variable	X^2	p-Value
System of banana production	236.63	0.001*
Crop change	36.35	0.001*
Effect on banana production	17.4	0.004*
Effect on banana transport	7.89	0.019*
Effect on banana trading	1.19	0.55
Mode of transport	26.63	0.001*
Post handling and value addition strategies	28.73	0.001*
Reasons for value addition	36.43	0.001*
Highest banana production season	50.85	0.001*
Mode of infrastructures	22.94	0.001*
Climate variability perception	29.87	0.001*
Mode of infrastructure	22.94	0.001*
Understanding of the climate variability	29.87	0.001*

N = 381, * Significant at 5%

Majority of the respondents (52.3%) in Mukurweini Sub County and (45.0%) in Imenti South Sub county reported that high cost of transport was the main effect of climate variability during rainy seasons (Figure 4.8). This affirms findings of other studies on rural areas in Kenya by Wambugu (2005); Mwithirwa (2010). Miriti, Wamue, Masiga, and Murithi, (2013) who noted that rural areas in Kenya have poor roads network. Mwithirwa (2010) found out that 95 % of the traders used poorly maintained dry weather roads to access major buying areas. Miriti *et al*., (2013) in their study in Meru reported that bad rural road was the main constraint (highest ranked) facing banana farmers in the area.

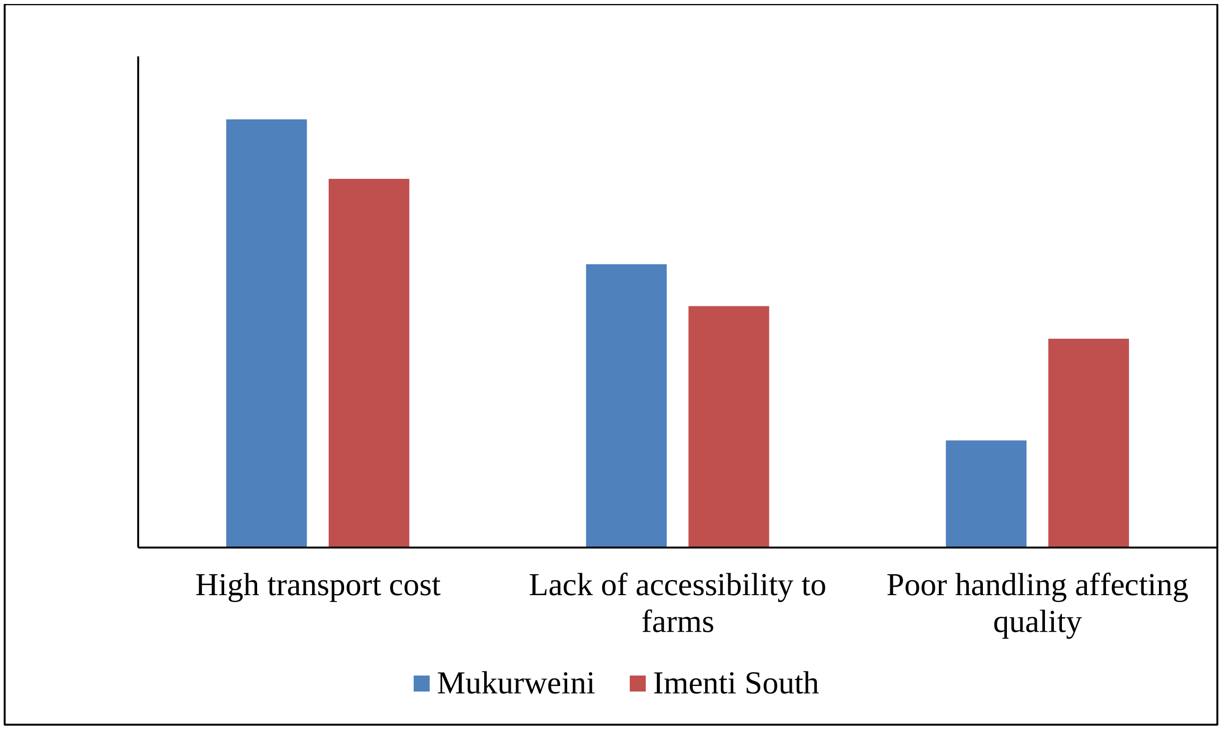

Figure 4.8: Effects of rainfall variability on banana transport

About 34.6% and 29.5% of the respondents in Mukurweini and Imenti south Sub Counties respectively, cited inaccessibility to the farm during the same period as the subsequent most significant consequence of climate variability in the study region. This could be explained by the nature of the feeder roads to the farm which are mostly earth roads and may have affected the other facets of banana value chain. Due to the high transport cost and inaccessibility of farms, the study revealed that farmers opted for alternative methods of transport as analysed in Table 4. 10.

In reference to Table 4.10, most of the participants in the study region (51.4%) indicated that they preferred to use motorcycles commonly referred to as "*boda boda"* as means of transporting bananas to the collection point or market centers. In Mukurweini Sub County, farmers preferred human labour (43.1%) while Imenti South sub county they preferred motorcycle (55.8%).

Table 4.10: Mode of transport from farm to the selling/collection points/Market on region. Values in parentheses are the percentages

Study location	Human labour	Hand carts	Donkeys /cow carts	Motor cycles	Pickups	Lorries	Total
Mukurweini	56 (43.1%)	0 (0%)	2 (2%)	56 (43.1%)	13 (10.0%)	3 (2.3%)	130 (100%)
Imenti South	51 (20.3%)	5 (2.0%)	8 (3.2%)	140 (55.8%)	27 (10.8%)	19 (7.6%)	251 (100%)
Total	106 (27.8%)	4 (1.3%)	10 (26.3%)	196 (51.4%)	40 (10.5%)	22 (5.8%)	381 (100%)

During the study period it was observed that greatest number of the banana collection centers were located along the main roads and this could have been a strategy due to the challenges associated with climate variability on farm accessibility. These modes of transport lead to post handling losses. This supported by Technoserve (2004) that observed poor handling of the produce lead to physical injury inflicted on the fruits at all levels of the chain leading to high post-harvest losses of about 40%. Poor handling during ripening can significantly reduce green life and shelf life which is 5–10 days after harvest. Strategies such as appropriate transportation and proper storage for limiting post-harvest losses are not readily available and, where they are, access might not be equitable due to social differentiation (Hailu, Workneh & Belew, 2013).

Distance from the farms to collection centers or market was tabulated as shown in Table 4.11. The study further revealed that majority of the participants (63.8%) transported banana for a distance of less than 5km from their farms to market while 2.4%, transport bananas for more than 20km to the market.

Table 4.11: Distance in Kilometers from the farms to the nearest market

Location	Less than 5km	5-10 km	10 - 20 km	Over 20 km	Total
Mukurweini	75(58.6%)	42(32.8%)	9(7%)	2(1.6%)	128(100%)
Imenti south	166(66.4%)	43(17.2%)	34(13.6%)	7(2.8%)	251(100%)
Total	**241(63.8%)**	**85(22.4%)**	**43(11.4%)**	**9(2.4%)**	**378(100%)**

In Mukurweini, 58.6% of the respondents and 66.4% in Imenti South Sub County transport of banana was within a distance of less than 5km respectively. The most popular banana market in Imenti South Sub County included Kanyakine and Ntharene market while in Mukurweini, Ichamara and Mihuti were the preferred market centers. All banana markets in the study regions were located adjacent to tarmac road for easy accessibility. Only 1.6% and 2.8% of the farmers in Mukurweini and Imenti South Sub Counties transported bananas to the market a distance of more than 20km respectively.

The study further found that most of the roads in the region were all season roads at 70% and 44.2% in Mukurweini and Imenti south Sub counties respectively (Figure 4.9), though major roads were poorly maintained and only partially accessible during the rainy seasons. Majority of the respondents (28.3%) who accessed banana markets through tarmac roads were from Imenti South Sub County. The seasonal roads were the feeder roads to the farms which were inaccessible during the wet seasons and prompted the farmers to use alternative means of transport as shown in Table 4.10. MOA (2016) noted that modern markets have been set up within the banana producing areas such as Kanyakine where buyers from far urban areas come to buy the bananas immediately after they are harvested.

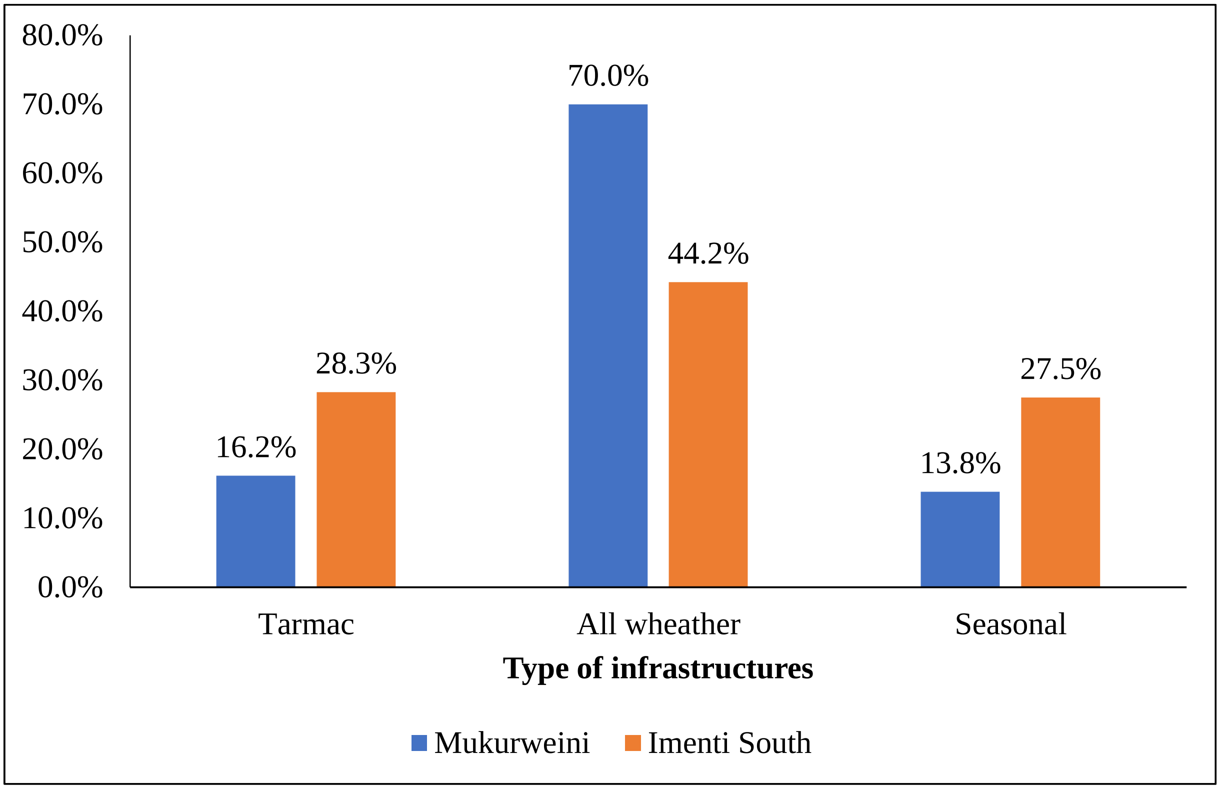

Figure 4.9: Types of road infrastructure from farm to the market center/collection point

Farmers reported that the County government had establishing banana collection centers but for political support. They gave an example of Mitunguu market where farmers refused and demonstrated against the establishment of banana market. They argued farm gate price is higher than market since the farmer has higher bargaining power as compared to taking the produce to market and waiting for middlemen and traders to dictate the price. There is need to involve farmers on issues concerning banana production. Community participation on matters concerning banana production is paramount.

4.4.8 Effects of Climate Variability on Post-Harvest handling and Value Addition of Banana

Post-harvest handling technologies adopted by respondents included cleaning of banana after harvest and packaging while processing and value addition technologies were ripening, processing flour, crisps and wine juice production.

Table 4.12: Strategies of banana post-harvest handling and value addition of banana adopted by farmers

Location	Post-harvest handling		Value addition (Processing)				
	Cleaning	Packaging	Ripening	Flour	Crisps	Wine juice	Total
Mukurweini	32 (24.6%)	25 (19.2%)	59 (45.3%)	11 (8.5%)	1 (0.7%)	2 (1.5%)	130 (100%)
Imenti South	153 (60.9%)	66 (26.3%)	25 (10.0%)	1 (0.4%)	1 (0.4%)	5 (2.0%)	251 (100%)
Total	**185 (48.6%)**	**91 (23.9%)**	**57 (22.0%)**	**12 (3.1%)**	**2 (0.5%)**	**2 (0.5%)**	**381 (100%)**

Majority of the respondents cited cleaning (48.6%) as the main strategy of banana post handling activity in the study region and which was associated with high prices (Table 4.12). This was applicable for the produce that was being transported to urban centers. In Mukurweini Sub County, farmers preferred ripening (45.3%) followed by cleaning (24.6%) while in Imenti Sub County they preferred cleaning (60.9%) followed by packaging in crates and sacks (26.3%). Processing of the banana fruits to high value products was limited in the study region. However, few farmers engaged in producing flour (3.1%), crisps and wine juice (0.5%) as processing strategies for value addition (Table 4.12). This concurs with MOA (2016) which observed that processing facilities in Meru County were limited thus ripening the banana at the farm level was aimed to increase the market demand and its shelf life while cleaning the fruits was aimed at making the fruit more appealing to consumers.

Farmers adopted value addition of bananas in order to increase market quality (42.3%), thus fetching high market prices. Cleaning would give the produce appealing state making the fruit more demanded hence fetching high market prices while ripening and value addition of the banana increased the shelf life. This concurs with MOA (2016) who noted that value addition helps the small holders' farmers to earn more from their products. Nevertheless, most of the commodities produced in the Meru County are sold in raw form, without any value addition thus fetching low prices (MOA, 2016).

In Mukurweini Sub-County the need of value addition was to achieve high market demands (42.3%) while in Imenti South County was to enhance market quality (51.0%) (Figure 4.10). Mbuthia (2018) in her studies noted that banana value addition could prolong the shelf life of bananas, create more jobs in the sector and enhance domestic and international marketing.

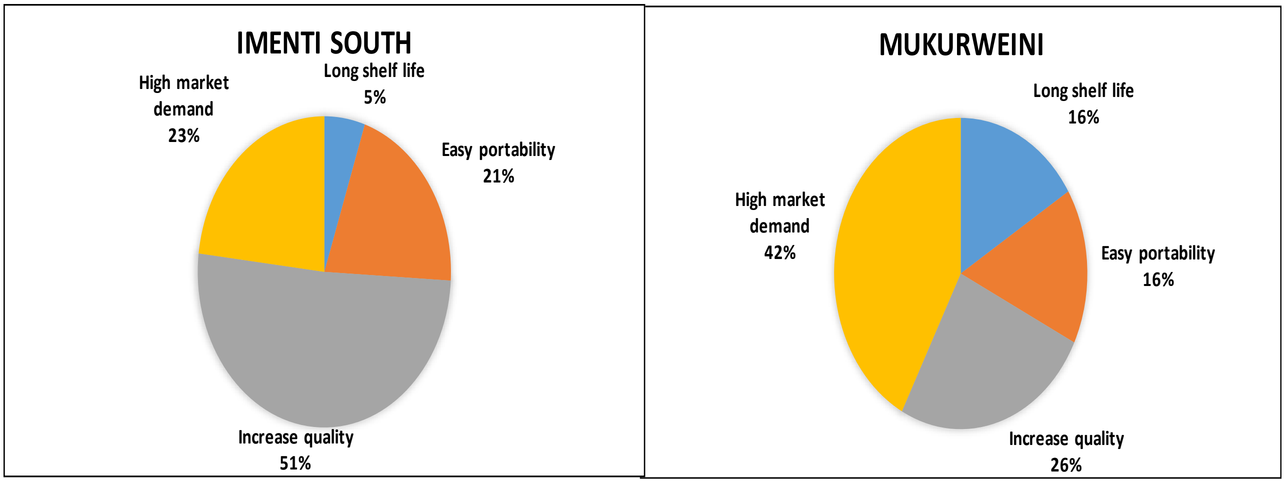

Figure 4.10: Reasons of banana value addition by farmers

4.4.9 Effects of Climate Variability on Banana Marketing and Trading

The findings identified that different weather seasons had substantial effect on banana trading (Table 4.13). The consequences of climate variability on banana market were identified as variations on market demands, market prices and variation in produce quality depending on seasons.

Table 4.13: Effects of climate variability on banana trading

	Rainy season				Dry season			
Study Location	Low market demands	Poor quality of produce	Low market prices	Total	Market demands	Low market prices	Low quality of produce	Total
Mukurweini	32 (24.6%)	32 (24.6%)	66 (50.8%)	130 (100%)	44 (33.8%)	38 (29.3%)	48 (36.9%)	130 (100%)
Imenti South	45 (17.9%)	127 (50.6%)	79 (31.5%)	251 (100%)	105 (41.8%)	31 (12.4%)	115 (45.8%)	251 (100%)
Total	77 (20.2%)	159 (41.7%)	145 (38.1%)	381 (100%)	149 (39.1%)	69 (18.1%)	163 (42.8%)	381 (100%)

Majority of the respondents in Mukurweini Sub-County (50.8%) indicated that during high rainfall season bananas fetched low prices while in Imenti south there was low banana quality at 50.6% (Table 4.13). During the dry season, respondents indicated that bananas were of low quality in Mukurweini (36.9%) while in Imenti South Sub County 45.8% reported that bananas were of small sizes usually referred to as "***seketas***". The bananas quality is determined by the finger size, bunch firmness, and the level of damage as a result of pest and diseases infestation or presence of physical injury resulting from poor handling of the produce (Niven, Reardo, Chege, Odera, Weatherspoon & Mwaura, 2005).

Respondents in Imenti South (41.8%) reported that the market demand for banana is usually very high. High rainfall and low temperatures delays ripening of the banana fruits whereas during cold season there is low consumption of banana thus there is increased rotting during ripening period due to low temperatures. During dry season the banana supply in the market is low in Mukurweini Sub-County due to overdependence on rainfed production. In Imenti south sub-County the supply was of low quantity due to water shortage for irrigation. Prices soar during periods of low production, particularly in the dry spell, when only few farmers have bananas to sell. Other reasons cited as affecting marketing of banana were lack of appropriate information on banana markets.

However, 67.7% of the respondents in the study area had access to market information. The study found that majority of farmers had to access market information at 60.0% and 71.7% in Mukurweini and Imenti south Sub Counties respectively and they were using the information to make trading decisions primarily on banana prices (Table 4.13). Out of those who had access to market information, 51.2% accessed through calling brokers followed by calling other farmers (38.0%) in the study area. In Mukurweini Sub County, 48.7% accessed information through calling brokers followed by calling other farmers (38.5%) while in Imenti South Sub County majority of the respondents opted calling brokers (52.2%) followed by calling other farmers (37.8%). This concurs with Ndubi, Ouma and Murithi (2000) observed that farmers obtain market information by visiting banana market and calling middlemen. Middlemen control banana supply network within Kenya (Niven *et al.*, 2005). For the respondents who accessed market information, indicated they used the information in making decisions concerning banana trading, 87.2% and 73.3% in Mukurweini and Imenti South respectively (Table 4.14).

Table 4.14: Mode of access and use of market information in banana trade in the study region

Study Location	Access to market inform		Mode of Access	Frequency	Use of market information	
Mukurweini	Yes	78(60.0%)	Calling other farmers	30(38.5%)	Yes	68(87.2%)
			Calling brokers	38(48.7%)	No	10(12.8%)
			Radios	4(5.1%)		
			Cellphones	6(7.7%)		
	No	52(40'0%)				
Imenti South	Yes	180(71.71%)	Calling other farmers	68(37.8%)	Yes	132(73.3%)
			Calling brokers	94(52.2%)	No	48(26.7%)
			Radios	7(3.9%)		
			Cellphones	11(6.1%)		
	No	71(28.28%)				
Total		**381(100%)**		**258 (67.7%)**		

Values in parentheses are the percentages

4.4.10 Hypothesis Testing One

H_o. There is no significant relationship between rainfall changes and banana transport in Mt Kenya region. The hypothesis was tested at p=0.05, Rainfall trend line showed that Mukurweini sub-County had R^2=0.1064 indicating there was a change of about 10.64% while in Imenti South sub-County the trend line indicated an R^2 of 0.1014 translating to 10.14% (Figure 4.3). The trend line showed negative slope (-9.1757 and -6.4444 for Imenti South and Mukurweini Sub counties respectively). On effects of changing climate on banana value chain, the study established that, there exist a significant association on the effect of rainfall variability on banana farming and study location at (X^2=17.4, p=0.004) (Table 4.9). This shows there exist a significant association on the effect of rainfall variability on banana transport and study location (X^2=7.895, p=0.001) within Mt Kenya region (Table 4.9). This shows that there was significant relationship amid banana value chain and rainfall variability risks in the study area. The study therefore rejects the null hypothesis and adopts the alternate hypothesis that there exists relationship between rainfall changes and banana transport.

4.5 Farmers' Perception of Climate Variability and its Effects on Banana Production

The study sought to establish farmers understand of climate variability and factors that influence farmer's perception to climate variability. The climate variables under consideration were rainfall and temperature and more specifically rainfall amounts and patterns, temperature fluctuations, drought frequency and soil water availability.

4.5.1 Farmers' Understanding of Climate Variability

To establish the observed change in rainfall or temperature in the last 20 years, the respondents were required to specify if they had observed any changes in precipitation level or temperature (Table 4.15). Majority of the respondents (79%) had observed changes in rainfall amounts and temperature levels while only 21% stated they had not observed any changes in the past 20 years (Table 4.15), this contends with a study conducted by Shankara, Shivamurthy and Kumar (2013) which found that the majority of the small holder farmers had high levels of perception to climate variability in the study conducted in North Indian.

The study further sort to evaluate farmers' understanding of climate variability as shown in Table 4.15. Majority of the farmers in Mt. Kenya region viewed climate variability as unpredictable rainfall (64.6%) followed by low rainfall (18.6%). In both Mukurweini and Imenti South sub–counties, the study revealed that respondents understood climate variability as unpredictable rainfall (53.5%) and (70. 1%) respectively (Table 4.15). The respondents understanding of climate variability was based on rainfall unpredictability.

Table 4.15: Respondents' perspectives on climate variables in the study area (Mukurweini and Imenti south sub counties). Values in parentheses are the percentages

Variable	Specific variable	Mukurweini (N=130)	Imenti South (N=251)	Total (N=381)
Observed climate variability	Yes	102(78.5%)	199(79.3%)	301(79.0%)
	No	28 (21.5%)	52 (20.7%)	52(21.0%)
Farmers understanding of climate variability	Unpredictable rainfall	70 (53.5%)	176 (70.1%)	246 64.6%)
	High temperatures	8 (6.1%)	26 (10.4%)	34 (8.9%)
	Low rainfall	37 (28.4%)	34 (13.6%)	71(18.6%)
	Low temperature	1 (1.0%)	9 (3.6%)	10(2.6 %)
	Drought	14 (10.0%)	30 (12%)	44(11.6%)

The effect of climate variation on banana production was analyzed based on farmer's perception on several parameters including scarcity of irrigation water, changes in planting days, labour cost, reduced yields, delayed harvest and pest and disease infestations. Majority of the respondents in the study area perceived effects of climate variability on banana production as low yields (79.2%) in Mukurweini and 60. 2% and Imenti South sub counties respectively (Table 4.16). Labour cost effects on banana production in the study area was lowest at 1.1% from the respondent's perception. Water shortages was cited as the second most significant effect of climate variability in the study area (16.5%) (Table 4.16). This concurs with finding by Umesh, (2015) who observed that climate variability is anticipated to intensification temperature events and decrease precipitation in East Africa leading to reduced yields. The studies are further supported by MOA (2016) who observed increase in unpredictability of rainfall and temperature variability in Meru County.

Table 4.16: Respondents' perception of climate variability effects banana farming

	Mukurweini	Imenti South	Total
Water shortage	15(11.5%)	48 (19.1%)	63 (16.5%)
Change in planting season	7 (5.4%)	15 (6.0%)	22 (5.8%)
High labour cost	1 (1.0%)	3 (1.2%)	4 (1.1%)
Low yields	103 (79.2%)	151 (60.2%)	254 (66.7%)
Delay in harvesting	2 (1.5%)	22 (8.8%)	24 (6.3%)
Pest and diseases infection	2 (1.5%)	12 (4.9%)	14 (3.7%)
Total	130 (100%)	251 (100%)	381 (100%)

4.5.2 Socio-economic Aspects Influencing Farmer's Perception on Climate Variability

The respondent's awareness to climate variability usually is a function of individual household characteristics (i.e., gender of house hold head (HHH), age group of HHH, level of education, land size, type of farming, land under banana production, farming system, access to market information, group membership, access to financial assistance, access to extension services and land ownership.

4.5.2.1 Socio-economic Factors Influencing Farmers' Perception on Climate Variability in Mukurweini Sub-County

Results of univariate analysis of socio-economic factors influencing farmers' perception on climate variability showed that the type of farming system was significant in elucidating farmers' perception of climate variability on banana production (Table 4.17). Whereas other aspects of the households namely the level of education and age of the household did not significantly affect farmers' perception in the study area while studies conducted in other places, reported those as being significant factors (Deressa *et al*., 2009). Several studies such as Mertz *et al*., (2009); Below *et al*., (2012) and Maddison (2007) have indicated that the level of education, gender, age, and wealth of the head of household; access to meteorological information, social capital, agro ecological settings, influence farmers' perceptions and decisions regarding climate variability.

Table 4.17: Socio-economic factors influencing farmer's perception on climate variability in Mukurweini sub-county

Social economic characteristic		Not Perceived Climate variability	Perceived Climate variability	Total	X^2 P Value
Gender of the HHH¶	Male	12(21.1%)	45(78.9%)	57(100%)	Ns
	Female	16(21.9%)	57(78.1%)	73(100%)	
Level of education	No formal education	4(40%)	6(60%)	10(100%)	Ns
	Primary	12(22.6%)	41(77.4%)	53(100%)	
	Secondary	9(15.8%)	48(84.2%)	57(100%)	
	Tertiary	4(40%)	6(60%)	10(100%)	
Age group	Less than 20 years	0 (0%)	1 (100.0%)	1(100%)	Ns
	21 – 30 years	4 (23.5%)	13 (76.5%)	17(100%)	
	31 – 40 years	2 (13.3%)	13 (86.7%)	15(100%)	
	41-50 years	9 (29.0%)	22 (71.0%)	31(100%)	
	51-60 years	6 (18.2%)	27 (81.8%)	33(100%)	
	Over 60 years	13 21.2%)	46 (78.8%)	60(100%)	
Types of farming practice	Subsistence	0 (0%)	3 (100%)	3(100%)	0.028*
	Cash-crop farming	1 (100 %)	0 (0 %)	1(100%)	
	Mixed farming	27 (11.4%)	99(78.6%)	126(100%)	
Membership to farming group	No	25 (21.7%)	90 (78.3%)	115(100%)	Ns
	Yes	3 (20 %)	12 (80%)	15(100%)	
Access to market information	Yes	6(12.5%)	42 (87.5%)	48(100%)	Ns
	No	22 (26.8%)	60 (73.2%)	82(100%)	
System of farming	Rainfed	25 (20.2%)	99 (79.8%)	124(100%)	Ns
	Irrigation	1(33.3%)	2 (66.7%)	3(100%)	
	Rainfed and irrigation	2 (66.7%)	1 (33.3%)	3(100%)	
AEZ⁑	LM	0 (0%)	30 (0%)	0(0%)	Ns
	UM	28 (21.5%)	102(78.5%)	130(100%)	
	LH	0 (0%)	0 (0%)	0 (0%)	
Access to weather information	Yes	16 (18.4%)	71 (81.6%)	87(100%)	Ns
	No	12(27.9%)	31 (72.1%)	43(100%)	
		Mean	**Mean**		**t-test**
Land under banana (ha)		0.60	0.63		Ns
Size of land (ha)		2.20	2.18		Ns
Perception on production		3.54	3.43		Ns

¶ HHH = House Hold Head; ⁑ =AEZ based on Jaetzold *et al*., (2006); N=130, * Significant at 5% probability level; Ns not significant. Numbers in parenthesis indicate the perception in (%). Values in parentheses are the percentages

Multinomial Logit model analysis of socioeconomic factors influencing farmers' perception of climate variability in Mukurweini Sub-County

The findings of the multinomial logit model analysis of farmers' perception of climate variability are tabulated in Table 4.18. The model was significant at p<0.01 and acceptably predicted 83.5% of both those who identified and who never identified changes in rainfall and temperature in the last 20 years in Mukurweini Sub County. Four variables: Gender of HHH, farming systems, type of farming practice and access to weather information were significant in explaining the farmers' perception of climate variability in Mukurweini Sub-county.

Table 4.18: Factors influencing farmers' perception to climate variability in Mukurweini

Socioeconomic Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**-0.321***	0.354	0.725	**0.092**	1.352
Age of HHH	0.034	0.171	0.341	0.860	1.027
Level of education of HHH	0.246	0.247	0.994	0.319	1.279
Farm Land size	0.254	0.139	3.354	0.287	1.289
Access to market information	-0.456	0.722	0.398	0.528	0.634
Farming system	**-0.731****	0.290	4.72	**0.030**	0.532
Group membership	0.494	0.397	1.551	0.213	0.610
Agro-Ecological Zone	-.0720	0.284	0.065	0.799	0.930
Farming practice	**-0.255***	0.528	0.233	**0.099**	1.29
Access to weather information	**0.184****	0.245	0.477	**0.044**	1.185
Land under banana	-0.490	0.289	2.887	0.289	0.612

N=130, ** Significant at 5% probability level, *Significant at 10% probability level

Gender of the household head negatively and significantly (β=-0.321, p=0.092) influenced farmers' perception towards climate variability (Table 4.18). This implies that female headed households who practised banana production identified more with changes in rainfall and temperature than male headed households. The type of farming system negatively (β=-0.731, p=0.03) influenced farmers' perception (Table 4.18). The farmers who depended on rainfed banana production identified themselves more with climate variability as compared to those who used irrigation and combination of rainfed and irrigation on banana production. This concurs with studies conducted in Mt Kenya region (MOA, 2016) that observed that farmers' who wholly depend on rain-fed farming experience serious challenges brought about by climate vagaries. Farming practice negatively and significantly (β=-0.255, p=0.099) influenced farmers' perception. This implies that the subsistence farmers in the study area identified themselves more with climate variability as compared to those who practiced cash crop farming and mixed farming.

Access to weather information positively and significantly (β=0.169, p=0.044), influenced farmer's perception to climate variability. This implies that those who got weather information identified themselves more with variation in rainfall and temperatures as compared to those who didn't have access to weather information. This is supported by Maddison (2007), who identified access to climate data increases farmer perception of climate variability and the accompanying risks.

4.5.2.2 Socio- economic factors influencing farmers' perception on climate variability in Imenti South Sub-County

Results of univariate analysis of socio-economic factors influencing farmers' perception to climate variability in Imenti south showed that type of farming system was significant in explaining farmer's perception to climate variability on banana production (Table 4.19).

Table 4.19: Socio-economic factors influencing farmers' perception on climate variability in Imenti south sub county

Social economic characteristic		Climate variability not identified	Climate variability noted	Total	x^2 P Value
Gender of the HHH	Male	28(22.8%)	95(77.2%)	123(100%)	Ns
	Female	24(18.8%)	104 (81.2%)	128(100%)	
Level of education	No formal education	4(33.3%)	8(66.7%)	12(100%)	Ns
	Primary	29(22.3%)	101(77.7%)	130(100%)	
	Secondary	14(17.1%)	68(82.9%)	82(100%)	
	Tertiary	5(18.5%)	22(81.5%)	27(100%)	
Age group	Less than 20 years	0 (0%)	4 (100.0%)	4(100%)	Ns
	21 – 30 years	3 (14.3%)	18 (85.7%)	21(100%)	
	31 – 40 years	19 (21.8%)	68 (78.2%)	87(100%)	
	41-50 years	15 (19.0%)	64 (81.0%)	79(100%)	
	51-60 years	9 (26.5%)	25 (73.5%)	34(100%)	
	Over 60 years	6 (23.1%)	20 (76.9%)	26(100%)	
Types of farming system	Subsistence	0 (0%)	9 (100%)	9(100%)	0.028
	Cash-crop farming	4(40 %)	6 (60 %)	10(100%)	
	Mixed farming	47 (20.5%)	182(79.5%)	229(100%)	
Membership to farming group	No	38(19.7%)	155(80.3%)	193(100%)	Ns
	Yes	14(25 %)	42 (75%)	56(100%)	
Access to market information	Yes	42(22.7%)	143 (77.3%)	185(100%)	Ns
	No	10(15.2%)	56 (84.8%)	66(100%)	
System of farming	Rainfed	3 (8.8%)	31(91.2%)	34(100%)	Ns
	Irrigation	12(25.5%)	35 (74.5%)	47(100%)	
	Rainfed + irrigation	37 (21.8%)	133 (78.2%)	170(100%)	
AEZ	LM	11 (26.8%)	30 (73.2%)	41(100%)	Ns
	UM	27 (17.5%)	127(82.5%)	154(100%)	
	LH	14 (25%)	42 (75%)	56(100%)	
Access to weather information	Yes	7 (18.9%)	159 (81.1%)	196(100%)	Ns
	No	15(27.3%)	40 (72.7%)	55(100%)	
		Mean	**Mean**		**t-test**
Land under bananas		0.60	0.63		Ns
Size of land		2.20	2.18		Ns
Perception on production		3.54	3.43		Ns

N=130, ** Significant at 5% probability level, *Significant at 10%probability level

Multinomial Logit model analysis of factors influencing farmer's perception on climate variability in Imenti south Sub County

The findings of the Multinomial Logit model are displayed in Table 4.20. The model was significant at $p<0.01$ and correctly predicted 80.5% of both those who identified and those who never identified with fluctuations in rainfall and temperature levels in the last 20 to 30 years in the Imenti Sub County. Five variables: Gender of HHH, Agro-Ecological Zone, type of farming system, access to weather information and acreage under banana production were significant in explaining the farmer's perception of climate variability in Imenti south sub county.

Table 4.20: Factors influencing farmers' perception to climate variability in Imenti South

Socioeconomics Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**-0.301***	0.724	0.626	0.084	1.378
Age of HHH	0.027	0.351	0.031	0.566	1.063
Level of education of HHH	0.384	0.443	0.674	0.212	1.079
Farm Land size	0.574	0.256	2.314	0.267	1.469
Access to market information	-0.525	0.642	0.398	0.528	0.629
Type of farming system	**-0.671****	0.329	2.752	0.042	0.499
Group membership	0.494	0.294	1.231	0.423	0.410
Access to weather information	**0.488****	0.243	4.021	0.049	1.629
Farming practice	0.324	0.489	0.473	0.629	1.290
Agro-Ecological Zone	**0.048***	0.286	0.028	0.068	0.953
Land under banana	**-0.352***	0.483	3.586	0.089	0.756

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

Gender of the household head negatively and significantly (β=-0.301, p=0.084) influenced perception to climate variability in Imenti South Sub-County (Table 4.20). This implies that female headed households who practised banana production identified more with changes in rainfall and temperature than male headed households. This concurs with studies conducted in Meru County by MOA (2016) which observed female are more actively involved in banana production as compared to male headed households.

Land size under banana production of the farmer negatively and significantly (β= -0.352, p=0.089) influenced farmers' perception on climate variability (Table 4.20). As the farmers' land sizes decreased the more the farmers' perception on effects of rainfall and temperature on banana production increased. The type of farming system negatively and significantly (β=-0.671, p=0.042) influenced farmers' perception (Table 4.20). The farmers who depended on rainfed banana production identified themselves more with climate variability as compared to those who used irrigation and combination of rainfed and irrigation on banana production.

Access to weather information positively and significantly (β=0.488, p=0.049), influenced farmers' perception to climate (Table 4.20). This indicated that those who accessed weather information identified themselves more with changes in rainfall and temperatures as compared to those who didn't have access. Agro-Ecological Zone where banana production was being practiced positively (β=0.48, p=0.068) influenced farmer's perception to climate variability (Table 4.20). This means farmers who practised banana production in Lower Humid Zones perceived climate variability more than those who practiced in Lower Highland Zone. Similar findings were observed by Maddison (2006), where farmers' responsiveness of variations in climate variables (temperature levels and precipitation) were important in perceiving climate variability.

In order to progress banana production, most of the farmers in the study area indicated they would want to receive data on the rainfall onset (48.8%) followed by rainfall distribution data and data on rainfall within the seasons in future (45.7%) (Table 4.21).

Table 4.21: Relevant future weather forecasts information needed by farmers

Study location	Onset of rain	End of rainy season	Distribution of rainfall within seasons	Occurrence of floods	Total
Mukurweini	62(47.7%)	1(0.8%)	64(49.2%)	3(2.3%)	130(100.0%)
Imenti South	124(49.4%)	11(4.4%)	110(43.8%)	6(2.4%)	251(100.0%)
Total	**186(48.8%)**	**12(3.1%)**	**174(45.7%)**	**7(2.4%)**	**381(100.0%)**

Majority of the respondents in Mukurweini Sub County preferred to get information on distribution of rainfall within seasons (49.2%). This is because most of the farmers depend on rainfed banana production. About 49.4% of the respondents in Imenti South Sub County preferred to get information onset of rainfall during the seasons to enable them plan for the planting of banana.

4.5.3 Hypothesis Testing Two

Ho. There exists no significant relationship between farmer's perception and socioeconomic characteristics

The results of the Multinomial Logit model presented disclosed four variables (Table 4.18): Gender of HHH, type of farming system, access to weather information, farming practice and five variables (Table 4.20): gender of HHH, Agro-Ecological Zone, type of farming system, access to information on weather and acreage under banana production as significant factors explaining farmers' perception to climate variability in Mukurweini and Imenti south Sub-Counties respectively. Thus, the null hypothesis was rejected and opted for alternate hypothesis that there exists a relationship between farmers' perception on climate variability and socioeconomic characteristics.

4.6 Climate Variability's Adaptation Strategies among Smallholder Farmers in Mukurweini and Imenti South Sub Counties

In response to enduring perceived changes to climate, the farmer in the study areas have undertaken various adaptation measures including adoption of drought resistant banana varieties, crop diversification, shifting planting dates and practicing of irrigation as revealed in Table 4.22. Adger *et al*., (2003) observed adaptation as a policy options to decrease the harmful impact of climate variability to smallholders

Table 4.22: Production adaptation strategies adopted by the respondents.

	Drought tolerant varieties	**Crop diversification**	**No adaptation**	**Shifting planting dates**	**Use of Irrigation**	**Total**
Mukurweini	42 (32.3%)	47 (36.2%)	11 (8.5%)	25 (19.2%)	5 (3.8%)	130 (100%)
Imenti south	5 (2.0%)	6 (2.4%)	15 (5.9%)	12 (4.8%)	213 (84.9%)	251 (100%)
Total	**47 (12.3%)**	**58 (13.9%)**	**26 6.8%)**	**37 (9.7%)**	**218 (57.2%)**	**381 (100%)**

The majority of the respondents in Mukurweini Sub County preferred crop diversification (36.2%) followed by planting of drought tolerant varieties (32.3%) as their adaptive strategies to climate variability. This concurs with the study conducted by Nyanga, Johnsen, and Aune, (2011) which concluded that main adaptation to climate variability was crop diversification. Supporting and promoting appropriate technology for irrigation is paramount. In Imenti south Sub County, majority of the respondents opted for irrigation programs (84.9%). Some respondents preferred no adaptation strategy at all, in Mukurweini and Imenti south sub-counties at (8.5%) and (5.9%) respectively. In Mukurweini Sub County, irrigation as an adaptation strategy was least opted (3.8%) while in Imenti south sub-County banana drought tolerant varieties were least preferred (2.0%) (Table 4.22). Enhanced food productivity can be improved with proper adaptations at household level (Di Falco & Veronesi, 2013; Di Falco, 2014).

4.6.1 Socio-economic Factors Influencing Farmers' Adaptation to Climate Variability

Multinomial Logit regression model was utilized to establish the factors influencing farmers' choice of adaptation strategies to counter climate variability. The choice to use adaptation strategies was assumed to be a function of individual household characteristics (i.e. gender of HHH, age group of HHH, level of education, land size, type of farming, land under banana, farming system, access to market information, group membership, access to financial assistance, access to extension services, perception to climate variability, future information on weather and land ownership).

4.6.2 Adaptation to Climate Variability through drought tolerant banana varieties

4.6.2.1 Socio-economic factors influencing farmers' choice of drought tolerant banana varieties in Mukurweini Sub- County

Results of univariate analysis of socio-economic factors influencing farmers' perception on climate variability showed that size of the land under banana production was significant in explaining farmers' choice on drought tolerant banana varieties as a response to climate variability (Table 4.23).

Studies conducted have recommended planting more suitable and/or resilient crop varieties as an adaptation measures to mitigate the impact of climate variability (IPCC 2007). Likewise, Tachie-Obeng, Akponikpe and Adiku (2013) established that introduction of drought tolerant maize varieties is likely to increase maize produce in a study conducted in Ghana.

Table 4.23: Socio-economic factors influencing farmers' choice on drought tolerant banana varieties in Mukurweini sub county.

Socio-economic characteristic		Yes, to drought resistance varieties	No to drought resistance varieties	Total	x^2 P Value
Gender of the HHH	Male	16(28.1%)	41(71.9%)	57(100%)	Ns
	Female	31(42.5%)	42(57.5%)	73(100%)	
Level of education	No formal education	4(44.4%)	5(55.6%)	9(100%)	Ns
	Primary	20(37.7%)	33(62.3%)	53(100%)	
	Secondary	18(31.6%)	39(68.4%)	57(100%)	
	Tertiary	4(40%)	6(60%)	10(100%)	
Age group	Less than 20 years	1(100%)	0 (0%)	1(100%)	Ns
	21 – 30 years	6 (35.3 %)	11(64.7%)	17(100%)	
	31 – 40 years	5(33.3%)	10(66.7 %)	15(100%)	
	41-50 years	15 (48.4%)	16(51.6%)	31(100%)	
	51-60 years	8 (24.2%)	25 (75.8%)	33(100%)	
	Over 60 years	12(36.4%)	21(63.6%)	33(100%)	
Types of farming practice	Subsistence	1 (33.3%)	2(66.7%)	3(100%)	Ns
	Cash-crop farming	0 (0 %)	1(100%)	1(100%)	
	Mixed farming	46 (36.5%)	80 (63.5%)	126(100%)	
Land ownership	Yes	45 (36.3%)	79(63.7%)	124(100%)	Ns
	No	2 (33.3%)	4 (66.7%)	6(100%)	
Group Membership	No	43 (37.4%)	72 (63.7%)	115(100%)	Ns
	Yes	4 (26.7 %)	11(73.3%)	15(100%)	
Agroecological Zone	LH	0(0%)	0 (0%)	0(0%)	Ns
	UM	47(36.2%)	83(63.8%)	130(100%)	
	LM	0 (0%)	0(0%)	0(0%)	
System of farming	Rain fed	46 (37.1%)	78 (62.9%)	124(100%)	Ns
	Irrigation	1 (33.3%)	2 (66.7%)	3(100%)	
	Rainfed + irrigation	0 (0%)	3 (100%)	3(100%)	
Access to extension services	Yes	30 (41.6%)	43 (58.9%)	73(100%)	Ns
	No	17 (29.8%)	40 (70.2%)	57(100%)	
Perception on Climate variability	Yes	36 (35.5%)	66(64.7%)	102(100%)	Ns
	No	11 (39.3%)	17(60.7%)	28(100%)	
Access to predicted weather	Yes	30(34.5%)	57(65.5%)	87(100%)	
	No	17(39.5%)	26(60.5%)	53(100%)	
Access to credit	Yes	6(40%)	9(60%)	15(100%)	Ns
	No	41 (35.7%)	74(64.3%)	115(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.8940	2.3245		**0.001****
Land under bananas		0.3243	0.6901		Ns

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

Multinomial Logit model analysis of factors influencing bananas farmers' adaptation to drought tolerant banana varieties in Mukurweini sub-county showed that the model was significant at $p<0.01$ and correctly predicted 86% of both adopters and non-adopters to drought tolerant varieties as shown in Table 4.24. Four variables: Gender of HHH, farming system, level of education and perception to climate variability were significant in explaining the farmer's adaptation to drought tolerant banana varieties in Mukurweini.

Table 4.24: Factors influencing bananas farmers' adaptation to drought tolerant banana varieties in Mukurweini sub-county.

Socioeconomic characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**0.309***	0.326	0.900	**0.062**	1.362
Age group of HHH	-0.195	0.146	1.766	0.940	0.823
Level of education	**0.284***	0.252	0.019	**0.097**	0.466
Land size	-0.160	0.115	1.928	0.165	0.876
Type of farming	0.208	0.48	0.046	0.830	1.569
Land under Banana	0.880	0.253	4.445	0.235	0.204
Farming System	**-0.370****	0.445	2.436	**0.001**	0.149
Access to market information	0.502	0.399	2.001	0.378	3.897
Group membership	-0.023	0.789	0.002	0.876	0.542
Access to financial assistance	-0.796	0.897	2.197	0.178	0.897
Access to Extension services	-0.066	0.369	0.031	0.959	0.336
Perception to climate variability	**0.723****	0.924	0.539	**0.049**	0.867
Information on weather	-0.520	0.653	0.033	0.669	0.917
Land ownership	0.899	0.764	0.764	0.587	1.400

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

Gender of the household positively and significantly ($\beta=0.309$, $p=0.062$) influenced farmers' adaptation to drought tolerant banana varieties (Table 4.24). This implies that female headed household adopted drought tolerant banana varieties more than their male headed counterparts. Female easily take new knowledge and skills.

Farming system negatively and significantly (β=-0.370, p=0.001) influenced farmers' adaptation to drought tolerant banana varieties (Table 4.24). Farmers who relied on rain fed banana production adopted drought tolerant banana varieties as compared to those who practiced both irrigation and rain fed banana production.

The study revealed that education level of the household head negatively and significantly (β=-0.284, p=0.097) influenced farmers' adaptation to drought tolerant banana varieties (Table 4.24). This implies that the level of education determined farmer's choice on adaptation strategy. In this regard, farmers who had tertiary level of education adopted more to drought tolerant banana varieties as compared to those who had no-formal level of education. Finally, farmers' perception to climate variability was positive and significantly (β=0.723, p=0.049) influenced farmers' adaptation to drought tolerant banana breeds (Table 4.24). This meant that farmers who had an understanding of climate variability adopted more of the drought tolerant banana varieties as compared to those who had low understanding of climate variability.

4.6.2.2 Socio-economic factors influencing farmers' choice on drought tolerant banana varieties in Imenti south sub-county

Results of the univariate analysis of socio-economic factors influencing farmers' adaptation strategy to climate variability showed that size of the land and system of farming on banana production were significant in explaining farmer's choice on drought tolerant banana diversities as a response to climate variability (Table 4.25).

Table 4.2511: Socio-economic factors influencing farmers' choice on drought tolerant banana varieties in Imenti south sub county

Social economic characteristic		**Yes, to drought resistance varieties**	**No to drought resistance varieties**	**Total**	**x^2 P Value**
Gender of the HHH	Male	3(2.4%)	120(97.6%)	123(100%)	Ns
	Female	3(2.3%)	125(97.7%)	128(100%)	
Level of education	No formal education	0(0%)	12(100%)	12(100%)	Ns
	Primary	4(3.1%)	126(96.9%)	130(100%)	
	Secondary	1(1.2%)	81(98.8%)	82(100%)	
	Tertiary	1(3.7%)	26(96.3%)	27(100%)	
Age group	Less than 20 years	0(0%)	4(100%)	1(100%)	Ns
	21 – 30 years	0(0%)	21(100%)	21(100%)	
	31 – 40 years	2(2.3%)	85(97.7 %)	87(100%)	
	41-50 years	1(1.3%)	78(98.7%)	79(100%)	
	51-60 years	1 (2.9%)	33(97.1%)	34(100%)	
	Over 60 years	2(7.7%)	24(92.3%)	26(100%)	
Types of farming practice	Subsistence	1 (11.1%)	8(88.9%)	3(100%)	Ns
	Cash-crop farming	0 (0 %)	10(100%)	10(100%)	
	Mixed farming	5(2.2%)	224(97.8%)	229(100%)	
Land ownership	Yes	5(2.1%)	237(63.7%)	242(100%)	Ns
	No	1(12.5%)	7(87.5%)	8(100%)	
Group Membership	No	43 (37.4%)	72 (63.7%)	115(100%)	Ns
	Yes	4 (26.7 %)	11(73.3%)	15(100%)	
Agroecological Zone	LH	0(0%)	41(100%)	41(100%)	Ns
	UM	4(2.6%)	150(97.4%)	154(100%)	
	LM	2 (3.6%)	54(96.4%)	56(100%)	
System of farming	Rain fed	4 (11.8%)	30(88.2%)	34(100%)	0.001**
	Irrigation	0(0%)	47(100%)	47(100%)	
	Rainfed + irrigation	2(1.2%)	168(98.8%)	170(100%)	
Access to extension services	Yes	4 (1.9%)	204 (98.1%)	208(100%)	Ns
	No	2 (4.7%)	41(95.3%)	43(100%)	
Perception on Climate variability	Yes	5(2.5%)	194(97.5%)	199(100%)	Ns
	No	1(1.9%)	51(98.1%)	52(100%)	
Access to predicted weather	Yes	5(2.6%)	191(97.4%)	196(100%)	
	No	1(1.8%)	54(98.2%)	55(100%)	
Access to credit	Yes	2(3.3%)	58(96.1%)	60(100%)	Ns
	No	4(2.1%)	187(97.9%)	191(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.7340	2.2525		0.001**
Land under bananas		0.3243	0.6721		Ns

N=251, ** Significant at 5% probability level, *Significant at 10% probability level

Multinomial Logit model analysis of socio-economic factors influencing farmers' adaptation to drought tolerant banana varieties in Imenti South Sub County showed that the model was significant at $p<0.01$ and correctly predicted 97.6% of both adopters and non- adopters to drought tolerant varieties as shown in Table 4.26. Five variables: Gender of HHH, farming system, land ownership, land under banana and access to financial services were significant in explaining the farmer's adaptation to drought tolerant banana varieties in Imenti South Sub County.

Table 4.26: Factors influencing bananas farmers' adaptation to drought tolerant banana varieties in Imenti South

Independent variables	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**
Agro-ecological Zone	0.256	1.529	0.028	0.867	1.291
Gender of HH	**4.831***	2.704	3.192	**0.074**	0.008
Age group of HH	0.524	0.446	1.377	0.241	1.688
Land under Banana	**-29.587***	17.855	2.746	**0.098**	0.000
Farming System	**-4.397***	2.497	3.103	**0.078**	0.012
Group membership	6.414	4.181	2.353	0.125	610.222
Land ownership	**5.352***	3.007	3.168	**0.075**	210.947
Level of education	1.142	.970	1.387	0.239	3.133
Land size	0.071	0.047	2.322	0.128	1.074
Type of farming	-2.300	1.536	2.242	0.134	0.100
Access to market information	-0.291	0.380	0.588	0.443	0.747
Access to financial assistance	**4.580***	2.576	3.162	**0.075**	0.010
Access to Extension services	1.859	1.648	1.272	0.259	6.418
Perception to climate variability	-5.316	4.134	1.654	0.198	0.005
Information on weather	-2.032	1.644	1.528	0.216	0.131

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

Land acreage under banana production negatively and significantly influenced farmers' at (β =-29.587, p=0.098) while gender of the household positively and significantly influenced farmers' adaptation to drought tolerant banana varieties a (β=4.831, p=0.074). This implies that male headed households adopted to drought tolerant banana varieties.

Marenya and Barrett (2007), for instance, found that male-headed households have high tendency to adoption. The authors further argue inherent resource disparities between men and women by cultural conditions in many African societies made men own properties traditionally women never owned the right for secure entitlements to property such as land.

Farmers who owned land on banana production positively and significantly ($\beta=5.352$, $p=0.075$) influenced adaptation strategy. Farmers who owned land on banana production embraced drought tolerant banana varieties as compared to those who leased land. Farmers who owned land possessed land rights.

Farming system negatively and significantly influenced farmers' adaptation to drought tolerant banana varieties ($\beta=-4.397$, $p=0.078$). This meant that the system of banana production influenced banana farmers' choice on adaptation strategy to drought tolerant banana varieties. Farmers who relied on rainfed banana production adopted drought tolerant banana varieties as compared to those who practiced irrigation, and both irrigation and rainfed banana production.

Access to financial services positively and significantly influenced farmers' adaptation to drought tolerant banana varieties ($\beta=4.580$, $p=0.075$). This implies that farmers who accessed financial services adopted more of the drought tolerant banana varieties as compared to those who never accessed financial services. Farmers' perception to climate factors negatively and significantly influenced farmers' adaptation to drought tolerant banana varieties ($\beta=-0.723$, $p=0.049$). This meant that farmers who perceived existence of climate variability adopted to drought tolerant banana varieties.

4.6.3 Adaptation to Climate Variability through Crop Diversification

Several factors were identified that influenced farmer's choice on crop diversification as an adaptation strategy to climate variability in the study region. Shikuku *et al*., (2017) in his studies in Machakos County, Kenya showed integrating dual-purpose sweet potato variety in farming systems would be sufficient to offset the undesirable impacts of climate variability

4.6.3.1 Socio- economic factors influencing adaptation to climate variability through crop diversification in Mukurweini

Results of the univariate analysis of socio-economic features influencing farmers' adaptation strategy to climate variability showed that gender of the household and size of the land on banana production were significant in explaining adoption of crop diversification as an adaptation strategy to climate variability by farmers in Mukurweini Sub County (Table 4.27). This has been supported by studies conducted in Vihiga, Kenya which showed that planting dual-purpose sweet potato breeds together with improved animals' pasture would fully offset the impacts (Kelvin *et al*., 2016).

Table 4.27: Socio- economic factors influencing adaptation to climate variability through crop diversification in Mukurweini

Socioeconomic characteristic		**No, to Crop diversification**	**Yes, to** Crop **diversification**	**Total**	**X^2 P Value**
Gender of the HHH	Male	33(57.9%)	24(42.1%)	57(100%)	0.035
	Female	55(75.3%)	18(24.7%)	73(100%)	
Level of education	No formal education	8(88.9%)	1(11.1%)	9(100%)	Ns
	Primary	32(60.4%)	21(39.6%)	53(100%)	
	Secondary	40(70.2%)	17(29.8%)	57(100%)	
	Tertiary	3(30%)	7(70%)	10(100%)	
Age group	Less than 20 years	1(100%)	0 (0%)	1(100%)	Ns
	21 – 30 years	9 (52.9 %)	8(47.1%)	17(100%)	
	31 – 40 years	11(73.3%)	5(26.7 %)	15(100%)	
	41-50 years	25 (80.6%)	6(19.4%)	31(100%)	
	51-60 years	22(66.7%)	11(33.3%)	33(100%)	
	Over 60 years	20(60.6%)	13(39.4%)	33(100%)	
Change of crop	Yes	83 (66.9%)	41(33.1%)	124(100%)	Ns
	No	5 (83.5%)	1(16.7%)	6(100%)	
Land ownership	Yes	83(66.9%)	41 (33.1%)	124(100%)	Ns
	No	5 (83.3%)	1(16.7%)	6(100%)	
Group Membership	No	79 (68.7%)	36 (31.3%)	115(100%)	Ns
	Yes	9(60%)	6(40%)	15(100%)	
Agroecological Zone	LH	0(0%)	0 (0%)	0(0%)	Ns
	UM	88(67.7%)	42(32.3%)	130(100%)	
	LM	0 (0%)	0(0%)	0(0%)	
System of farming	Rain fed	83 (66.9%)	41(33.1%)	124(100%)	Ns
	Irrigation	3 (100%)	0 (0%)	3(100%)	
	Both rainfed and irrigation	2(66.7%)	1(33.3%)	3(100%)	
Access to extension services	Yes	48 (65.8%)	25(34.2%)	73(100%)	Ns
	No	40(70.2%)	17(29.8%)	57(100%)	
Perception on Climate variability	Yes	68(66.7%)	34(33.3%)	102(100%)	Ns
	No	20(71.4%)	8(28.6%)	28(100%)	
Access to predicted weather	Yes	60(69%)	27(31%)	87(100%)	
	No	28(65.1%)	15(34.9%)	53(100%)	
Access to credit	Yes	9(60%)	6(40%)	15(100%)	Ns
	No	79 (68.7%)	36(31.3%)	115(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.6794	3.4545		0.001**
Land under bananas		0.8943	0.9981		Ns

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

Multinomial Logit model analysis of factors influencing bananas farmers' adaptation to crop diversification in Mukurweini sub-county disclosed that the model was significant at p<0.01 and correctly predicted at 80.6% of both those who adopted and never adopted to crop diversification. Four variables: Gender of HHH, education level, perception to climate variability and farming system were significant in explaining the farmers' response to crop diversification in Mukurweini (Table 4.28).

Table 4.28: Factors influencing bananas farmers' decision to adopt crop diversification in Mukurweini Sub County

Socioeconomic Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**1.195****	0.436	7.506	**0.006**	0.303
Age group of HHH	0.075	0.136	0.301	0.583	1.078
Land under Banana	0.642	0.665	6.090	0.014	0.194
Farming System	**0.182****	0.473	21.236	**0.001**	0.113
Group membership	0.076	0.541	0.020	0.888	1.079
Land ownership	-0.817	1.157	0.499	0.480	0.442
Level of education	**0.324***	0.300	1.168	**0.089**	0.723
Land size	0.071	0.047	2.322	0.128	1.074
Access to market information	-0.291	0.38	0.588	0.443	0.747
Access to financial assistance	-0.291	0.563	0.266	0.606	0.748
Access to Extension services	-0.420	0.383	1.205	0.272	0.657
Perception to climate variability	**-0.678***	0.462	0.011	**0.098**	1.049
Information on weather	0.028	0.386	0.005	0.942	1.028

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

Gender of the household positively (β=1.1905, p=0.006) influenced farmers' adaptation strategy to climate variability. Households heads dominated by females adopted crop diversification as an adaptation strategy as compared to male headed households. Level of education positively (β=0.3240, p=0.089) influenced farmers' adaptation strategy to climate variability indicating that education level influenced farmers' choice on adaptation strategy to climate variability. Farmers who had tertiary education level adopted to crop diversification as compared to those without any formal education.

Farming system positively (β=0.182, p=0.001), indicating that mode of banana production influenced farmers' choice on adaptation strategy to climate variability. Farmers who practiced both rain-fed and irrigation banana production preferred crop diversification as compared to farmers who practiced rain fed. Perception to climate variability negatively (β=-0.678, p=0.098), influenced farmers' choice on adaptation strategy to climate variability. Farmers who perceived climate variability preferred crop diversification as compared to farmers who never perceived climate variability.

4.6.3.2 Socio-economic factors influencing adaptation to climate variability through crop diversification in Imenti South sub-county

Results of the univariate analysis of socio-economic factors influencing farmers' adaptation strategy to climate variability showed that farmers' age, system of banana production and size of the land under banana production was significant in explaining farmers' choice on adaptation strategy to climate variability through crop diversification (Table 4.29).

Table 4.29: Socio-economic factors influencing adaptation to climate variability through crop diversification in Imenti South

Socioeconomic characteristic		No, to crop diversification	Yes, to crop diversification	Total	x2 P Value
Gender of the HHH	Male	121 (98.4%)	2(1.6%)	123(100%)	Ns
	Female	125(97.7%)	3(2.3%)	128(100%)	
Level of education	No formal education	11(91.7%)	1(8.3%)	12(100%)	Ns
	Primary	129(99.2%)	1(0.8%)	130(100%)	
	Secondary	80(97.6%)	2(2.4%)	82(100%)	
	Tertiary	26(96.3%)	1(3.7%)	27(100%)	
Age group	Less than 20 years	3(75%)	1(25%)	4(100%)	0.005
	21 – 30 years	21 (0%)	(100%)	21(100%)	
	31 – 40 years	86(98.9%)	1 (1.1%)	87(100%)	
	41-50 years	78(98.7%)	1(1.3%)	79(100%)	
	51-60 years	34 (100%)	0(0%)	34(100%)	
	Over 60 years	24(92.3%)	2(7.7%)	26(100%)	
Land ownership	Yes	237(97.9%)	5(2.1%)	242(100%)	Ns
	No	8(100%)	0(0%)	8(100%)	
Group Membership	No	168(97.4%)	5(26%)	185(100%)	Ns
	Yes	56(100 %)	0(0%)	56(100%)	
Agroecological Zone	LH	41(100%)	0(0%)	41(100%)	Ns
	UM	151(98.1%)	3(1.9%)	154(100%)	
	LM	254(96.4%)	2(3.6%)	56(100%)	
System of farming	Rain fed	30(88.2%)	4(11.8%)	34(100%)	0.001**
	Irrigation	47(100%)	0(0%)	47(100%)	
	Both rainfed and irrigation	169(99.4%)	1(0.6%)	170(100%)	
Access to extension services	Yes	203(97.6%)	5 (2.4%)	208(100%)	Ns
	No	43(100%)	0(0%)	43(100%)	
Perception on Climate variability	Yes	195(98%)	4(2%)	199(100%)	Ns
	No	51(98.1%)	1(1.9%)	52(100%)	
Access to predicted weather	Yes	193(98.5%)	3(1.5%)	196(100%)	
	No	53(96.4%)	2(3.6%)	55(100%)	
Access to credit	Yes	60(100%)	0(0%)	60(100%)	Ns
	No	186(97.4%)	5(3.6%)	191(100%)	
		Mean	**Mean**		**t-test**
Size of the land		0.7340	0.2525		Ns
Land under bananas		0.8243	2.6721		0.001

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

Multinomial Logit model analysis of factors influencing bananas farmers' adoption to crop diversification in Imenti South showed that the model was significant at p<0.01 and correctly predicted at 87.6% of both adopters and non-adopters to crop diversification. Two variables: gender of HHH and farming system were significant in explaining the farmers' adaptation strategy to crop diversification in Imenti South (Table 4.30).

Table 4.30: Factors influencing bananas farmers' decision to adopt to crop diversification in Imenti south sub-county

Socioeconomic Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**-0.442****	0.788	2.873	**0.004**	**0.875**
Age group of HHH	0.895	0.136	0.301	0.583	1.078
Land under Banana	0.642	0.665	6.090	0.014	0.194
Farming System	**-0.788****	0.473	21.236	**0.007**	**0.113**
Group membership	0.076	0.541	0.020	0.888	1.079
Land ownership	-0.889	0.857	0.499	0.480	0.442
Level of education	0.022	0.615	0.001	0.971	1.022
Access to market information	-0.291	0.380	0.238	0.473	0.547
Access to financial assistance	-0.291	0.863	0.896	0.807	0.799
Access to Extension services	-0.786	0.399	1.205	0.272	0.297
Perception to climate variability	0.078	0.452	0.011	0.409	1.780
Information on weather	0.740	0.800	0.059	0.862	0.678

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

Gender of the household positively (β=-0.442, p=0.004) influenced farmers to embrace crop diversification as an adaptation strategy. This implies that female headed households adopted crop diversification as an adaptation strategy to climate variability more as compared to male headed households.

Farming system negatively (β=-0.788, p=0.007), influenced farmers' choice on adaptation strategy to climate variability. Farmers who practiced both rain-fed banana production preferred crop diversification as compared to farmers who practiced rainfed and irrigation.

Farmers intercropped bananas with other food crops such potatoes, maize and beans. Farmers preferred crop diversification in Mukurweini as an adaptation strategy as compared to Imenti south. This is due overdependence on rainfed production where there are high chances of one crop failing.

4.6.4 Adaptation to Climate Variability through Shifting Banana Planting dates

Several factors were identified that influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability in Mukurweini and Imenti South Sub-Counties. Studies conducted in East Africa established that farmers preferred varying land preparation or planting dates to reduce climate related risks (Kelvin *et al*., 2016).

4.6.4.1 Socio-economic factors influencing adaptation to climate variability through shifting banana planting dates in Mukurweini sub-county

Univariate analysis of socio-economic factors influencing farmers' adaptation strategy to climate variability in Mukurweini Sub-County showed that size of the land was significant in explaining farmers' choice on adaptation strategy to climate variability through shifting banana planting dates (Table 4.31).

Table 4.31: Socio-economic factors influencing adaptation to climate variability through shifting banana planting dates in Mukurweini sub-county.

Socioeconomic characteristic		**No, to shifting planting dates**	**Yes, to shifting planting dates**	**Total**	**x2 P Value**
Gender of the HHH	Male	49(86%)	8(14%)	57(100%)	Ns
	Female	56(76.7%)	17(23.3%)	73(100%)	
Level of education	No formal education	6(66.7.9%)	3(33.3%)	9(100%)	Ns
	Primary	46(86.8%)	7(13.2%)	53(100%)	
	Secondary	44(77.2%)	13(22.8%)	57(100%)	
	Tertiary	8(80%)	2(20%)	10(100%)	
Age group	Less than 20 years	1(100%)	0 (0%)	1(100%)	Ns
	21 – 30 years	17(100 %)	0(0%)	17(100%)	
	31 – 40 years	9(60%)	6(40%)	15(100%)	
	41-50 years	26(83.9%)	5(16.1%)	31(100%)	
	51-60 years	27(81.8%)	6(18.2%)	33(100%)	
	Over 60 years	20(60.6%)	13(39.4%)	33(100%)	
Land ownership	Yes	102(82.3%)	22(17.7%)	124(100%)	Ns
	No	3(50%)	3(50%)	6(100%)	
Group Membership	No	91(79.1%)	24(20.9%)	115(100%)	Ns
	Yes	14(93.3%)	1 (6.7%)	15(100%)	
Agroecological Zone	LH	0(0%)	0 (0%)	0(0%)	Ns
	UM	105(80.8%)	25(19.2%)	130(100%)	
	LM	0 (0%)	0(0%)	0(0%)	
System of farming	Rain fed	99 (79.8%)	25(20.2%)	124(100%)	Ns
	Irrigation	3(100%)	0 (0%)	3(100%)	
	Both rainfed and irrigation	3(100%)	0(0%)	3(100%)	
Access to extension services	Yes	60(82.2%)	13(17.8%)	73(100%)	Ns
	No	45(78.9%)	12(21.1%)	57(100%)	
Perception on Climate variability	Yes	82(80.4%)	20(19.6%)	102(100%)	Ns
	No	23(82.1%)	5(17.9%)	28(100%)	
Access to predicted weather	Yes	68(78.2%)	19(21.8%)	87(100%)	
	No	37(86%)	6(14%)	43(100%)	
Access to credit	Yes	14(93.3%)	1(6.7%)	15(100%)	Ns
	No	91(79.1%)	24(20.9%)	115(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.0794	2.4845		0.001**
Land under bananas		0.8303	0.6781		Ns

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

The findings of the Multinomial Logit model for Mukurweini Sub County are displayed in Table 4.32. The model was significant at p<0.01 and correctly predicted 90% of both on those who adopters and non-adopters to shifting banana planting dates. Four variables: Gender of HHH, land under banana, access to weather information and land ownership were significant in explaining the farmers' adaptation to shifting banana planting dates in Mukurweini Sub-County.

Table 4.32: Factors influencing farmers' choice on shifting banana planting dates as an adaptation strategy to climate variability in Mukurweini Sub County

Socioeconomic Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	**0.903***	0.524	2.963	**0.085**	2.466
Land under Banana	**2.030***	1.106	3.371	**0.066**	7.617
Land ownership	**1.769***	1.013	3.048	**0.081**	5.864
Land size	-0.027	0.110	0.058	0.809	0.974
Access to market information	-0.090	0.424	0.045	0.832	0.914
Access to Extension services	0.476	0.497	0.916	0.338	1.609
Age group of HHH	0.202	0.199	1.024	0.311	1.223
Level of education	0.303	0.356	0.723	0.395	1.354
Type of farming	0.058	0.475	0.015	0.902	1.060
Farming System	-0.897	0.986	1.584	0.897	0.064
Group membership	-1.418	1.104	1.649	0.199	0.242
Access to financial assistance	1.737	1.346	1.664	0.197	5.678
Perception to climate variability	-0.388	0.607	0.409	0.523	0.678
Information on weather	0.**419***	0.553	0.572	**0.089**	0.658

N=130, ** Significant at 5% probability level, *Significant at 10% probability level

Gender of the household positively (β=0.903, p=0.085), influenced farmers' choice to shifting planting dates as a response to climate variability. This implies that male headed households adopted shifting planting dates for banana as an adaptation strategy to climate variability. Land size under banana production positively (β=2.030, p=0.066) influenced farmer's choice on shifting banana planting dates as a response to climate variability. This implies that farmers who owned large land size under banana production adopted to shifting banana planting dates as compared to farmers who has small size of land under banana.

Access to weather information positively (β=0.419, p=0.089) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. This shows that access to meteorological information plays key role on farmers' determining the adaptation strategy. Farmers who accessed weather information adopted to shifting in planting dates, whereas those farmers who never accessed such information never adopted to this strategy. Land ownership positively (β=1.769, p=0.081) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. Farmers who owned land preferred shifting banana planting dates as an adaptation strategy (Table 4.32).

4.6.4.2 Socio-economic factors influencing adaptation to climate variability through shifting banana planting dates in Imenti South sub-county.

In Imenti South Sub-County results of the univariate analysis of socio-economic factors influencing farmers' adaptation strategy to climate variability showed that education level, system of farming, provision of credit facilities and land acreage under banana production were significant in explaining farmers choice on adaptation strategy through shifting banana planting dates (Table 4.33).

Table 4.33: Socio-economic factors influencing adaptation to climate variability through shifting banana planting dates in Imenti South sub-county

Socioeconomic characteristic		No, to shifting planting dates	Yes, to shifting planting dates	Total	X^2 P Value
Gender of the HHH	Male	116 (94.3%)	7(5.7%)	123(100%)	Ns
	Female	123(96.1%)	5(3.9%)	128(100%)	
Level of education	No formal education	11(91.7%)	1(8.3%)	12(100%)	0.048*
	Primary	127(97.7%)	3(2.3%)	130(100%)	
	Secondary	74(90.2%)	8(9.8%)	82(100%)	
	Tertiary	27(100%)	0(0%)	27(100%)	
Age group	Less than 20 years	4(100%)	0(0%)	4(100%)	Ns
	21 – 30 years	21(100%)	0(0%)	21(100%)	
	31 – 40 years	83(95.4%)	4(4.6%)	87(100%)	
	41-50 years	76(96.2%)	3(3.8%)	79(100%)	
	51-60 years	31(91.2%)	3(8.8%)	34(100%)	
	Over 60 years	24(92.3%)	2(7.7%)	26(100%)	
Land ownership	Yes	230(95%)	12(5%)	242(100%)	Ns
	No	8(100%)	0(0%)	8(100%)	
Group Membership	No	182(94.3%)	11(5.7%)	185(100%)	Ns
	Yes	55(98.2 %)	1(1.8%)	56(100%)	
Agroecological Zone	LH	40(97.6%)	1(2.4%)	41(100%)	Ns
	UM	150(97.4%)	4(2.6%)	154(100%)	
	LM	49(87.5%)	7(12.5%)	56(100%)	
System of farming	Rain fed	23(67.6%)	11(32.4%)	34(100%)	0.001**
	Irrigation	47(100%)	0(0%)	47(100%)	
	Rainfed + irrigation	169(99.4%)	1(0.6%)	170(100%)	
Access to extension services	Yes	198(95.2%)	10(4.8%)	208(100%)	Ns
	No	41(95.3%)	2(4.7%)	43(100%)	
Perception on Climate variability	Yes	188(94.5%)	11(5.5%)	199(100%)	Ns
	No	51(98.1%)	1(1.9%)	52(100%)	
Access to predicted weather	Yes	187(95.4%)	9(4.6%)	196(100%)	
	No	52(94.5%)	3(5.5%)	55(100%)	
Access to credit	Yes	60(100%)	0(0%)	60(100%)	0.047
	No	179(93.7%)	12(6.3%)	191(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.7650	1.2805		Ns
Land under bananas		0.7043	1.8021		0.001**

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

The results of the Multinomial Logit model for Imenti South are presented in Table 4.34. The model was significant at p<0.01 and correctly predicted 98% of both on adopters and non-adopters to shifting banana planting dates. Four variables: Land under banana production, provision of extension services, access to weather information and system of banana farming were important in explaining the farmers' adaptation to shifting banana planting dates in Imenti south sub-county.

Table 4.34: Factors influencing farmers' choice on shifting banana planting dates as an adaptation strategy to climate variability in Imenti South sub-county

Socioeconomic characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	0.730	1.028	0.504	0.478	2.074
Age group of HHH	0.228	0.475	0.230	0.632	1.256
Level of education	0.230	0.611	0.142	0.707	1.258
Land ownership	-0.875	0.951	0.845	0.358	0.417
Banana farming System	**-1.635****	0.692	5.574	**0.018**	0.195
Land under Banana production	**0.561****	0.290	7.541	**0.008**	2.162
Group membership	0.691	0.352	3.848	0.450	1.996
Access to financial assistance	0.221	0.564	0.154	0.695	1.248
Access to Extension services	**0.906***	0.209	8.085	**0.064**	0.490
Information on weather	**0.325****	0.876	0.654	**0.045**	1.770
Agro Ecological Zone	0.321	0.957	0.112	0.738	1.378
Perception to climate variability	0.298	0.426	2.290	0.791	1.058

N=251, ** Significant at 5% probability level, *Significant at 10% probability level

Land size under banana production positively (β=0.561, p=0.008) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. This implies that the farmers who controlled large land size under banana production adopted to shifting banana planting dates as compared to farmers who had small size of land under banana.

Farming system negatively (β=-1.635, p=0.018) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. Farmers who practiced rain fed banana production preferred shifting banana planting dates as an adaptation strategy.

Access to weather information positively (β=0.325, p=0.045) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. This infers that provision of weather information determined farmers' choice on adaptation strategy. Farmers who accessed weather information adopted to shifting in planting dates, whereas those farmers who never accessed such information never adopted to this strategy.

Access to extension services positively (β=0.906, p=0.064) influenced farmer's choice on shifting banana planting dates as an adaptation strategy to climate variability. Farmers who accessed extension services adopted to shifting in planting dates, whereas those farmers who never accessed such services never adopted to this strategy

4.6.5 Adaptation to Climate Variability through Irrigation.

Several factors were identified that influenced farmer's choice on irrigation as an adaptation strategy on banana production in Mukurweini and Imenti South sub-counties.

4.6.5.1 Socio-economic factors influencing adaptation to climate variability through irrigation in Mukurweini Sub County.

Results of the univariate analysis of socio-economic factors influencing farmers' adaptation strategy to climate variability showed that access to extension services and size of the land production were significant in explaining farmers' choice on irrigation as an adaptation strategy in Mukurweini Sub County (Table 4.35). Moreover, the risks linked with availability of water resources in future might decrease the prospect of adaptation through irrigation within the region (Lee, 2005; Bryan *et al*., 2013).

Table 4.35: Socio-economic factors influencing adaptation to climate variability through irrigation in Mukurweini Sub county.

Socioeconomic characteristic		**No, to Irrigation**	**Yes, to Irrigation**	**Total**	**x^2 P Value**
Gender of the HHH	Male	48(84.2%)	9(15.8%)	57(100%)	Ns
	Female	66(90.4%)	7(9.6%)	73(100%)	
Level of education	No formal education	8(88.9%)	1(11.1%)	9(100%)	Ns
	Primary	48(90.6%)	5(9.4%)	53(100%)	
	Secondary	48(84.2%)	9(15.8%)	57(100%)	
	Tertiary	8(80%)	2(20%)	10(100%)	
Age group	Less than 20 years	1(100%)	0 (0%)	1(100%)	Ns
	21 – 30 years	14(82.4%)	3(17.6%)	17(100%)	
	31 – 40 years	15(100%)	0(0%)	15(100%)	
	41-50 years	26(83.9%)	5(16.1%)	31(100%)	
	51-60 years	27(81.8%)	6(18.2%)	33(100%)	
	Over 60 years	31(93.9%)	2(6.1%)	33(100%)	
Land ownership	Yes	108(87.1%)	22(12.9%)	124(100%)	Ns
	No	6(100%)	0(0%)	6(100%)	
Group Membership	No	103(89.6%)	12(10.4%)	115(100%)	Ns
	Yes	11(73.3%)	4(26.7%)	15(100%)	
Agroecological Zone	LH	0(0%)	0 (0%)	0(0%)	Ns
	UM	114(89.6%)	16(19.2%)	130(100%)	
	LM	0 (0%)	0(0%)	0(0%)	
System of farming	Rain fed	112(90.3%)	12(9.7%)	124(100%)	Ns
	Irrigation	1(33.3%)	2(66.7%)	3(100%)	
	Both rainfed and irrigation	(33.3%)	2(66.7%)	3(100%)	
Access to extension services	Yes	68(93.2%)	5(6.8%)	73(100%)	0.032**
	No	46(80.7%)	11(19.3%)	57(100%)	
Perception on Climate variability	Yes	90(88.2%)	12(11.8%)	102(100%)	Ns
	No	24(85.7%)	4(14.3%)	28(100%)	
Access to predicted weather	Yes	76(87.4%)	11(12.6%)	87(100%)	
	No	38(88.4%)	5(11.6%)	43(100%)	
Access to credit	Yes	13(86.7%)	2(13.3%)	15(100%)	Ns
	No	101(87.8%)	14(12.2%)	115(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.0794	2.4845		0.001**
Land under bananas		0.7343	0.6051		Ns

*N=130, ** Significant at 5% probability level, *Significant at 10% probability level*

Results of the Multinomial Logit model are presented in the Table 4.36. The model was significant at $p<0.01$ and correctly predicted 88.4% of both for adopters and non-adopters on bananas irrigation as an adaptation strategy. Four variables: Access to extension services, banana farming system, access to financial assistance and perception to climate variability were significant in explaining the farmers' adaptation to climate variability in Mukurweini Sub County**.**

Table 4.36: Factors influencing farmers' choice on irrigation as an adaptation strategy to climate variability in Mukurweini

Socioeconomic Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Gender of HHH	-0.29	0.616	0.222	0.637	0.748
Age group of HHH	-0.15	0.232	0.415	0.519	0.861
Level of education	0.067	0.431	0.024	0.876	1.07
Land ownership	-0.823	0.561	0.877	0.608	0.297
Land size	-0.526	0.382	0.309	0.234	0.967
Banana farming System	**-2.221****	**0.828**	**7.188**	**0.097**	**9.217**
Land under Banana production	-0.497	1.946	0.065	0.798	0.608
Group membership	0.595	0.766	0.603	0.438	1.813
Access to financial facilities	**0.027***	**1.112**	**0.001**	**0.081**	**1.027**
Access to Extension services	**1.548****	0.739	4.388	**0.036**	4.703
Perception to climate variability	**-0.315****	0.496	0.404	**0.025**	1.37
Information on weather	0.041	0.659	0.004	0.95	1.042

N=130, ** Significant at 5% probability level, *Significant at 10% probability level

Existence of extension services positively ($\beta=1.548$, $p=0.036$) influenced adaptation strategy indicating that farmers who accessed extension services on banana production adopted to irrigation as compared to those farmers who never accessed extension services. Access to financial assistance positively ($\beta=0.027$, $p=0.081$) influenced adaptation strategy. Farmers who accessed financial facilities adopted irrigation.

Type of farming system negatively (β=-2.221 p=0.097) influenced adaptation strategy. Farmers who practiced rainfed system of farming adopted irrigation. Perception to climate variability negatively (β=-0.315, p=0.025) influenced farmers' choice on adaptation strategy. Farmers who perceived climate variability on banana production adopted irrigation as adaptation strategy as related to those who didn't perceive climate variability.

4.6.5.2 Socio-economic factors influencing adaptation to climate variability through irrigation in Imenti South sub-County

In Imenti South Sub-County, results of the univariate analysis of socio-economic factors influencing farmers' adaptation strategy showed that level of education, system of farming, access to credit facilities and size of the land under banana production were significant in explaining farmers' choice on adaptation strategy through irrigation to climate variability (Table 4.37).

Table 4.37: Socio-economic factors influencing adaptation to climate variability through irrigation in Imenti South sub-county.

Socioeconomic characteristic		No, to irrigation	Yes, to irrigation	Total	X^2 P Value
Gender of the HHH	Male	116 (94.3%)	7(5.7%)	123(100%)	Ns
	Female	123(96.1%)	5(3.9%)	128(100%)	
Level of education	No formal education	11(91.7%)	1(8.3%)	12(100%)	0.048**
	Primary	127(97.7%)	3(2.3%)	130(100%)	
	Secondary	74(90.2%)	8(9.8%)	82(100%)	
	Tertiary	27(100%)	0(0%)	27(100%)	
Age group	Less than 20 years	4(100%)	0(0%)	4(100%)	Ns
	21 – 30 years	21(100%)	0(0%)	21(100%)	
	31 – 40 years	83(95.4%)	4(4.6%)	87(100%)	
	41-50 years	76(96.2%)	3(3.8%)	79(100%)	
	51-60 years	31(91.2%)	3(8.8%)	34(100%)	
	Over 60 years	24(92.3%)	2(7.7%)	26(100%)	
Land ownership	Yes	230(95%)	12(5%)	242(100%)	Ns
	No	8(100%)	0(0%)	8(100%)	
Group Membership	No	182(94.3%)	11(5.7%)	185(100%)	Ns
	Yes	55(98.2 %)	1(1.8%)	56(100%)	
Agroecological Zone	LH	40(97.6%)	1(2.4%)	41(100%)	Ns
	UM	150(97.4%)	4(2.6%)	154(100%)	
	LM	49(87.5%)	7(12.5%)	56(100%)	
System of farming	Rain fed	23(67.6%)	11(32.4%)	34(100%)	0.001**
	Irrigation	47(100%)	0(0%)	47(100%)	
	Both rainfed and irrigation	169(99.4%)	1(0.6%)	170(100%)	
Access to extension services	Yes	198(95.2%)	10(4.8%)	208(100%)	Ns
	No	41(95.3%)	2(4.7%)	43(100%)	
Perception on Climate variability	Yes	188(94.5%)	11(5.5%)	199(100%)	Ns
	No	51(98.1%)	1(1.9%)	52(100%)	
Access to predicted weather	Yes	187(95.4%)	9(4.6%)	196(100%)	
	No	52(94.5%)	3(5.5%)	55(100%)	
Access to credit	Yes	60(100%)	0(0%)	60(100%)	0.047**
	No	179(93.7%)	12(6.3%)	191(100%)	
		Mean	**Mean**		**t-test**
Size of the land		1.7650	1.2805		Ns
Land under bananas		0.7043	1.8021		0.001

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

The results of Multinomial Logit model for Imenti south are presented in Table 4.38. The model was significant at p<0.01 and correctly predicted 93.5% of both adopters and non-adopters to irrigation as an adaptation strategy to banana production. Six variables: land under banana production, access to extension services, access to financial facilities, age of the HHH Agro-ecological zone and farmers perception to climate variability were significant in explaining the farmers' adaptation to irrigation in Imenti south sub-county.

Table 4.38: Factors influencing farmers' choice on irrigation as an adaptation strategy to climate variability in Imenti South sub county

Socioeconomic Characteristics	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(B)**
Gender of HHH	0.252	0.591	0.182	0.670	1.286
Age group of HHH	**-0.482***	0.263	3.353	**0.067**	0.617
Level of education	-0.282	0.401	0.495	0.482	0.754
Land ownership	-1.849	1.415	1.707	0.191	0.157
Land size	-0.026	0.042	0.375	0.540	0.981
Land under Banana production	**-0.771****	0.279	7.611	**0.006**	2.162
Type of farming System	2.167	0.416	27.186	0.675	8.734
Group membership	1.292	0.913	2.005	0.157	3.642
Access to financial facilities	**0.221****	0.564	0.154	**0.046**	1.248
Access to Extension services	**0.766****	0.974	8.445	**0.004**	0.905
AEZ	**-1.219****	0.573	4.524	**0.033**	0.296
Perception to climate variability	**-0.275****	0.626	0.982	**0.035**	1.907
Information on weather	0.229	0.426	0.29	0.591	1.258

*N=251, ** Significant at 5% probability level, *Significant at 10% probability level*

Agro-ecological zone negatively (β=-1.219, p=0.033) influenced adaptation to irrigation as an adaptation strategy. Farmers who practiced banana production in the Lower Midland zones were more likely to embrace irrigation as an adaptation strategy as compared to the counterpart farmers in the Upper Highland.

Land under banana production negatively (β=-0.771, p=0.006) influenced adaptation strategy. Farmers who had small land size under banana production adopted to irrigation as compared to those farmers who had large track of land. Access to extension services positively ($\beta=0.766$, $p=0.004$) influenced adaptation strategy indicating that farmers who accessed extension services on banana production adopted to irrigation as compared to those farmers who never accessed extension services. Perception to climate variability negatively ($\beta=-0.275$, $p=0.035$) influenced farmers' choice on adaptation strategy. Farmers who perceived climate variability effects on banana production adopted irrigation as adaptation strategy.

Age of the HHH was negative and significant ($\beta=-0.482$, $p=0.067$). The young farmers opted to irrigation as compared to the old one. This can be attributed to the fact that irrigation is labour intensive and requires young persons.

4.6.6 Hypothesis Testing Three

H_o.-There exists no relationship between adaptation strategies and household socioeconomic characteristics. The hypothesis was tested and the following results were obtained. The results of the Logit models presented in Tables 4.28, 4.30, 4.32, 4.34, 4.36 and 4.38 suggested that the models were significant at $p<0.1$. Various variables were significant in explaining the farmers' adaptation strategies in both Mukurweini and Imenti south Sub Counties. The null hypothesis was rejected and alternative hypothesis adopted meaning adaptation strategies were significant to the socioeconomic characteristic of the households.

4.7 Relationships between banana production and climatic elements in the study area

Climate variability impact on banana production was limited for the period between 2009 to 2017 due to lack of adequate data from the agricultural offices in Mt. Kenya region. The results showed that banana acreage and production has been increasing in the period between 2009 and 2017 in Imenti South and Mukurweini sub counties (Figure 4.11). Land under banana production increased gradually in both Sub-Counties starting at 960 and 400 hectares of land in 2009 and increasing up to 2910 and 460 hectares in 2017 for Imenti South and Mukurweini sub counties respectively. The production increased from 17,280 and 8,100 tonnes in 2009 to 116,400 and 9,000 tonnes in 2017 for Imenti South and Mukurweini sub-Counties respectively (Figure 4.8 (a) and (b). Banana being a perennial crop provides a steady source of income and food to the family possibly all year round. This has been supported by Kabunga, Dubois and Qaim (2014) who cited that in Kenya, banana is almost grown by every smallholder farmer for home consumption and for markets.

4.8 Climate Variability Impacts on Banana Value Chain Development in Mt Kenya Region

Banana value chain development in the study area has been affected by the changing rainfall and temperatures levels and patterns. The extent of the impact can be clustered into three echelons according to the observed value chain presented in Figure 4.1. Thus, production level (comprising of harvesting and storage), retail level and consumer level comprising farming, transport, and marketing.

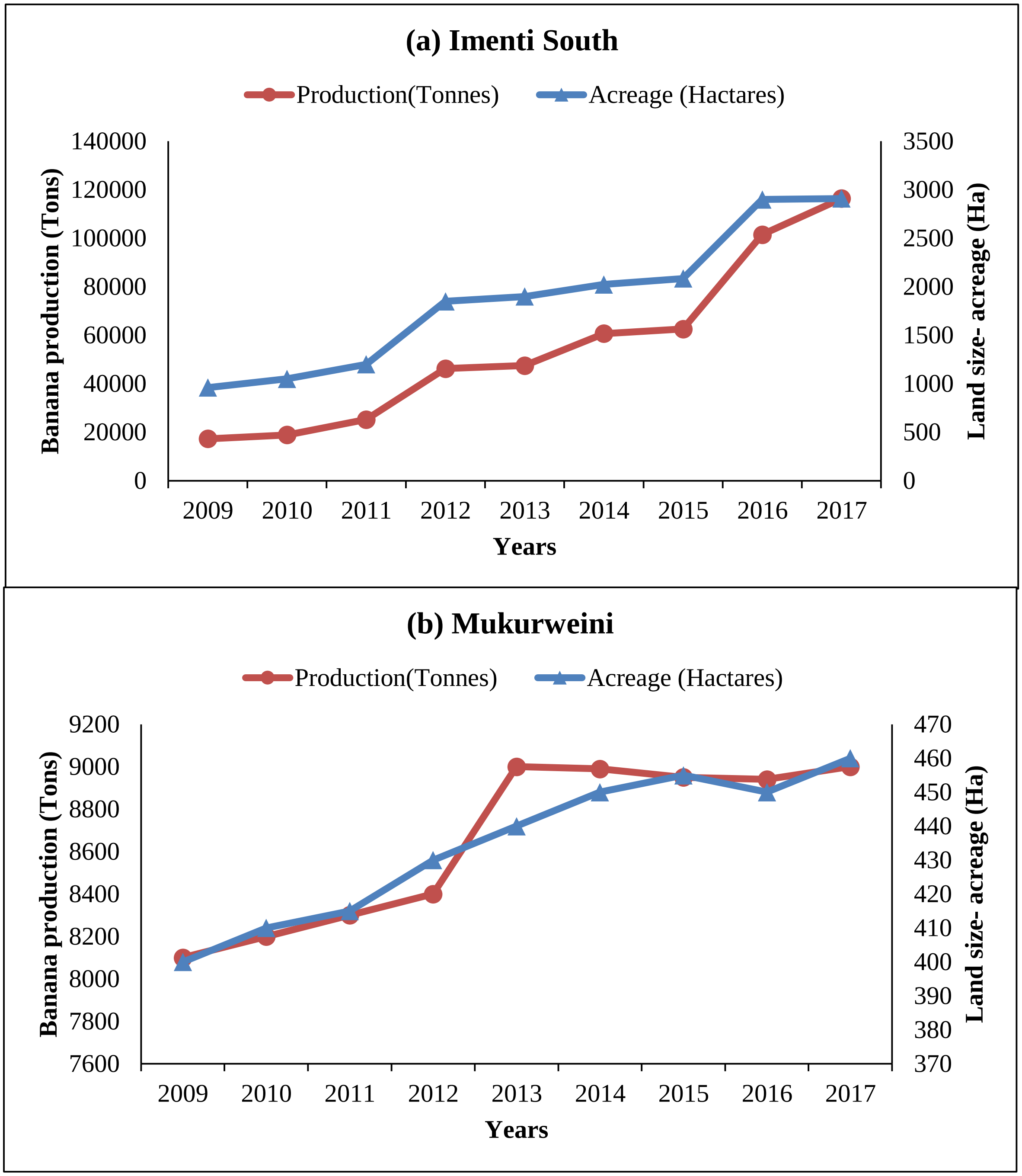

Figure 4.11: Trend of the changes in banana production against changes in acreage for (a) Imenti south and (b) Mukurweini sub counties

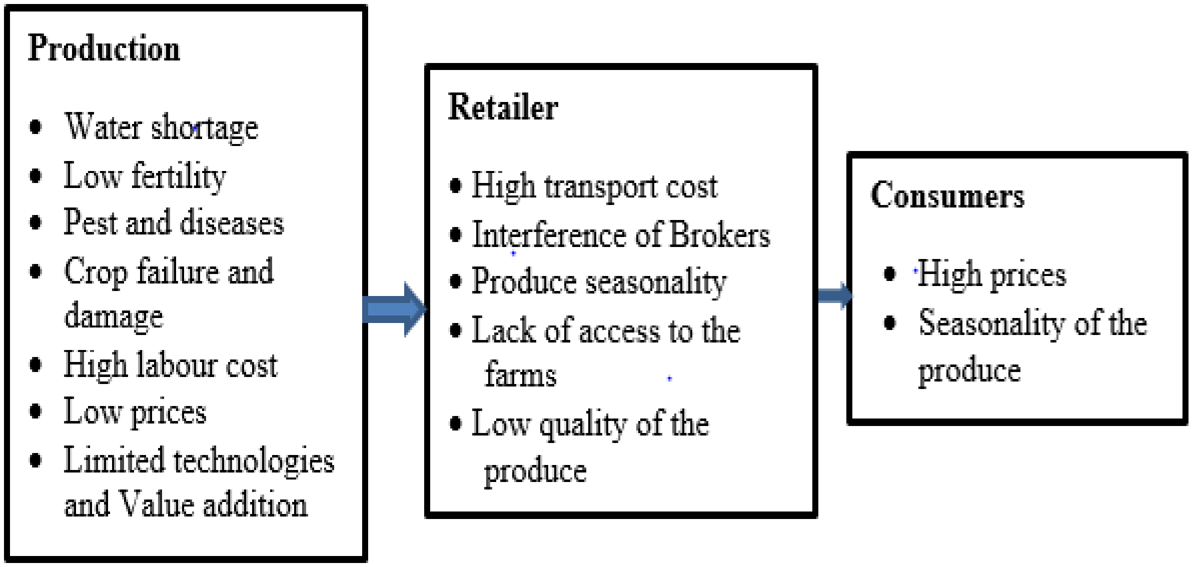

Figure 4.12: Climate variability impacts on Bananas value chain

At production level, climate impacts were associated with water shortages thus the need for irrigation, increased pest and diseases infestation, crop failure, high labour costs, lack of storage, post-harvest losses and associated low prices of produce (Figure 4.12). In between production and retiling transport occurred facilitating the movement of the produce. The consumers included all those who directly consume the bananas while in between the retailer and consumers there were other actors who facilitated the movements of the produce (transport) and trading.

In the second level, the impacts are related to retailers or the traders who buy the produce from farmers in order to sell them to the consumers. The retailers include the urban retailers, rural retailers and wholesalers. High transport cost also affected the movement of the produce especially during rainy season due to lack of access roads to the farms and the presence of brokers. The preceding level of impacts are felt by the consumers who depend on banana for consumption, this can be at household level or institutions mostly in the urban centers. Middle men played a vital role within the chain by connecting producers to the consumers despite manipulating banana pricing for their personal gain. Most of the produce is sold to middlemen and a few deliver them to the market where buyers from urban centers directly buy the produce. The impacts were negative and this required adoption of responses in order to lessen the vulnerability of the subsistence farmers.

CHAPTER FIVE

SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the summary of research results, conclusions and offer recommendations of the study.

5.2 Summary of the Research Findings

5.2.1 Banana Value Chain Trend in Mt Kenya Region

The study established that the main banana value chain actors in the region are small scale farmers (producers), local traders, market vendors, transporters, middlemen and facilitators. Farmers sell their produce to small-scale retailers (middlemen) who aggregate and sell to wholesalers who then transport and sell the produce to urban markets. Chain facilitators help in offering advisory services and coming up with relevant policies in order to enlighten the producer. At local setting women traders sell the produce at local markets or road sides.

Value addition on banana fruit has been limited in the region. Farmers argued that they have tried value addition on bananas but failed due to lack of market links for the processed produce. They also complained of long process of certification of banana products by Kenya Bureau of Standards. In addition, there is market restriction of the processed produce in the Kenyan markets.

5.2.2 Climate Variability Trends and Related Impacts on Banana Value Chain in Mt Kenya Region

The results from this study revealed that temperature has increased in the region during the period under consideration (1980-2017). Imenti south Sub-County was observed to be slightly warmer as compared to Mukurweini Sub-County with average annual mean temperature of 18.9^{0}C and 18.6^{0}C respectively (Figure 4.2; Table 4.3). The overall annual change in temperature in Mukurweini sub-county for the study period was 0.02^{0}C while in Imenti South was 0.016^{0}C which translates to 0.2^{0}C and 0.16^{0}C per decade respectively.

Rainfall in the region showed decreasing trends during the study period as shown in Figure (4.3) and Table (4.4). In the current study, the average rainfall for Mukurweini and Imenti South sub counties were on average 949mm and 1286mm respectively. The seasonal rainfall distribution showed that the MAM season received the highest amount of rainfall in Mukurweini (Figure 4.7b) while OND season recorded the highest amount of rainfall in Imenti South during the study period (4.7a).

5.2.3 Impacts of Rainfall and Temperature on Banana Production

In Imenti South Sub County, banana production increased from year 2009 as rainfall decreased until 2013 when rainfall reached 1500mm (Figure 4.5a). This could be attributed to introduction of new banana varieties and adoption of new systems of banana of production such as irrigation. In Mukurweini Sub County a unique observation was noted where rainfall increased in the year 2012 leading to drop in production Fig 11(b). This can be explained by the pest infestations and banana stool collapsing due to wind storms. In the study area, there exist a general trend whereby temperature increase led to a corresponding drop in banana production and as temperature decreases, increase in banana production was observed (Fig 4.6(a) and (b)).

Soil fertility was another factor affecting banana productivity in the region (Table 4.7). This could be explained in terms of soil nutrients level and its capacity to retain moisture. Presence of organic matter positively affect banana growth and disease suppression. Soil organic matter greatly enhances soil pH, water retention capacity and nutrient availability. The main impact of climate variability on banana farming in the region was concluded to reduce banana produce.

5.2.4 System of Banana Production and its Dynamics

The study found that 42.8% of the farmers had changed the crop type they were farming for the last 10 years. About 30% of the respondents in this study admitted having changed from other crops to banana production. This could be explained by reduction of coffee prices in the global market as well as high cost of coffee production. Many coffee growers shifted to banana growing after sustained periods of depressed coffee prices, mismanagement of co-operative societies, high cost of inputs and low productivity (GOK, 2002).

The study also revealed that the main system of banana production was both rainfed and irrigation. In Imenti South Sub County the production was mainly through irrigation and rainfed systems while in Mukurweini Sub County production was mainly rainfed. Use of irrigation in banana production increases the produce making banana fruit an all-year-round crop with constant harvest. Those farmers who depend on rainfed system of production face serious challenges brought about by climate variability leading to a decline in production as was observed in Mukurweini which depended on rainfed banana production.

5.2.5 Effect of Climate Variability on Banana Transport

The study revealed that climate had significant effect on transportation of bananas from the farms to markets or collection centres. The main mode of the transport from the farms was motorcycle "*boda boda*". The mode of transportation together with inefficient post handling of the produce leads to high levels of wastage and low quality of the banana fruit. The poor infrastructure mainly earth roads, during the rainy season are rendered impassable hence increasing the cost of transport from the farms to the market/collection centers. The distance travelled by majority of the farmers from the farm to the collection/market was less than 5km.

5.2.6 Effects of Climate Variability Dynamics on Processing Technologies and Value Addition

The study revealed that value addition strategy adopted by most of the farmers in Imenti South was banana cleaning. The study found that some banana farmers have formed cooperative union to produce banana wine and flour which was sold in various supermarkets in the region. This was however hindered by low investments in agro-processing, lack of business bureaucracy in produce certification and technical skills.

Findings from the study found that the main reasons for value addition was to increase the quality of the banana fruit, increase market demand and increase the shelf life. Good banana quality creates demand for the produce whether in the market or the consumers thereby fetching more money in the market. Banana fruit quality (size) determines the price (Dijkstra, 1997).

Banana in the study region is primarily grown for income and food. Banana farming as an agribusiness among smallholders is the key to economic empowerment and livelihood improvement among the rural community. Economic development of smallholders, mainly through increased agricultural productivity, has been recognized as a model to reduce poverty levels especially in rural areas (Birner & Resnick, 2010).

5.2.7 Effects of Rainfall Variability on Trading

This study demonstrated that changing climate had negative consequence on banana quality and trading. Banana consumption also varied with seasons hence affecting trading, during rainfall season consumption declined hence low market demands. On the other hand, during hot season ripening is fast and there is high consumption hence high demand. Extreme weather events whether rainfall or temperature are detrimental to the quality of produce. The study established that banana produce is not regulated by any recognized quality or safety standards in the market.

Farmers accessed market information mainly through calling middlemen and farmers. They connect farmers to the buyers and they act as middlemen between the farmers and buyer hence influence banana market prices. The middlemen involved possess market power; they trade highest volumes of banana and are more knowledgeable about prices both at the farm gate and in the urban markets (Niven *et al*., 2005). To delink the brokers from this dominance in banana trade, digital market information needs to be enhanced through e-platform and media such as radio.

5.2.8 Banana Farmers' Perception of Climate Variability and Its Impacts on Production, Transport and Trade

The study established that most of the respondents had a perception of how climate had changed in the region in the previous 20 years. Majority of the respondents 79% indicated that they perceived climate variability in the region. The respondents perceived climate variability to mean unpredictable rainfall whose effect was low or declining banana production. Thus, low rainfall, excessive rainfall and low temperature or very high temperature affect the productivity of banana.

Transport of banana produce varied due to the climate inconsistency. During the wet and rainy season, transport charges were high from the farm to the market or collection points because the farms were rendered inaccessible. Studies conducted by Technoserve (2004) on perishable produce found that transportation and poor handling practices leads to high post-harvest wastage as well as change in the market demand. The study concluded that farmers perceive the effect of climate variability on banana trading as low market prices during rainy spell while during dry season it was low quality for the produce. During the rainy season there is high banana supply in the market leading to low demand while during the dry spell banana produce is of low quality and of small size.

5.2.9 Socio-economic Factors Influencing Farmers Perception on Climate Variability

The results of Multinomial Logit model revealed that the gender of house hold, type of farming system coupled with access to meteorological information were significant in explaining the farmers' perception of climate variability in the last 20 years in Mt Kenya region. In Mukurweini Sub County farming practice exceptionally influenced the way farmers perceived climate variability while age of household, Agro-Ecological Zone and acreage under banana production were significant in explaining the farmers' perception of climate variability in Imenti South Sub County.

Gender of the household head was significant and negatively influenced farmers' perception to climate variability. Female headed households who practised banana production identified more with variations in rainfall amounts and temperature levels than male dominated households. This is because farm activities are mainly undertaken by women but income goes to men. The farmers who depended on rainfed banana production perceived climate variability due to the unpredictability of rainfall seasons leading to untimely planting hence crop failures and reduced yields.

Access to weather information such as information on seasonal and daily weather forecasting (i.e., temperature and rainfall) had substantial effect on the likelihood of varying crop types and even changing planting dates. The study observed that farmers would wish to receive weather forecast information like rainfall onset during the season and rainfall distribution within the seasons. The results suggest that accurate and timely weather forecast is necessary to enhance timely planning and shifting planting dates to correspond to the season hence less crop failure.

5.2.10 Analysis of Climate Variability Adaptation Strategies Among Smallholder Farmers

Perception is essential precondition for adaptation among subsistence farmers. Adaptation depends on whether farmers perceive the existence of climate variability. In this study four adaptation strategies were identified which included planting of drought tolerant banana varieties, crop diversification, shifting planting dates and use of irrigation to enhance production. The study recognized that irrigation and crop diversification were most ideal adaptation strategies to banana farmers in the region. Farmers treasure irrigation as the option to unreliable and unpredictable rains within the seasons while crop diversification offered an alternative source of income and food if banana crop failed.

5.2.11 Socio-economic Factors Influencing Adaptation to Climate Variability

The only sure way of addressing the adverse impacts of climate variability is through proper adaptation measures. Though, socio economic factors greatly influence farmers' ability to adaptation. In this study, gender of household and farming system, were significant in explaining the farmer's adaptation to drought tolerant banana varieties and crop diversification in the study region. Level of education and perception to climate variability were significant in Mukurweini while land ownership, land under banana and access to financial services were significant in explaining the farmer's adaptation to drought tolerant banana varieties in Imenti South Sub County.

Gender of the household positively and significantly influenced farmers' adaptation to drought tolerant banana varieties. Male dominated households are likely to embrace drought varieties since they're the ones who make farming decisions and possess the land rights. Men attend agricultural workshops and Barazas that disseminate information on new varieties and have purchasing ability. This explains why male dominated households adopted new varieties more readily that women. It was noted that female headed households adopted crop diversification as an adaptation strategy compared to male dominated households. This can be attributed to the fact that female diversify their source of livelihoods to provide food as well as source of income to basic household goods in the family.

Farming system negatively influenced farmers' adaptation to drought tolerant banana varieties. Farmers who relied on rainfed banana production adopted drought tolerant banana varieties and practiced crop diversification as compared to those who practice both irrigation and rainfed banana production. These farmers have limited options for commercial crop production. The farmers could inter crop the banana with other food crops to safeguard them in case one crop fails due to climate related issues such as water deficiency or pest and diseases. Given the over-reliance on rain fed agriculture, the opportunity which seems to exist include intensifying production of drought tolerant banana varieties and crop diversification.

Banana planting should occur at the beginning of the rainy season; the suckers need 4-6 months to grow without water stress. Changes on the onset dates during the rainy season result to farmers shifting planting dates to avoid crop failure. The reason behind such practices is that they involve little capital to implement such as training and information dissemination whereas other practices need huge investments in time and cash. In this study, farmers who had large land sizes adopted to shifting banana planting dates as compared to farmers who had small sizes of land. This can be elucidated by the element of the large land size which facilitated shifting of the planting dates in portions.

Irrigation as an adaptation strategy require greater investments but hold high returns in banana productivity. It was revealed in this study that farmers who accessed extension services on banana production adopted irrigation as compared to those farmers who never accessed extension services. This is due to the awareness and skills gained from the extension officers on irrigation as an alternative to rainfed production. Through workshops and seminars farmers are trained on the irrigation techniques as means of increasing productivity. Farmers who were mindful of climate variability impacts on banana production practiced irrigation to safeguard their productivity and to ensure year-round produce. Further, households with access to financial facilities preferred irrigation as an adaptation strategy. Irrigation requires capital investment which has financial implications. Establishing links with banks and microfinance institutions to provide credit and loans to farmers to invest on irrigation equipment is important. Research conducted on adoption on agricultural technologies showed that there exist a positive relationship between the level of adoption and the availability of credit (Yirga, 2007).

5.2.12 Extent to which Rainfall and Temperature Impact on Banana Value Chain in the Study Region

The observed trend in the study area showed increased yield and acreage of banana production from 2009-2017. This is due to the existing demand of bananas produce in the urban areas and coffee farmers uprooting their crop. The decline in global coffee prices also contributed to the demand of banana within the region as a cash crop. At the local level, banana production can be attained without much inputs thereby less costly to produce among the small holders' farmers as cited by FGDs in Imenti South Sub-County (Plate 1). Unique observation was noted in the study region showing production decreases with increase in the amount of rainfall, the reason being high amount of rainfall comes together with pest and diseases while storms destroy banana crops hence decline in banana yields. The law of diminishing returns is also applicable for this case; whereby every crop has the maximum amount of rainfall that gives maximum yields. High rainfall does not necessarily translate to high banana yields. Rainfall pattern is also crucial in banana production.

The extent of climate variability impact on banana value chain can be explained under three levels mainly production, retailer/trading and consumption. The impacts are so severe at production level. This calls for adaptation strategies to reduce the level of vulnerability among the subsistence small holders' farmers. Value addition and presence of processing technologies are some of the mechanism that can help uplift the farmers in terms of generating high income as well as rising the banana market demand.

5.3 Conclusion

The study concludes based on the research objectives that;

Climate has been changing during the study period between 1980 and 2017. The overall annual change in temperature in Mukurweini Sub-county for the study period was 0.02^0C while in Imenti South was 0.016^0C which translates to 0.2^0C and 0.16^0C per decade respectively. Rainfall has been declining in Mt Kenya region too during the study period 1980-2019. These trends in climate are expected to negatively affect banana productivity in the region hence food insecurity will persist unless precautionary adaptive measures are taken. These adaptive measures, both at the local farm level and county levels are necessary to reduce the potential negative effects associated with these changes in temperature levels and precipitation amounts.

Banana production decreases with increase in the rainfall amount in the study area. Rainfall distribution is important leave alone the rainfall amount. High rainfall events sometimes accompanied by strong storms destroy banana and increase incidences of pest infestations and diseases hence low yields. Banana value chain starts from the farm level where smallholder farmers produce bananas and sell their produce to small-scale retailers (middlemen) who aggregate and sell to wholesalers. A few farmers practice value addition to their produce and thus earn more income from their produce.

The major impact of climate variability on banana productivity in Mt. Kenya is reduced banana yields. The reduced yield can be viewed in two perspectives, firstly low rainfall hence reducing the banana productivity and also low quality of produce leading to banana with small bunches referred to as “seketa” and on the other hand high temperature led to damage of banana crops and also host pests and diseases leading to decline in yields. High rainfall and storms led to damage of the banana stool and infestation of new pest and diseases leading to low yields. Other additional factor affecting banana productivity in the region was soil fertility. Soil fertility is affected by the presence of pest and diseases in the soils while high soil temperature permits the spread of panama disease in the soil, hence affecting banana production negatively.

The study revealed that many farmers had changed the type of crop they were previously farming and embraced banana farming. This was due to the fall of coffee price in the global market as well as high cost of inputs for coffee production. Farmers therefore opted banana production as source of steady income and food for the household due to its perennial nature and the possibility of year-round harvest. The main systems of banana production system were both rainfed and irrigation in the study area.

High transport cost to farms was another effect on banana production arising due to climate variability. The presence of earth roads in the region during the rainy season made roads impassable to the farms hence increasing the cost of transport from the farms to the market/collection centers. This was the case in some parts of Mitunguu and Kaheti in Imenti South and Mukurweini Sub Counties respectively. The County government need to maintain the feeder roads to all weather status in order for the farmers to access the banana market /collection centers. The farmers have opted for motorcycle “boda boda” as the main mode of banana transport from the farms to the collection centres.

Climate variability developments has led to innovations in value chain of the banana produce though it is minimal due to the complicated procedures involved during marketing and certification of the products. At local and households level, ripening was preferred while cleaning made the banana fruit appealing to the consumers. Ripening and cleaning increased quality and hence demand of bananas thus leading to competitive market prices. Low quality of banana fruit as a result of extreme weather events (rainfall and temperature) led to lower market value of the produce. Some of the shortfalls of these approaches entails lack of market information, bureaucratic procedure, price glut, delink of stakeholder involvement, climate variability challenges and in the event of these outcomes, the smallholder farmer is at the losing end.

Banana farming has enormous potential to benefit not only producers but other actors along the value chain. However, several interdependent constraints that amplify each other, inherent in the chain, hinder the realization of the benefits. The constraints include; small farms, inadequate irrigation water, inadequate know-how on banana management, low production, limited price information, lack of controlled market, limited value addition, low selling prices and poor roads to the farms. It is therefore important that interventions be made from the County government, national government and other actors in order to comprehensively address these constraints.

Farmers accessed market information through calling brokers or other farmers to determine the selling prices for the produce. However, this information was not sufficient as brokers collude with buyers on the price of the produce and encourage banana theft during market days. To counter this, market information need to be enhanced through e- platforms such as e-shamba and social media to keep farmers more informed on banana pricing.

Farmers' perceived the effect of climate variability on banana production as low or decline on yields and quality, and escalated transport cost. Socio- economic factors such as gender of household head, type of farming system and access to weather information also influenced the perception of the farmers. Male headed households perceive the effect of climate variability differently when compared to females. Farmers preferred that future weather information on banana production to be onset of the rainfall season and distribution within the seasons. This would enable farmers to plan their planting calendar through shifting of the planting dates to correspond with the seasons.

Farmers adapted to climate variability in various ways including planting of drought tolerant banana varieties, crop diversification, shifting planting dates and practicing irrigation to enhance production. The study found that irrigation and crop diversification were the most preferred adaptation strategies to banana production in the region. Socio-economic factors influencing adaptation of drought tolerant banana varieties and crop diversification included gender of household and farming system. Shifting of banana planting dates depended on farmers land size and land under banana production while access to extension services and financial facilities were significant in explaining the farmers' adaptation to irrigation as an adaptation strategy.

In order to address the small holders' constraints, providing climate information to farmers is critical. This will enhance proper adaptations strategies such as irrigation, encouraging crop diversification and adoption of validated varieties of crops in different Agro ecological zones. These might be effective in enhancing resilience of farming in the short-term. At a farm level, policies that allow establishment of farmers groups are required in the efforts to promote competitive marketing of the banana produce.

Likewise, important policies that are meant to improve the livelihood status of the individual's household should be encouraged such as crop diversification. These might increase innovativeness and contribute to better adaptations. Social safety nets are useful at lower levels of adaptations. Increasing provision of credit is required to improve long-term adaptive transformation. Huge venture in human resource, social and physical wealth, soil management, water conservation and land use management practices are equally required to achieve this.

The acreage under banana production has been increasing in the study region from 2009 to 2017. This is as a result of increased demand of banana produce in urban and peri urban area for hotels and also big institutions such as schools and hospitals. Banana being perennial crop provides steady source of income and food to the family possibly all year round.

Nevertheless, the future of banana production in Mt Kenya may not be predicted especially in Imenti South Sub-County due to challenges associated with bananas production, especially unavailability of water and unstable markets. Farmers are opting to reverse to coffee farming due to new prices and the new amended Coffee Act which has positively transformed coffee value chain since February 2014 in Meru County. The County government has started coffee milling, branding and marketing hence rising the market prices. Many others farmers are opting to dairy farming.

The study concludes that smallholder rural farmers in Mt. Kenya region seem to be fabricating perceptions on climate variability which are consistent with realism hence taking up adaptation strategies which are available and affordable to cope up with the diverse impacts of climate variability. Thus, there is essential need to put in proper mechanisms along the banana value chain that will advance banana productivity and encourage societal adaptations to the imminent and uncertain to climate variability conditions.

5.4 Recommendations

The study proposes the following recommendation in the banana value chain: -

- At the banana production level, the study proposes water harvesting to aid in irrigation, planting resistance and drought tolerant banana varieties and crop diversification with crops that consume less water such as avocado or mangoes should be encouraged. Regarding transport, access to road networks to market/collection points from farms should be improved to all weather roads. The transportation of bananas from collection centres sites (farms) to urban centres should be done with suitable transportation system, proper handling and controlled temperature to reduce damages that could lower the banana quality.

- At marketing level, market information from other traders and from urban market should be provided so that farmers can get the banana prices from the urban markets and thus reduce the involvement of brokers/middlemen. To enhance value addition of the produce, new outlets should be opened for the processed products, currently there is limited market for the produce.

- The County government should include the following in banana policy formulation and trade in the region; organize market, search for banana markets outside the region and regulate the markets. County trade policies that encourage cooperatives/ farmers group should be operationalized and supported to form consortium for banana produce.

- The County government should assist the community in establishing irrigation projects in the region to allow farmers access water for irrigation. The irrigation projects will address water shortages and tap into the County's irrigation potential. This will guarantee high yields and year-round harvest. To reduce declining soil fertility caused by soil erosion, soil and water conservation measures should also be up-scaled.

- To address disease and pest incidences, farmers need to control them through proper crop husbandry practices. Farmers should invest in reducing postharvest losses that result from high rainfall and perishability of the produce. Alternative crops should also be introduced to diversify the crops grown to avoid over relying on banana which might be vulnerable to climate variability.

- The County government should motivate and support farmers to embrace banana value addition in the region by setting up banana processing factories for wines, crisps and flour, certification training and market of produce so as to enhance the welfare of residents. This will enhance the potential of smallholder farmers to fully exploit the opportunities in banana value chain. This will create employment opportunities for the youth on either permanent or temporary basis.

- Access to finances is critical to improve the level of farmers' participation in the banana value chain. The small holder farmers have challenges in obtaining working capital and they require affordable credit facilities. The County governments should articulate policies on affordable credit to small-scale farmers within the region such as Uwezo or Youth Funds.

- Market information is critical for the growth of agricultural marketing. It is important for the public agricultural extension officers and providers to integrate market information in the electronic platform.

- Investment in infrastructure such as roads, electricity and storage facilities need to be increased. This would serve as an incentive to farmers to increase agricultural productivity. To increase the farmers' involvement in produce marketing groups both the public and private sectors need to participate through creating awareness to the farming groups on the socioeconomic benefits associated with farming groups.

- With the rising incidence of climate related impacts, institutional capacity to adjust to these changes need to be enhanced. The County government should provide adequate budget provisions to enable them undertake climate risk management activities. This should be accompanied by policies and interventions anchored in the county development plans, to provide an enabling framework for various stakeholders in climate risk management and to coordinate and work together towards strategies that help farmers manage climate variability. Additionally, there should be concerted efforts in sharing information among the various stakeholders regarding the planning and implementation of climate risk management strategies and improving efficiency and effectiveness of interventions. Adaptation strategies should be integrated into core development policies, strategies and plans. Integrated Policymaking approach (IP) should be adopted, which takes into consideration economic, social, and environmental variables.

- This study further recommends up-scaling of available climate adaptive inputs, technologies and production strategies including success stories in relevant agro-climatic zones. Market access improvement activities should be encouraged to ensure small-scale farmers deliver crops at a fair price to market in the face of changing climate. The counties should contribute to the development of climate information sharing and knowledge management systems; strengthen collaboration between Ministry of Agriculture, Kenya Meteorological Department and others; enhance capacity for agro-meteorological information provision and ensure effective service delivery mechanisms including climate smart extension.

- The region should embrace Climate Smart Agriculture with more emphasis being on Climate Smart Crops which can endure the changing climate.

5.5 Areas for Further Research

- Comprehensive studies should be conducted on adoption of public-private partnership approaches, explore engagement with private sector and the role of partners in designing policy and programmes aimed at supporting growth of the banana value chain.
- More research on controlling banana disease and pests should be initiated in relationship with the changing rainfall and temperature within the region, this will ensure proper control of the diseases and pests that affect the farmers hence increasing banana yields in the region.
- Further investigation is required to ascertain the impacts of numbers of rainy days in each year on banana value chain in the region.
- A comprehensive study need to be conducted on the role of relative humidity on the growth and production of bananas within the region.

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APPENDICES

Appendix 1: Questionnaire

This questionnaire is part of my research studies at Karatina university and targets banana farmers in Imenti South and Mukurweini Sub-Counties within Mt Kenya region. The purpose of the survey is to obtain views, experiences and suggestions of farmers on the determinant of banana value chain induced by climate variability. It will explore on banana production and how these changes have influenced the farmers' production, adaptations and other business actors in the banana value chain. Based on the results of the study, recommendations will be made on how to improve the conditions of farmers in future in policy formulation in the light of climate variability.

You have been selected as one of the participants in this study to assist in providing information. You are requested to feel free to answer all of the questions asked or decline in any instance you may not wish to. Your name will not be quoted in the findings of this study. Furthermore, the information you provide will be used strictly for academic reasons and your confidence will be upheld.

Otherwise, you are very welcome to answer the questions that hereby follow.

SECTION I

Please fill the blank spaces at the end of each item or simply tick where appropriate.

DEMOGRAPHIC DATA

1. Give the name of your:
   Location…………………………Number of year of banana farming_______
   Sub-location………………………………………..
   Village……………………………………………..
2. Indicate the gender of the household head: a.Male … b. Female……
3. Indicate your age in groups below in years
   a) Below 20 years ………………………
   b) 21 – 30 years ………………………
   c) 31- 40 years ………………………..
   d) 41- 50 years ………………………..
   e) 51-60 years …………………….
   f) Above 61yrs
4. Indicate the type of farming you practice
   a) Cash production …………..
   b) Food production ……………
   c) Mixed farming………………

d) Horticultural farming…………………

5. Apart from Bananas, indicate the other types of crops you grow;
   a) Maize
   b) Tea
   c) Coffee
   d) Others (Specify)
6. Tick the approximate size of your land in acres and the percentage area under bananas crop.

   Land less 2 …………. Cultivated portion ……………….
   Land 2– 4 …………. Cultivated portion……………….
   Land 4 – 6 …………. Cultivated portion……………….
   Land 6 – 8 …………. Cultivated portion……………….
   Land more 8acres ………… Cultivated portion……………..

7. Indicate the method you use to grow your bananas;
   a) Rain fed
   b) Irrigation
   c) Both rain-fed and irrigation
8. If irrigation, where is the source of water?
   a. Rivers ………… Name ………………………., ……………………..
   b. Borehole …………………..
   c. Dams
   d. Water tank
   e. Any other source, state ……………………..
9. Indicate the types of crops you were growing and its proportion in the farm ;

LAST NUMBER OF YEARS	CROPS	PROPORTION
40		
30		
20		
10		
PRESENT		

10. What drives you in banana farming
    a) Market demand/High market prices
    b) Loss of coffee prices
    c) Diversification of crops
    d) Favourable climatic conditions
11. What are the main purposes of growing bananas?
    a. Domestic consumption
    b. For market
    c. Both consumption and market
12. In the last 20 years, have you changed your crops portion? 1. Yes 2. No
    If Yes why…………………………………………….

SECTION II

ECONOMIC SCALE

1. Which is the main source of labour in your banana production?
   a) Family members
   b) Hired labour.
   c) Both family and hired
2. Indicate where you sell your banana produce and proportion during rainfall and drought

Where do you sell	Rainy season	Proportion	Drought	Proportion
Neighbors /Farm gate				
Local market				
Middle men				
Cooperative union				
Factory				
Supermarket				

3. Do you get information on banana market prices?
   a) Yes
   b) No
4. **If Yes proceed to Q 5 and If No proceed to Q 9**
5. How do you get market information?
   a) Calling other farmers
   b) Calling brokers
   c) Radios
   d) Cell phones
   e) Others………………….
6. Do you normally make use of market information to guide your banana selling decisions?
   a) Yes,
   b) No
7. How often do you receive this kind of information?
   a) Daily,
   b) Weekly,
   c) Monthly
8. What is your perception on the relative importance of this information?
   a) Very useful,
   b) Useful,
   c) Not useful
9. Are you a member of group/society dealing with banana production and marketing?
   a) Yes
   b) No
   If No why

i. Poor leadership and management
ii. Delay in payment
iii. Lack of strategies to find banana market

10. How far is the Banana market from you farm?
    a. Less than 5 Km …………
    b. 5 Km – 10 Km …………..
    c. 10 Km – 20Km ………….
    d. Over 20 Km …………..
    Nearest town Name……………….
11. How do you transport your banana produce from farm to gate level
    a) Family labour
    b) Hired labour
    c) Others-------
12. How do you transport you farm produce from farm to the selling/collection points/Market?
    a) Human labour ……………..
    b) Hand carts ……………..
    c) Donkey/ cow carts ………….
    d) Motor cycles ……………..
    e) Pick-ups ……………
    f) Lorries …………………….
    g) others …………

13. Which is the type of infrastructures from your farm to the market
    a) Tarmac
    b) All weather
    c) Seasonal roads
14. Do you get financial assistances (loans)?
    a) Yes ......….. From Banks………..
        a. From SACCO …………
        b. NGOs ……………………………
    b) No …………
15. Approximately how much do you spend on banana farming per annum, per acre?
    a) Less than Sh 5000 ………………..
    b) Sh 5001 – Sh 10,000 …………………
    c) Sh 10001 – Sh 20,000 ……………….
    d) Shs over 20,000 ……………….
16. How many acres of land are under banana farming…………
17. What is the production per acre per annum(Kg).......................selling price per kg............
18. Which strategies do you use in banana production to add value?
    a. Cleaning

b. Packaging
c. Producing flour
d. Crips
e. Producing wine
f. Others………..

12. What is the main purpose of value addition?
    a) Last longer
    b) Easy portability
    c) Increase quality
    d) High market demand

C. CLIMATE RELATED ISSUES AND FARMERS PERCEPTION

1. Have you observed any significant changes in rainfall and/or temperature over the last 20 to 30 years?
   a. Yes,
   b. No

2. Do you receive any information on predicted weather conditions?
    a) Yes
    b) No

3. If yes, proceed to question 4. If no, proceed to question 10.

4. Where do you get such information from?
    a) Extension officer
    b) Radio
    c) Cell phone
    d) Others……………………..
5. Do you normally make use of the weather forecast information to guide your banana farming decisions?
    a) Yes,
    b) No
6. How often do you receive this kind of information?
    a) Daily,
    b) Weekly,
    c) Monthly
7. What is your perception on the relative importance of this information?
    a) Very useful,
    b) Useful,
    c) Not useful
8. What are the **main** means of obtaining weather forecast information?
    a) Radio,
    b) Television,
    c) Verbal message,
    d) Mobile phone,
    e) Internet [email, website],
    f) Print media e.g. newspapers,
    g) Others [Specify…………………………………………………..]
9. Is the information provided timely?

a) Yes,
b) No

10. What **main** kind of relevant information would you like to receive in future weather forecasts that is currently not provided or is inadequately provided?

Type of information	**Tick ONE main type**
Onset of rains	
End of rainy seasons	
Distribution of rainfall within seasons	
Occurrence of floods	
Other (Specify…………………….……………….)	

11. What do you understand by climate variability?
    a) Unpredictable rainfall
    b) High temperatures
    c) Low rainfall
    d) Low temperature
    e) Drought
    f) Others…………………………..
12. How does climate variability affect agricultural production?
    a) Low production
    b) High production
    c) Unpredictable seasons
    d) Pest and diseases infestation
    e) High production

13. What are the effects of climate variability on banana production?
    a) Water shortage
    b) Changes in planting season
    c) High labour cost
    d) Pest and diseases infestation
    e) Low yields
    f) Delay in harvesting
14. What are the effects of climate variability on banana transport?
    a) High transport cost
    b) Lack of accessibility to farms
    c) Poor handling affecting quality
15. What are the effects of climate variability on banana marketing and distribution?
    a) High market demands
    b) Low market prices
    c) Low quality of produce
16. According to your observations in the last 10 years plus, what changes have you noticed in:
    a. Rainfall amounts 1 Generally increasing 2. Generally reducing

b. Rainfall patterns 1. Generally reliable 2. Generally unreliable
c. Temperature levels 1. Generally increasing 2. Generally decreasing
d. Droughts frequency 1.Constant 2. Changing/Increasing
e. Water availability 1 Constantly available 2. Decreased/Scarcity

17. Which season do you have high banana produce?
    a) Jan- March
    b) April-June
    c) July-Sept
    d) Oct-Dec
18. Which season do you have lowest banana produce?
    a) Jan- March
    b) April-June
    c) July-Sept
    d) Oct-Dec
19. What are the adaptations strategies have you adopted to cope with impacts of climate variability?
    a) Irrigation
    b) No adaptation
    c) Crop diversification
    d) Early planting dates/Shifting planting dates
    e) Drought tolerant varieties

Please respond to the following statements in relation to your abilities and knowledge. Record your answer by circling 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

Part I

	PRODUCTION	**1**	**2**	**3**	**4**	**5**
1	I feel am improving my economic status from banana farming					
2	I get banana farming advice from the extension officers					
3	I require a lot of capital to farm bananas					
4	I have desired to increase the farming portion in future					
5	I rely on rain fed to produce my bananas					
6	I feel I should attend agriculture seminars/ trade fairs to improve my bananas farming skills					
7	Farming bananas crops is very demanding					
8	There is need to incorporate new/ modern farming methods					
9	Pests and diseases are affecting my banana production					

10	High rainfall increases the crop productions					
11	Low rainfall reduces /lowers the crop quality					
12	High temperatures reduce banana quality					
13	Low temperature reduces production					
14	**During hot season diseases and pests' infections are high**					
15	I use water conservation method to produce my bananas					
16	I get credit facilities to assist in my bananas farming					
17	The county government supports bananas production					
18	Pests and diseases reduce the crop production and quality					
19	Frequent dry period lowers quantity and quality of production					
20	My banana production relies on family labour					
21	Application of manure increases production					
22	I use weather forecasting information in my banana production					
23	Value addition of my produce fetches high prices					
24	I carefully time the planting season when planting bananas					

Part II

	TRANSPORT					
1	During dry spell transport charges are low					
2	Transport charges are likely to be high during rainy seasons					
3	Proper road network improves banana availability to the market					
4	During rainy season transport is not available					
5	Poor transportation facilities reduce banana quality					
6	I use of refrigerated trucks to transport my bananas.					
7	During rainy seasons I use motorcycle or human to transport my bananas to market					
8	Proper packaging of my produce eases transportation					
9	Transporting as a group is cheaper					
10	Bananas handling affects quality					
11	During dry season I use vehicles					
	MARKETING AND DISTRIBUTION					
1	The marketing body (Cooperatives, Brokers…..) help in marketing produce					
2	I sell my bananas at farm gate					
3	Selling to middlemen makes banana farming less profitable					
4	During rainy season banana are not available to the market					
5	During rainy season, bananas are cheap at farm level					
6	During dry season banana are expensive in the market					
7	Market/demand for banana are assured during dry spell					
8	Selling direct to traders fetches more profit					

9	Farming of banana makes me earn reliable and stable income					
10	Farming of banana makes me food secure					
11	Value addition increases banana demands and price					
12	During dry season I sell direct to the traders					
13	During rainy spell I sell to middlemen					
14	Proper packaging of bananas increases banana quality and demand					
15	Bananas price is influenced by the quality					
16	Market standards influence banana prices					
17	I sell my banana on cash					
18	During rainy seasons the banana demands are high					

THANKS FOR YOUR PRECIOUS TIME

Appendix 2: HDC/Extension officers Interview Schedule

This questionnaire is part of my research studies at Karatina University. Its goal is to analyse the challenges of Climate variability on production of bananas and how these changes have influenced the farmers' production, the gender relations within the family and their relation to other business actors in the banana value chain. Based on the results of the study, recommendations will be made on how to improve the conditions of farmers in future.

You have been selected as one of the participants in this study to assist in providing information. You are requested to feel free to answer all of the questions asked or decline in any instance you may not wish to. Your name will not be quoted in the findings of this study, unless you so wish. Furthermore, the information you provide will be used strictly for academic reasons and your confidence will be upheld.

Otherwise you are very welcome to answer the questions that hereby follow.

SECTION I

In-depth Interview

Please fill the blank spaces at the end of each item or simply tick where appropriate.

DEMOGRAPHIC DATA

1. Give the name of your job title……………………………………………….
   Region in charge……………………………………
   Location……………………………………..
   Village…………………………………………..
2. Indicate your age in groups below in years
   a) Below 20 years ………………………
   b) 21 – 30 years ………………………
   c) 31- 40 years ………………………..
   d) 41- 50 years ………………………..
   e) 51-60 years …………………….
   f) Above 61yrs
3. Which the type of farming does the majority of residents practice
   a) Animal production …………..
   b) Poultry production………………
   c) Crop farming…………………
4. Indicate the types crops you grown starting with the most popular
   Explain why in 4 above
5. Indicate the approximate size of land in acres of majority and the area under bananas cultivated portion.
6. Indicate the method you used to grow banana;
7. If irrigation, where is the source of water?
   If Rivers ………… Name ……………………., ……………………..
   Any other source, state ……………………..

8. Indicate the types of crops you farmers have been growing and its proportion in the farm;

LAST NUMBER OF YEARS	CROPS	PROPORTION
40		
30		
20		
10		
PRESENT		

9. What are the main purposes of growing bananas in order of priority?
10. Do financial institutions give financial assistances (loans) to banana farmers?
11. Can you comment on the trends of banana production in this region for the last 30 years (Explain)?
12. In terms of land under bananas has it changes for the last 30 years (Explain)
13. How do farmers transport their bananas to the selling points?
14. Is banana transport affected by climate variability?
15. Which are the major bananas markets in the region?
16. To whom do banana farmers sell their produce?
17. What is the approximate cost of producing one acre of bananas per year?
18. How much can one acre of banana produce per year……………….(Kg) and price per Kg………..
19. What is the type of infrastructures to the market from the farm
20. In your own opinion in the last 20 years, have you changed the banana farming practices? Explain why
21. Have you observed any significant changes in rainfall and/or temperature over the last 20 to 30 years? Explain
22. Do farmers receive any information on predicted weather conditions? If YES how do they receive?
23. Do farmers normally make use of the weather forecast information to guide your farming decisions
24. If YES above How often do you receive this kind of information?
25. What is your perception on the relative importance of this information?
26. What is the **main** means of obtaining weather forecast information?
27. Is the information provided timely?
28. What **main** kind of relevant information would you like to receive in future weather forecasts that is currently not provided or is inadequately provided?

Type of information	**Tick ONE main type**
Onset of rains	
End of rainy seasons	
Distribution of rainfall within seasons	
Occurrence of floods	
Other (Specify…………………….…………)	

29. According to your observations in the last 10 years plus, what changes have you noticed in:

a. Rainfall amounts 1 Generally increasing 2. Generally reducing
b. Rainfall patterns 1. Generally reliable 2. Generally unreliable
c. Temperature levels 1. Generally increasing 2. Generally decreasing
d. Droughts frequency 1. Constant 2. Changing
e. Water availability 1 Constantly available 2. Decreased/Scarcity

30. How is labour pricing affected by
    a) High rainfall
    b) High temperatures
31. What is farmers perception on climate variability (rainfall and temperature)
32. Comment from your opinion the changes in banana production arising from
    a) Low rainfall amount
    b) High rainfall amount
    c) Temperature rise
    d) Rainfall predictability
    e) Temperature fluctuation
33. Has banana production been affected by these climatic changes, how and to what extent?
34. Which season do you have lowest banana produce?
    a. Jan- march
    b. April-june
    c. July-sept
    d. Oct-dec
35. Which season do you have highest banana produce?
    a) Jan- march
    b) April-june
    c) July-sept
    d) Oct-dec
36. Has banana transport been constrained by changing climate?
37. How is banana marketing and distribution affected by climate variability?
38. Is there ny relationship between climate variability and banana availability in the market
39. Does banana production relate to food security in this region?
40. Mention the major banana value chain actors in the region?
41. Outline the roles and characteristics of the (40 above)
42. In your person opinion using diagram illustrate the banana value chain that exist in this region
43. What adaptations strategies have you adopted to cope with impacts of climate variability on banana production?
44. What ways do the following actors add value/process the banana fruit
    a) Farmers
    b) Transporters
    c) Traders
45. How does the County government support banana farmers (in which ways)

46. As farmers what recommendations would you give to future banana producer in light with the changing climate
    a) Production
    b) Transport
    c) Marketing
    d) Value addition
47. Which recommendations can you suggest to the county government regarding banana policy formulation in light to the changing climate?

THANKS FOR YOUR PRECIOUS TIME

Appendix 3: Focus Group Discussions Interview Schedule

This questionnaire is part of my research studies at Karatina University. Its goal is to analyse the challenges of Climate variability on production of bananas and how these changes have influenced the farmers' production, the gender relations within the family and their relation to other business actors in the banana value chain. Based on the results of the study, recommendations will be made on how to improve the conditions of farmers in future.

You have been selected as one of the participants in this study to assist in providing information. You are requested to feel free to answer all of the questions asked or decline in any instance you may not wish to. Your name will not be quoted in the findings of this study, unless you so wish. Furthermore, the information you provide will be used strictly for academic reasons and your confidence will be upheld.

Otherwise you are very welcome to answer the questions that hereby follow.

SECTION I

Please fill the blank spaces at the end of each item or simply tick where appropriate.

DEMOGRAPHIC DATA

1. Location of the FDGs………………………………………………..
   Location………………………………………..
   Village……………………………………………..
   No of participants
2. Indicate the types crops you grown starting with the most popular
3. Indicate the approximate size of land in acres of majority of the farmers and the area under bananas cultivated portion.
4. Indicate the method you used to grow banana;
   If irrigation, where is the source of water?
   If Rivers ………… Name ………………………., ……………………..
   Any other source, state ……………………..
5. Indicate the types of crops you farmers have been growing and its proportion in the farm;

LAST NUMBER OF YEARS	CROPS	PROPORTION
40		
30		
20		
10		
PRESENT		

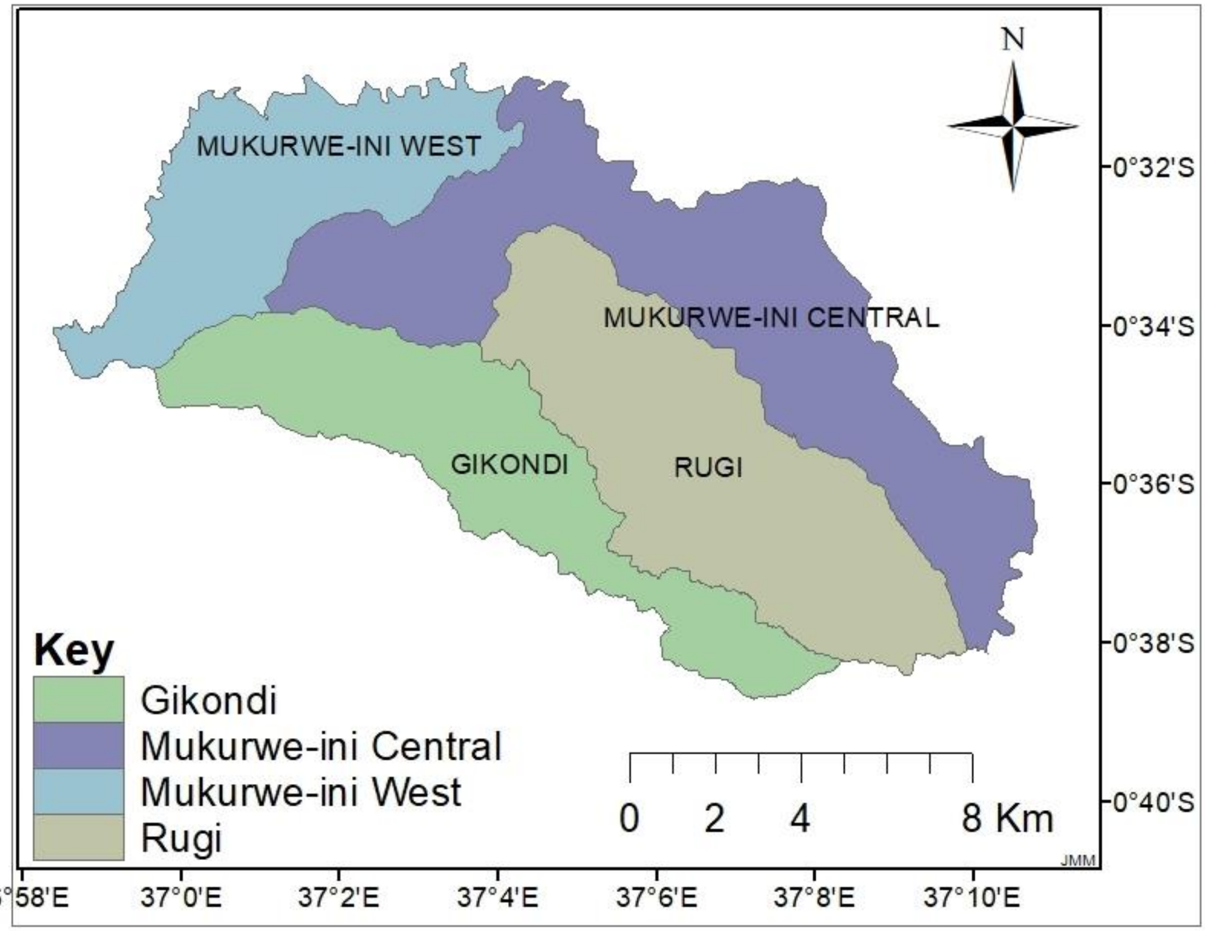
6. What are the main purposes of growing bananas in order of priority?

7. Do financial institutions give financial assistances (loans) to banana farmers?
8. Can you comment on the trends of banana production in this region for the last 30 years (Explain)?
9. In terms of land under bananas has it changes for the last 30 years (Explain)
10. How do farmers transport their bananas to the selling points?
11. Is banana transport affected by climate variability?
12. Which are the major bananas markets in this region?
13. To whom do banana farmers sell their produce?
14. What is the approximate cost of producing one acre of bananas per year?
15. How much can one acre of banana produce per year……………….(Kg) and price per Kg………..
16. What is the type of infrastructures to the market from the farm?
17. In your own opinion in the last 20 years, have you farmers changed the banana farming practices? Explain why
18. Have you observed any significant changes in rainfall and/or temperature over the last 20 to 30 years? Explain
19. Do farmers receive any information on predicted weather conditions? If YES how do they receive?
20. Do farmers normally make use of the weather forecast information to guide your farming decisions
21. If YES above How often do you receive this kind of information?
22. What is your perception on the relative importance of this information?
23. What is the **main** means of obtaining weather forecast information? Is the information provided timely?
24. What **main** kind of relevant information would you like to receive in future weather forecasts that is currently not provided or is inadequately provided?
25. According to your observations in the last 10 years plus, what changes have you noticed in:
    a. Rainfall amounts 1 Generally increasing 2. Generally reducing
    b. Rainfall patterns 1. Generally reliable 2. Generally unreliable
    c. Temperature levels 1. Generally increasing 2. Generally decreasing
    d. Droughts frequency 1. Constant 2. Changing
    e. Water availability 1 Constantly available 2. Decreased/Scarcity
26. How is labour pricing affected by
    a) High rainfall
    b) High temperatures
27. What is farmers perception on climate variability (rainfall and temperature)
28. Comment from your opinion the changes in banana production arising from
    a) Low rainfall amount
    b) High rainfall amount
    c) Temperature rise
    d) Rainfall predictability
    e) Temperature fluctuation

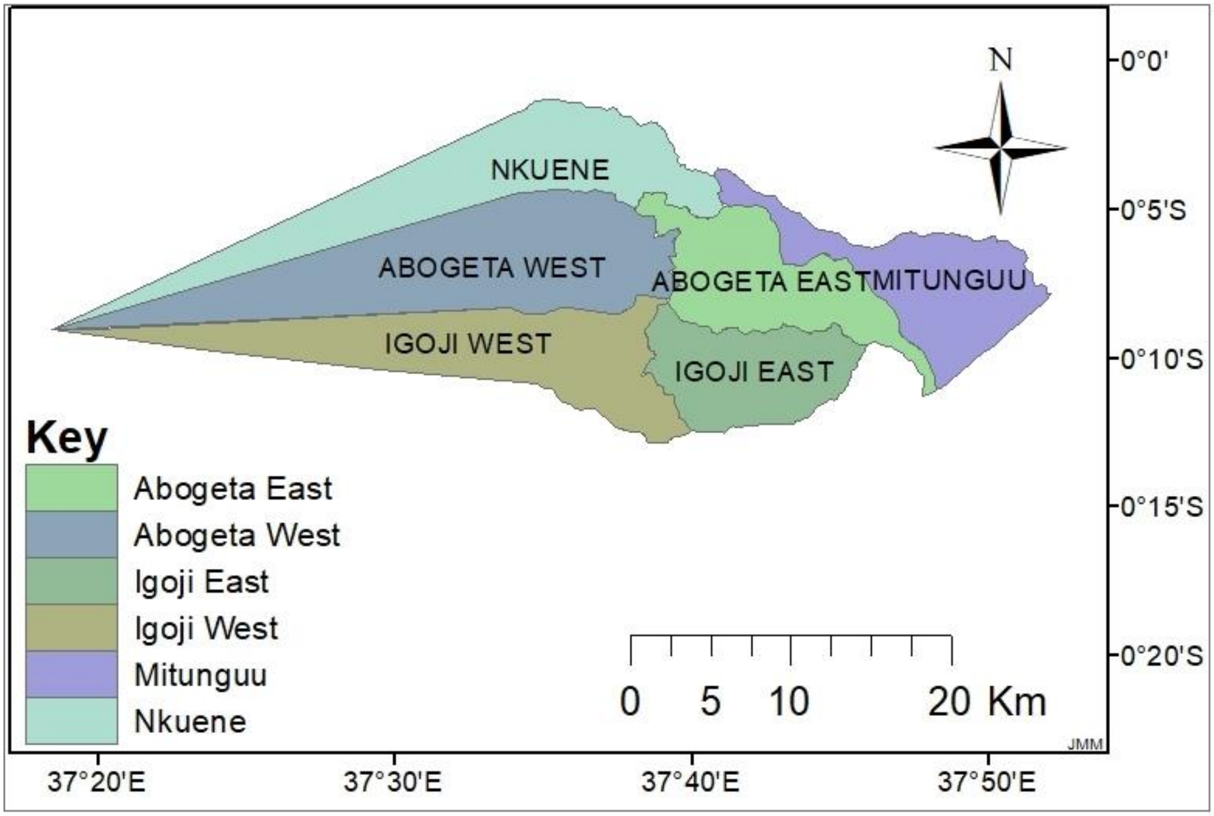
29. Has banana production been affected by these climatic changes, how and to what extent?
30. Which season do you have lowest banana produce?
    a. Jan- March
    b. April-June
    c. July-Sept
    d. Oct-Dec
31. Which season do you have highest banana produce?
    a) Jan- march
    b) April-June
    c) July-Sept
    d) Oct-Dec
32. Has banana transport been constrained by changing climate?
33. How is banana marketing and distribution affected by climate variability?
34. What adaptations strategies have you adopted to cope with impacts of climate variability on banana production?
35. Is there any relationship between climate variability and banana availability in the market?
36. Does banana production relate to food security in this region?
37. Mention the major banana value chain actors in the region?
38. Outline the roles and characteristics of the (37 above)
39. Diagrammatically illustrate the banana value chain that exist in this region
40. What ways do the following actors add value/process the banana fruit
    a) Farmers
    b) Transporters
    c) Traders
41. How does the County government support banana farmers (in which ways)
42. As farmers what recommendations would you give to future banana producer in light with the changing climate
    a) Production
    b) Transport
    c) Marketing
    d) Value addition
43. Which recommendations can you suggest to the county government regarding banana policy formulation in light to the changing climate?

THANKS FOR YOUR PRECIOUS TIME

Appendix 4: Location of the study sites in Mukurweini Sub- County, Nyeri County Kenya.



Appendix 5: Location of the study sites in Imenti South Sub- County, Meru County Kenya.



Appendix 6: Research Authorization Permit

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

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/81762/22896**

Date: **11th July, 2018**

David Kamau Karienye
Karatina University
P.O. Box 1957-10101
KARATINA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Evaluating climate change impacts and adaptation trends in banana value chain within Mt. Kenya Region"*** I am pleased to inform you that you have been authorized to undertake research in **Meru and Nyeri Counties** for the period ending **10th July, 2019.**

You are advised to report to **the County Commissioners and the County Directors of Education, Meru and Nyeri Counties** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

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

Copy to:

The County Commissioner
Meru County.

The County Director of Education
Meru County.

THIS IS TO CERTIFY THAT:
MR. DAVID KAMAU KARIENYE
of KARATINA UNIVERSITY, 1801-10101
Garissa,has been permitted to conduct
research in *Meru , Nyeri Counties*

on the topic: *EVALUATING CLIMATE CHANGE IMPACTS AND ADAPTATION TRENDS IN BANANA VALUE CHAIN WITHIN MT. KENYA REGION*

for the period ending:
10th July,2019

Permit No : NACOSTI/P/18/81762/22896
Date Of Issue : 11th July,2018
Fee Recieved :Ksh 2000

....
Applicant's Signature

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

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 19296

CONDITIONS: see back page

Appendix 7: Rainfall amounts (mm) for Meru and Nyeri in Kenya (1980-2017).

8937065			**MERU METEOROLOGICAL STATION**					**Precipitation; Monthly Total**					
Year	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
1980	78.1	0	8.8	121.9	124.8	0	1.1	10.4	3.4	130.6	383.2	23.1	**885.4**
1981	4.8	25.4	322	274	168.3	11.2	6.4	10.9	23.1	150.7	225.3	54.1	**1276.2**
1982	16.2	0.3	77.5	346.4	214.9	12.4	1.5	5	29.3	423.8	231.9	168.2	**1527.4**
1983	8.7	49.3	1.7	204	201.8	2.3	10.2	14.5	15.3	85.9	171.4	176.3	**941.4**
1984	10.6	12.1	11	154.4	53.2	0.2	15.1	3.7	4.4	496.2	311.6	114.3	**1186.8**
1985	23.3	6.2	167.4	249.9	145.7	7.7	16.1	7.7	17.8	144.6	193.4	42.3	**1022.1**
1986	5.6	3.6	87.6	417.2	105.6	41.5	1.1	0.5	11.8	935	237.8	132.3	**1979.6**
1987	34.9	0	64	209.8	93.3	28.1	3.5	16.8	0	2.2	187.1	29.4	**669.1**
1988	28.6	32.5	69.4	399.4	103.6	8.7	23.1	28.8	23	250.2	288.4	283.5	**1539.2**
1989	115.2	59.6	83.2	177.9	47.1	2.3	14.4	15.1	29.3	272.5	399.2	307.6	**1523.4**
1990	52.5	178.1	185	208.9	32	5.4	7.7	3.3	2	250.4	376.9	264.9	**1567.1**
1991	79.9	79.9	73.6	220.3	129.3	0.7	63.7	18.9	0.2	154.2	200.6	234.5	**1255.8**
1992	28.3	14.9	3.7	196.6	223.3	0.7	10.5	4.7	8.6	170.9	494.8	275.3	**1432.3**
1993	394.5	96.5	25.1	262.4	215.6	3.6	3.7	2.6	4.6	174.4	251.5	135.1	**1569.6**
1994	5.5	30.1	13.4	161	44.7	4.1	18.2	11.4	5.7	303.8	557.1	242.6	**1397.6**
1995	30.1	44.5	134.1	383.9	61.1	2.8	11.9	30.1	15.1	370.2	168.3	271.6	**1523.7**
1996	61.4	5.2	55.6	36.5	296.3	50	10	13.3	2.5	90.6	304.3	48.2	**973.9**
1997	18.5	0	97.8	414	70.2	9.2	2.6	1	3.8	585.4	672.8	344.6	**2219.9**
1998	570.8	158.4	117	144.5	147.4	50	7.7	27	7.5	50.6	232.6	23	**1536.5**
1999	16.5	9	115.5	121.8	67.6	2.8	6.2	5.4	4.8	61.7	378.8	225.9	**1016.0**
2000	10.4	8.2	7.2	90.2	23.4	2.4	9.8	7.6	6	49	241.6	142.4	**598.2**
2001	153	2.3	154.4	228.8	25.5	9.6	8.2	10.1	4.6	30.9	524.7	65.2	**1217.3**
2002	28.4	8	206.4	540.9	103.6	5.3	8.6	11.4	43	434.9	226.1	208.6	**1825.2**

2003	41	3.4	58.1	481.3	65.4	0.8	7	13.9	9.9	389.3	337.5	123.1	**1530.7**
2005	89.9	6.5	22.4	155.9	182.4	7.2	12	9.3	12.1	139	243	42.5	**922.2**
2007	109	10.6	110.1	188.9	167.3	33	16.3	18.3	11.6	304	205.8	110.7	**1285.6**
2008	95.1	0	62.5	201.2	8.7	2.1	11.1	3.4	7.5	279.1	270	40	**980.7**
2009	153.5	23.1	46.8	138.4	119.5	19.8	1.2	7.2	0.9	474	194.9	152.1	**1331.4**
2010	110.9	150	170	319.5	47.4	4	32.1	26.4	2.3	185.5	264.1	31.3	**1343.5**
2011	20.7	36.7	40	166.1	69.8	31.9	8.4	14.7	34.6	409.4	466.6	164.6	**1463.5**
2012	12.1	9	8	159	138.1	24.5	13.3	23	5.9	277.7	245.6	359.6	**1275.8**
2013	110.3	1.4	115.7	321.4	6.2	7.2	8.1	8.9	2.6	29.6	494.4	164.6	**1270.4**
2014	56	30.8	78.6	137.4	43.4	6.8	4.6	18.4	19.1	190.8	257.2	186.6	**1029.7**
2015	32.2	26	105.5	378.5	92.5	1	1	10.6	TR	146.8	391.2	237.2	**1422.5**
2016	114.9	33.7	42.2	204.6	40.47	6.3	4.42	3.14	5.25	11.21	415.8	57.21	**939.2**
2017	3.2	29.1	16.0	119.1	242.6	0.5	4.5	18.9	29.7	158.4	482.3	29.1	**1133.4**

9036288		**NYERI METEOROLOGICAL STATION**							**Precipitation; Monthly Total**				
Year	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
1980	62.7	19.8	37.6	57.1	209.2	3.0	4.9	49.8	3.7	106.8	141.0	54.3	**749.9**
1981	21.7	29.2	232.5	198.2	225.7	20.1	32.7	42.8	44.0	161.0	66.7	56.8	**1131.4**
1982	32.3	25.9	32.0	232.1	349.5	19.8	38.9	31.7	47.4	230.1	73.0	73.4	**1186.1**
1983	1.8	68.0	6.0	156.5	214.8	24.1	20.4	17.4	10.2	75.0	60.4	220.0	**874.6**
1984	16.3	1.0	4.7	97.5	34.1	22.7	16.3	2.8	40.8	177.7	273.8	79.4	**767.1**
1985	52.5	67.4	127.3	212.3	219.8	35.8	68.6	17.8	21.1	48.6	59.6	21.6	**952.4**
1986	17.9	30.5	48.5	456.4	208.2	57.4	7.9	9.6	8.0	55.6	64.0	169.7	**1133.7**
1987	25.9	10.5	33.6	77.8	242.5	48.3	9.6	72.3	6.8	10.7	122.6	4.0	**664.6**
1988	47.7	11.8	54.6	459.4	65.8	85.1	41.0	54.5	103.0	69.9	150.9	70.6	**1214.3**
1989	66.6	49.9	76.9	172.6	179.8	12.5	24.4	40.4	38.0	85.9	128.6	177.3	**1052.9**

1990	50.5	80.2	230.0	200.6	107.9	11.8	17.9	13.4	28.9	91.6	139.9	117.3	**1090.0**
1991	35.6	0.4	138.3	139.4	400.9	13.3	63.3	45.9	1.3	51.1	68.9	93.4	**1051.8**
1992	19.6	47.7	31.8	133.7	201.0	14.1	50.9	22.5	27.1	55.7	106.1	79.9	**790.1**
1993	139.1	47.3	63.6	114.8	218.7	28.3	16.6	28.4	7.5	67.6	98.5	69.2	**899.6**
1994	68.1	65.6	45.2	256.8	248.3	28.9	70.9	36.0	24.2	109.8	228.8	39.1	**1221.7**
1995	45.3	25.1	87	147.7	256.5	14.9	18.3	80.7	26.5	168.8	83.7	90	**1044.5**
1996	64.3	45.5	43.2	45.3	172.4	66.9	76.2	21.8	2.1	41.1	60	83.6	**722.4**
1997	39.1	18.1	68.9	319.6	93.3	52.4	30.6	9.5	1.2	424.9	380.1	184.5	**1622.2**
1998	302.3	136.6	125.1	136.3	221.8	68.6	36.7	35.1	11.6	35.9	88.4	19.8	**1218.2**
1999	8.8	21.9	52.4	149.6	110	10.1	12.6	10	13.9	26.2	144.7	26.6	**586.8**
2000	13.2	26.1	37.4	82.8	119.9	20.7	10.3	20.2	17.5	64.2	140.6	50.8	**603.7**
2001	88.2	29.5	116.1	407.7	96.1	23.4	11.9	8.3	7.8	70.3	131.2	30.8	**1021.3**
2002	44.1	33	69.4	225.3	143.1	28.9	18.8	43.4	34	186	81.9	124.2	**1032.1**
2003	18.7	7.6	46.3	258.3	269.6	13.7	5.6	69.9	7.9	211	106.6	84.7	**1099.9**
2004	13.7	13.7	132.7	123.7	269.6	13.7	13.7	13.7	57.9	57.9	57.9	57.9	**826.1**
2005	13.7	13.7	132.7	123.7	269.6	13.7	13.7	13.7	57.9	57.9	57.9	57.9	**826.1**
2007	15.3	5	53.3	165.7	241.9	18.5	31	12.9	25.8	69.3	35.7	5.7	**680.1**
2008	49.9	39.3	42.7	130.3	138.5	53.4	87	66.7	58.9	210.3	57.1	38.8	**972.9**
2009	57.4	46.4	103.3	110.4	64.2	18.3	20.4	18.3	23.5	110.5	134.6	35.2	**742.5**
2010	9.9	59.4	47.8	104.1	85.1	39	1.1	6.7	1.2	208.6	68.9	102.9	**734.7**
2011	42.6	66.9	104.7	208.8	257.6	7.5	33	30.9	1.2	41.8	113.3	25.7	**934.0**
2012	16.8	55.1	45	88.4	94.3	27.8	36.1	34.5	27.3	208.2	176.1	81.6	**891.2**
2013	57	9.5	3.3	235.3	380.3	53.5	49.2	59.5	102.9	137.1	40.9	77.9	**1206.4**
2014	40.8	22.6	23.1	261.6	98.1	21.6	29.4	39.7	35.8	28.1	121.6	142.2	**864.6**
2015	17.2	63.7	96.1	173.6	128.2	28.5	23.4	98.3	0	149.7	131.7	71.2	**981.6**
2016	6.6	60	26.6	117.3	115.2	14.9	12.7	5.1	0.3	132.6	247.5	106.9	**845.7**
2017	142.9	13	65.6	233.7	129.17	37.8	5.22	26.85	8.67	8.5	91.93	20.93	**784.3**

Appendix 8: Temperature data (^{0}C) for Meru and Nyeri County Kenya (1980-2017).

Year	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Nyeri	18.03	17.68	17.87	18.03	17.72	17.28	17.65	18.39	18.09	17.33	17.58	17.86	17. 71	17.66
Meru	18.53	18.35	18.66	18.11	18.54	17.93	18.45	18.23	18.84	18.23	18.23	18.19	18.24	18.28

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Nyeri	18.29	18.06	18.08	18.46	17.25	18.35	18.58	18.41	18.57	18.42	18.49	18.48	18.50	18.09
Meru	18.45	18.43	18.30	18.49	17.69	18.24	18.35	18.49	18.53	18.43	18.42	18.43	18.49	18.56

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Nyeri	18.03	18.73	18.48	18.44	18.13	18.21	18.25	18.65	18.44	18.24
Meru	18.35	18.62	18.80	18.78	18.62	18.52	18.84	18.93	18.81	18.61

Appendix 9: Production (Tonnes) and Acreage (Hectares) data for Imenti South and Mukurweini Sub- County Kenya (2009-2017).

Study Area	Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Imenti South	**Acreage (Hectares)**	960	1050	1200	1850	1900	2024	2085	2900	2910
	Production (Tonnes)	17280	18900	25200	46250	47500	60700	62550	101500	116400
Mukurweini	**Acreage (Hectares)**	400	410	415	430	440	450	455	450	460
	Production (Tonnes)	8100	8200	8300	8400	9000	8990	8950	8940	9000