

# CLIMATE VARIABILITY AND ADAPTATION AMONG SMALL HOLDER BANANA FARMERS IN MOUNTAIN REGIONS OF KENYA

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**ABSTRACT.** Banana production is the mainstay industry for majority of small holder farmers living in the mountain regions of Kenya. These regions are affected by climate-related impacts at all levels of the value chain. This paper therefore discusses climate trends, related impacts, and adaptations in banana value chain in Mt. Kenya region for the period between 1980 and 2017. The study locations were purposively selected from Mt. Kenya region to include both Imenti South and Mukurweini sub-counties. A sample of 381 respondents was selected using simple random sampling. Triangulation research design was used to guide the study by integrating both qualitative and quantitative methods in data collection and analysis. Historical document analysis was used to examine climatic data (temperature and rainfall) from the Kenya Meteorological Department, Nairobi. Results showed that rainfall and temperature have changed during the study period. Temperature trends in Mukurweini showed  $R^2 = 0.3314$  while in Imenti South  $R^2=0.3441$  with an overall annual increase in temperature in Mukurweini by  $0.02^\circ\text{C}$  while in Imenti South we registered an increase by  $0.016^\circ\text{C}$  for the study period. Mukurweini sub-county rainfall trend line had  $R^2=-0.1064$  while Imenti South sub-county had  $R^2=-0.1014$ . Adverse effects of climate variability on banana value chain included low yields in both Mukurweini (79.2%) and Imenti South (60.2%) sub-counties. Farmers in the study area preferred irrigation (57.2%) followed by crop diversification (13.9%) as adaptive strategies to climate variability.

**KEY WORDS:** Adaptations; banana; climate variability; value chain; small-holder farmers

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## INTRODUCTION

Agriculture, the mainstay activity for the smallholder farmers, is exposed to various menaces, ranging from weather variability, pests, and diseases to price volatility in the markets. Increased frequency of extreme climate events is projected to negatively affect local agricultural production, especially the subsistence sector and smallholder farmers located in the low-latitude areas (Wik et al. 2008). Agricultural production is particularly sensitive to climate hence crop yields depend largely on climate variables mainly temperature and rainfall patterns and amounts. Dynamics in these climatic variables affect agricultural productivity through physiological changes in crops (Chakraborty et al. 2000). According to Brown and Funk (2010), Mt. Kenya region has been experiencing climate variability related impacts. It has been recognized that adaptation strategies can minimize the adverse impacts of climate erraticism on crop production (Kabubo and Karanja 2005). Adger et al. (2003) reported that adaptation is one of the policy options to reduce the negative impact of climate change on smallholders; food productivity and access can be improved with proper adaptations at household level (Di Falco and Veronesi 2013; Di Falco 2014).

Previous studies conducted in the region have focused on socio-economic aspects of banana production and agribusinesses' prospects. However, little attention was paid to the extent of climate variability effects as well as associated adaptation measures in driving banana value chain development within the region. This study therefore aimed at evaluating the climate trends, related variability, impacts, and corresponding adaptation strategies on banana value chain development among small holder farmers in Mt Kenya region.

### Banana production among smallholder farmers

Bananas provide an important source of food and income for millions of smallholders in East Africa and other developing countries globally (Arias et al. 2003). Banana production as a horticultural crop and fruit is a new venture within Mt Kenya region, where coffee farming was previously dominating until 1990. According to Africa Harvest Biotechnology Foundation International (AHBFI) (2015), approximately 390,000 banana farmers operate in Kenya, of which approximately 84% are smallholder farmers (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 and Kiome 2001).

**Climate variability impacts on banana value chains development**

Value chain comprises all value-generating activities required to produce, deliver, and dispose of a commodity (Schmitz 2005). Agricultural production is inherently delicate to climate variability owing to the close natural connections and dependencies that exist between climatic weather conditions and plant growth (GOK 2013). High temperatures coupled by declining rainfall increase crop water demand by 12–15% (Washington and Pearce 2012) and reduce crop yields. 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 and CroleRees 2001). Weak infrastructure hampers efficient flow of products laterally on the chain thus constraining the flow and exchange of market information along the chains (Trienekens 2011). Lack of well-established banana value addition activities within the chain has been reported to constrain smallholders in other banana studies in Africa (Mwangi and Mbaka 2010; Ouma and Jagwe 2010). Mwangi and Mbaka (2010) recommended to maximize banana value through cleaning, packaging, and labelling to promote competition.

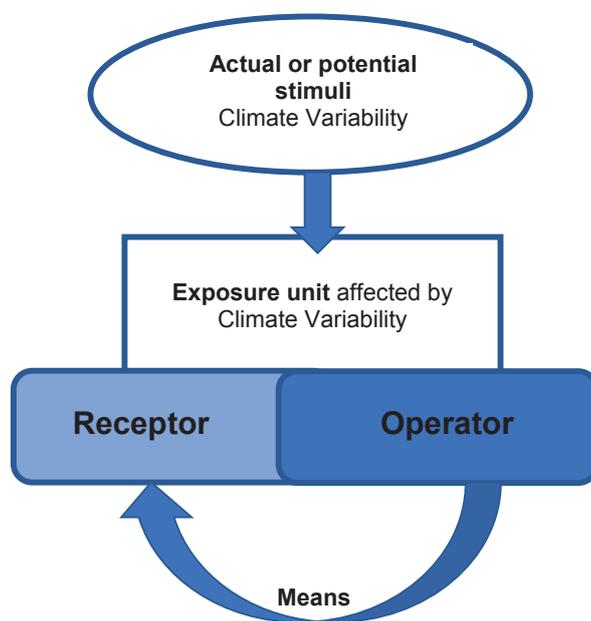
**Adaptation strategies to climate variability**

Climate variability adaptation refers to responses or changes within the production system geared towards reducing the negative effects and enhancing the positive influences of climate variability. The severity of environmental impacts due to climate related experiences can be reduced by adaptation strategies. Heavy dependence on rainfed crop production increases the susceptibility of smallholder farmers in the rural settings to harmful effects of climate variability (Mertz et al. 2009).

There are limits to adaptation and adaptive capacity for some human and natural systems if the warming exceeds 1.5°C from current levels particularly for the poor and disadvantaged populations (IPCC 2018). This calls for responsive measures to curb and reduce the associated effects of climate variability. Soil conservation measures, planting trees, water management, varying planting dates as well as crop diversification are some of the adaptation measures recommended for smallholder farmers (Gbetibouo 2009).

This study was guided by the Action Theory of Adaptation (Eisenack and Rebecca 2011). The theory focuses on the challenges linking biophysical factors and agricultural production. It emphasizes on the changes and contribution of meteorological variables. The theory is based on temperature and rainfall as the main climate variables.

The focus of this study is thus based on Action Theory of Adaptation to climate variability and focuses on the climate impacts on banana value chain and adaptation strategies of banana farmers in the region. This theory has previously been used to study poverty and vulnerability reduction related to climate risks in Kenya (Eriksen and O'brien 2007).



**Fig. 1. Schematic representation of the Action Theory of Adaptation**

(Adapted from: Eisenack and Rebecca 2011)

**Table 1. The experiment design**

County	2010		2011		2012	
	Area (Hectares)	Quantity (Tons)	Area (Hectares)	Quantity (Tons)	Area (Hectares)	Quantity (Tons)
Meru	5,027	124,793	5,843	150,485	6,241	315,720
Kirinyaga	4,089	140,195	4,224	181,920	4,148	160,606
Kisii	4,573	101,540	4,942	112,152	4,167	66,889
Nyamira	2,112	42,245	2,151	43,051	1,795	33,792

Source: MoA (2012)

The Meru county leads in banana production in Kenya followed by the Kirinyaga county. This indicates that banana production is one of the major economic activities in Mt Kenya region. The banana acreage continued to rise in the Meru county as compared to other counties, which showed declining trend in acreage (Table 1). The challenges in banana production are: prevalence of insect pests and diseases and high post-harvest losses (MoA 2012).

## METHODS AND MATERIALS

### General description of the study area

The objective of the study was to establish climate trends and associated variabilities related to impacts and adaptations on banana value chain in Mt Kenya region. For the purpose of understanding changes in banana production, and climate variables (rainfall and temperature) over time, we selected a target period from 1980 to 2017. A period of 30 years is enough to study climate and calculate the trend. The study sites are located in Meru and Nyeri counties, which are among the main banana growing counties in Kenya (Fig. 2). The Meru county

falls approximately between longitudes 370 0' 00" and 380 30' 00" East and latitude 00 20' 00" North and 00 40' 0" South (GOK 2015a). The Nyeri County is located between longitudes 360 and 380 East and between the equator and latitude 00 38' South (Murphy and Chirchir 2017). The rainfall regime in the Nyeri county is equatorial due to its location within the highland zone of Kenya (GOK 2015b). The major economic activities, which the local community is engaged in, include agriculture and livestock production specifically dairy, banana, coffee, and tea farming.

### Study design

The study adopted mixed study design to evaluate climate variability trends, their impacts on banana value chain and adaptation strategies used in Meru (Imenti South sub-county) and Nyeri (Mukurweini sub-county) within the Mt. Kenya region. The study area was purposively selected to include Agro-Ecological Zones (AEZ) and diverse locations where banana production has been grown for the target period from 1980 to 2017. According to GOK (2009) population statistics, the population of Imenti-South was approximately 179,604 people; the number of households was 47,197 while the population of

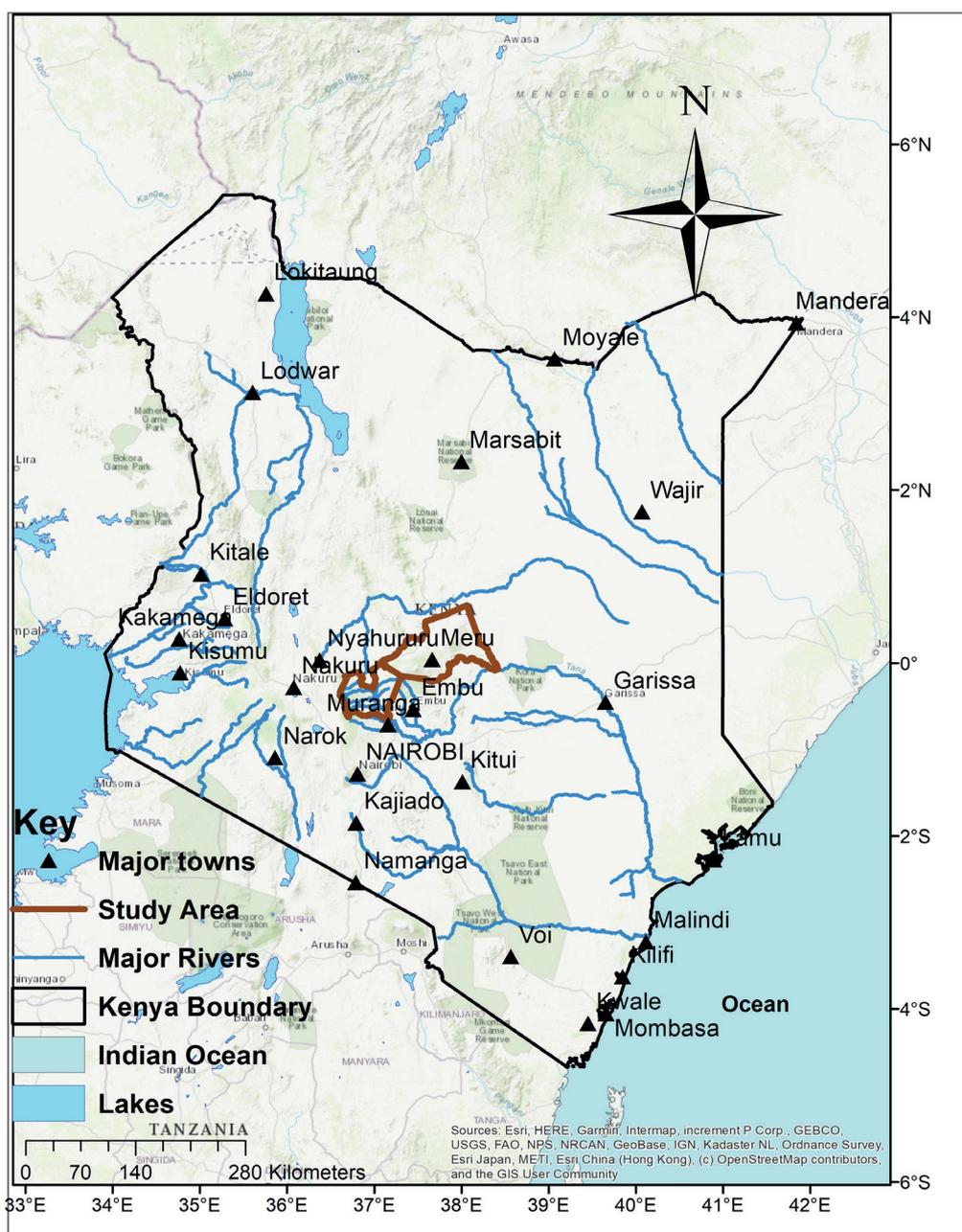


Fig. 2. Map of Kenya showing the location of the study areas in Meru and Nyeri counties

the Mukurweini sub-county was 83,932 people and the number of households was 24,083 households. Simple random sampling was used to obtain sample size of 381 participating respondents for the study using the method described by Krejcie and Morgan (1970).

### Data collection methods

Data collection included both primary and secondary sources. Questionnaires were used to capture the impacts of climate variability and adaptation strategies from individual households. Key issues on the impacts of climate variability on banana value chain were captured using in-depth interviews from key informants. Focus Group Discussion sessions were undertaken in each study site to validate data collected from individual households; 381 participants were interviewed (130 in Nyeri and 251 in Meru). Climatic data (temperature and rainfall) for Imenti South and Mukurweini sub-counties were obtained from the Kenya Meteorological Department in Nairobi. Banana production data was obtained from Horticulture Crop Directorate (HCD). In the period from 1980 to 2017 we had daily recorded data on rainfall and temperature for the two study areas, which were analyzed using time series to examine possible trends over the 37-year period under consideration.

### Limitations of the study

Two climatic elements, i.e. temperature and rainfall, were studied as presumably influencing banana value chain within the region while other biophysical factors were held constant during the study period from 1980 to 2017. The climatic data was sourced from the adjacent weather stations, which were not specific to the study sites while the selected study sites were assumed to represent the banana growing regions.

## RESULTS AND DISCUSSIONS

The impacts of climate variability were evaluated by their effect on various components of banana value chain comprising production, marketing, processing, and value addition. Changes in climate in terms of temperature and rainfall were analyzed annually. For both numerical and graphical measures, we analyzed temperature and rainfall data for the overall study period from 1980 to 2017.

### Temperature

The study's null hypothesis was that there is a negative trend in temperature within Mt. Kenya region. Temperature data from the two study areas revealed that Imenti South sub-county was slightly warmer than Mukurweini sub-county with mean average temperatures of 18.2°C and 18.6°C, respectively (Figure 3). There was a gradual increase in temperature in the two locations from an average of 17.7°C in Mukurweini and 18.1°C in Imenti South in 1980 and rising gradually to 18.2°C and 18.6°C in 2017 in Mukurweini and Imenti South, respectively. The highest mean temperature for Mukurweini sub-county was registered in 2009 – 18.8°C while the highest mean temperature for Imenti South sub-county was 18.8°C; it was registered in 2015. The lowest mean temperature in Mukurweini sub-county was 17.6°C; it was registered in 1982; while in Imenti sub-county it was 17.3°C; it was registered in 1985 and 1998. As evidenced from Figure 3, the two study areas showed increasing linear trends of temperature as shown by positive slope in the trend line equations. The study findings further revealed an increasing trend of temperature in Mt. Kenya region, which is represented by a positive slope in the corresponding trend line equations (Figure 3) thus  $y = 0.0206x + 17.727$  ( $R^2 = 0.3314$ ) for Imenti South and  $y = 0.0149x + 18.129$  ( $R^2 = 0.3314$ ) for Mukurweini. We reject the null hypothesis and accept the alternate hypothesis. The yearly trend line analysis of Mukurweini sub-county presented  $R^2 = 0.3441$  which translates to 33.14% change while in Imenti South  $R^2 = 0.3441$  translating to 34.41% (Figure 3).

This indicates that there was a positive but gradual change in temperature with a peak year occurring after every 3 to 5 years in the study areas. In Mukurweini the overall temperature change for 37 years (1980–2017) was 0.8°C translating to 0.02°C of annual increase while in Imenti South, the overall temperature change for 37 years was 0.6°C translating to 0.016°C annually. These findings concur with IPCC (2001), which showed that temperatures are projected to increase by around 0.4°C in East Africa for the same period.

High temperatures (particularly a change >3°C) are projected to dramatically affect agricultural productivity, farm incomes, and food security (Rosenzweig et al. 2014). This concurs with Niang et al. (2014) who projects an increase in temperature and precipitation in East Africa. It was observed that in the study areas, the temperature would get to peak after every three to five years and result in drought in the region. These findings

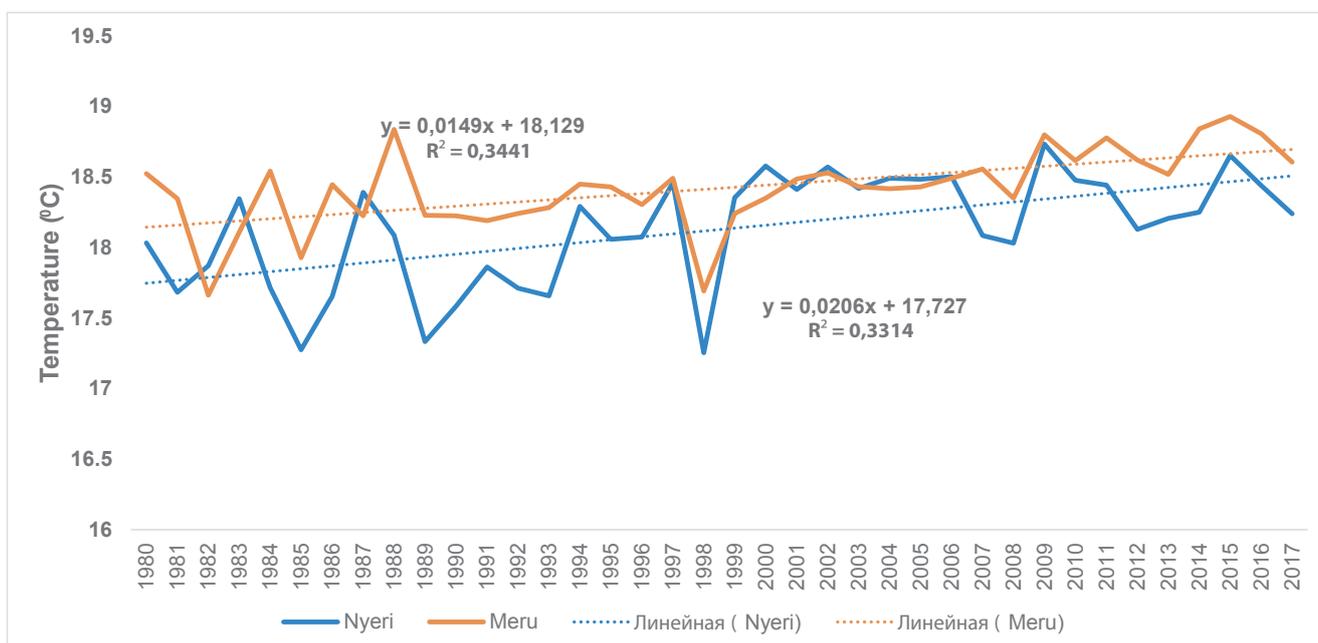


Fig. 3. Time series of annual temperature data for Meru (Imenti South sub-county) and Nyeri (Mukurweini sub-county) and their linear trend lines

further agree with NEMA (2014) who noted that drought is a frequent phenomenon in Kenya occurring after every 4 years, thus impeding agricultural investments (GOK 2013).

## Rainfall

The study's null hypothesis was that there is a positive trend in temperature within Mt. Kenya region. The highest recorded average annual rainfall for Mukurweini and Imenti South sub-counties between 1980 and 2017 were 949 mm and 1286 mm, respectively (Figure 4). High rainfall amounts were recorded in Imenti South in the years 1986, 1997, and 2002 amounting to more than 1800 mm annually while in the years 2000, 2004, and 2015, we recorded the lowest amount of rainfall (below 1000 mm annually). In Mukurweini sub-county, the rainfall was moderate – below 1500 mm annually except in the years 1997, when we recorded 1,620 mm. Rainfall amount below 600 mm was recorded in the years 1987, 1999, 2000, and 2005. Linear regression analysis of the rainfall data showed that rainfall decreased in both study locations and rainfall peaks were identified to occur after every four to seven years as shown in (Fig. 4). The study findings further reveal a decreasing trend in rainfall in Mt. Kenya region, which is represented by a negative slope in the corresponding trend of linear equations (Fig. 4) thus  $y = -9.1757x + 1510.7$  ( $R^2 = 0.1014$ ) for Imenti South and  $y = -6.4444x + 1087.7$  ( $R^2 = 0.1064$ ) for Mukurweini hence we reject the null hypothesis and adopt the alternate hypothesis. Similar trends in temperature have been documented by (IPCC 2001;

Rosenzweig et al. 2014). The authors recognize that rainfall trends in Africa are changing and the continent will experience increased drier conditions with rainfall decreasing at a rate of between 10% and 20% in Southern Africa and between 10% and 50% in eastern and northern parts of Africa (Shongwe et al. 2009; 2011; Schlenker and Lobell 2010).

## Impacts of climate variability on banana value chain

The effect of climate variability on banana production was analyzed based on respondent's assessment of climate factors such as scarcity of water for irrigation, changes in planting dates, labour cost, reduced yields, delay in harvest and pest and disease infestations while aspects of banana value chain under consideration were mainly in production, marketing, and value addition.

## Banana production

To understand the effects of climate variability on production, surveys involving farmers were conducted to find out the effect of climate variability on banana production. In the two study areas, reduced yield was reported as the main effect of climate variability on banana production with 79.2% of respondents in Mukurweini and 60.2% of respondents in Imenti South. Scarcity of water for irrigation was reported as the second most important effect of climate variability on banana production with 11.5% in Mukurweini and 19.1% in Imenti South (Table 2).

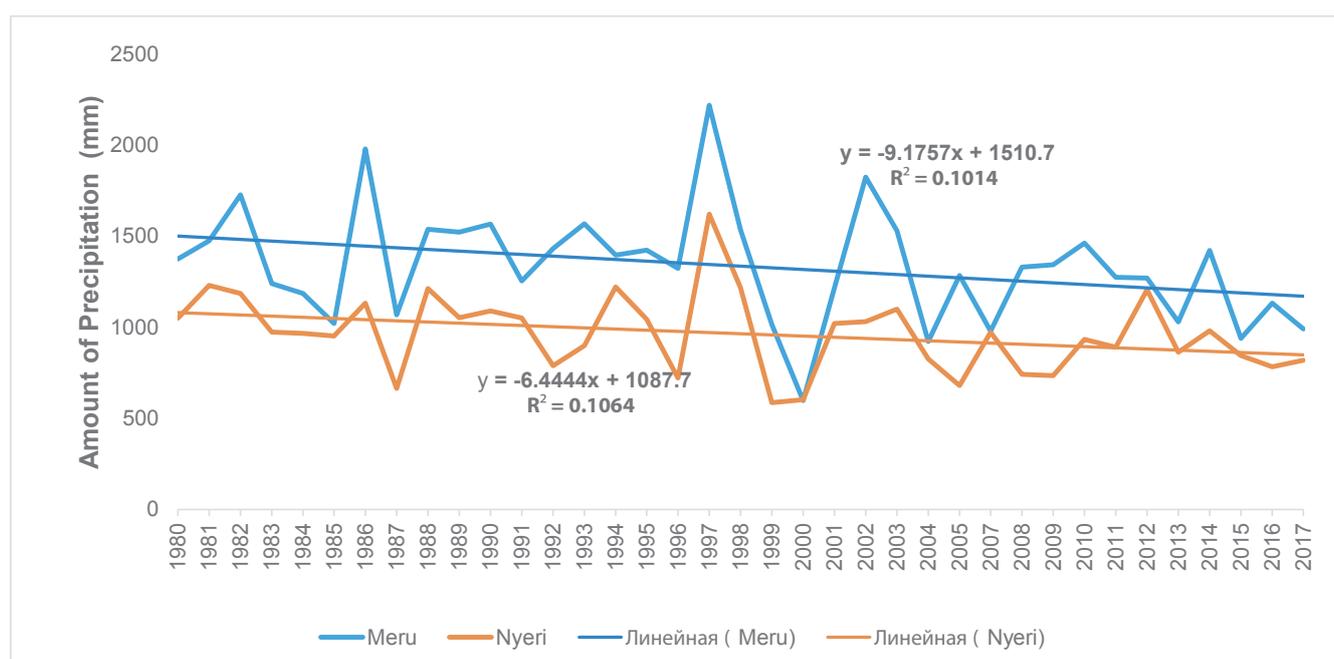


Fig. 4. Time series of annual Rainfall data for Meru (Imenti South sub-county) and Nyeri (Mukurweini sub-county) and their linear trend lines

Table 2. Effects of climate variability on banana production per study location

	Mukurweini (n=130)		Imenti South (n=251)	
	Frequency	Percentage	Frequency	Percentage
Scarcity of water	15	11.5	48	19.1
Changes in planting dates	7	5.4	15	6.0
Labour cost	1	0.8	3	1.2
Reduced yields	103	79.2	151	60.2
Delay in harvesting	2	1.5	22	8.8
Pest and diseases infestation	2	1.5	12	4.8
Total	130	100.0	251	100.0

These findings concur with Karienyé and Kamiri, (2020) who found out that decrease in temperature levels led to corresponding increase in banana production in the period from 2009 to 2012 while increase in temperature led to a decrease in production in the period from 2013 to 2015 in a study conducted in Kenya. Furthermore, Rodomiro (2012) noted that climate variability may affect banana and plantain yields negatively in Latin America. Studies conducted in some Feed the Future (FtF) countries in Africa, Asia, and Latin America revealed that drought stress is either the most important or the second most important constraint in banana production in the region (Van Asten et al. 2011). Meanwhile, highland bananas are projected to experience significant yield loss due to increased risk of pest and diseases if the temperature increases by 2°C (Thornton and Cramer 2012).

**Transportation of banana production to the market**

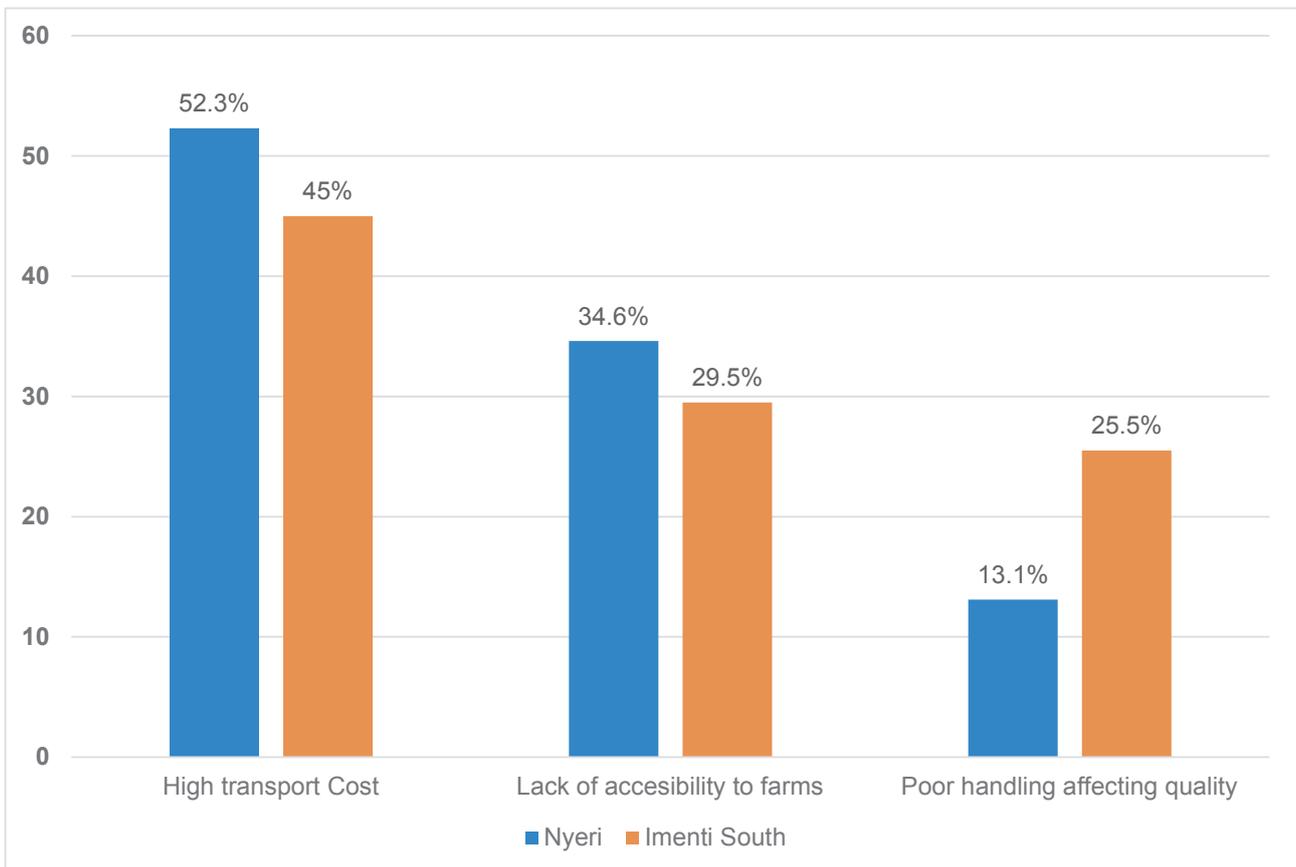
The effect of climate on banana transportation was analyzed based on respondent’s interpretations of transport issues such as changes in transport cost, accessibility to farms and handling of production, which affected the quality (Figure 5). The results indicated that majority of the respondents (52.3%) in Mukurweini and (45.0%) in Imenti South sub-counties found high cost of transport as the main effect of climate variability during rainy seasons that affected banana transport. Approximately 34.6% and 29.5% of the respondents in Mukurweini and Imenti South, respectively, cited lack of accessibility to the farm during the same period to have been affected by climate changes. Miriti et al. (2013) noted that rural areas in Kenya have poor roads connectivity. Poor infrastructure in the study area during the rainy season made roads impassable due to an increased cost of transport from the farms to the market or collection centers. This confirms the findings

of other authors such as by Wambugu (2005); Mwithirwa (2010). Mwithirwa (2010) reported that 95% of the traders used poorly maintained roads in dry weather to access major buying areas thus hindering timely access to the production centers.

Miriti et al. (2013) in the studies conducted in Mt. Kenya region reported that bad rural road was the main constraint (ranked the highest) faced by banana farmers in the area. In the study region it was observed that banana markets have been set up close to banana producing areas such as Kanyakine in Imenti South and Ichamara in Mukurweini sub-counties where buyers from far areas come to buy bananas immediately after they are harvested. Such markets are situated along the tarmac roads due to accessibility by long distance buyers (Fig. 6).

**Effects of climate variability on banana post-harvest handling**

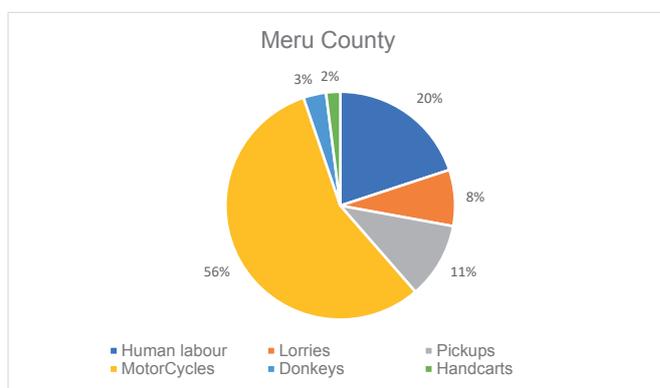
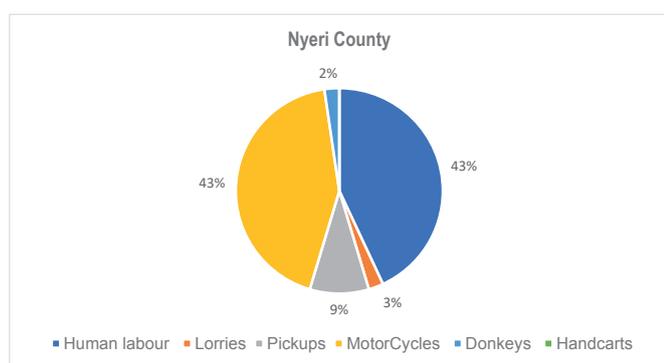
Post-harvest handling of banana products was affected by climate variability by 13.1% and 25.5% in Mukurweini and Imenti South, respectively (Fig. 5) and, thus, affected the market value of the fruit. The mode of transportation coupled with inefficient handling of the products led to high levels of deterioration and wastage of the banana fruit. These findings are supported by Technoserve (2004) who showed that poor handling of horticultural products inflicted physical damage of the fruits at all levels and led to high post-harvest losses estimated at 40%. In addition, poor handling during banana ripening can significantly reduce green and shelf life, which lasts 5–10 days after harvest. Strategies such as appropriate means of transportation and proper storage that could reduce post-harvest losses are not available in the region and where they are available access might not be equitable due to social differentiation (Hailu et al. 2013).



**Fig.5. Effect of climate variability on banana produce transport**



**Fig. 6. Lorries waiting to load bananas along the roadside in urban centers in Imenti South sub-county along the Meru-Nairobi highway (the Kanyakine Market) Dated 23rd June 2017**



**Fig. 7. Mode of transport from farm to collection points/Market in the study areas**

When mode of transport was considered, it was observed that most of the respondents (43%) in Mukurweini preferred using human labour where women carry the load on their backs and motorcycles commonly referred to as “boda boda” both while in Imenti South most farmers (56%) preferred to use motorcycles (Fig. 7).

**Effects of climate variability on banana processing and value addition**

Post handling of banana products and processing technologies adopted by the respondents as a result of the effect of climate variability in the region were indicated as cleaning of banana products to enhance their value, improved packaging, and value addition (flour production, crisps, wine juice) and ripening.

Majority of the respondents cited cleaning (48.6%) as the main strategy of banana value addition in the study region. In Mukurweini sub-county, majority of the respondents ranked ripening of bananas the first (45.3%) followed by cleaning (24.6%). In the Imenti South sub-county, farmers preferred cleaning (60.9%) followed by packaging in crates and sacks (26.3%) (Table 3). Ripening at the farm level was aimed at increasing market demand at the local market while cleaning the fruits was aimed at

making the fruit more appealing to buyers thus increasing the selling price. Processing of banana fruits to other high-value products was limited in the study region. However, the number of farmers engaged in producing flour (3.1%), crisps, and wine juice is small (0.5%). These findings concur with MoA (2016), which observed that banana processing facilities in the Meru county were limited. This is hindered by low investments in agro-processing, lack of business and technical skills. Agro-processing industries among smallholder farmers would unlock their production potential hence earning more from banana enterprise. Mbuthia and Wambugu (2018) reported that banana value addition could prolong the shelf life of bananas, create more jobs in the sector and enhance domestic and international marketing. MoA (2016) concluded that value addition could help small holder farmers to earn more from their products if adopted.

**Effects of climate variability on banana farmers’ welfare**

Climate variability has effect on the welfare of the smallholder farmers. The effect on welfare was identified as reduced income thus depending on the seasonal source of food for the household. During the dry season income increased due to market demands whereas during the

**Table 3. Value addition strategies adopted by banana farmers**

Study location	Cleaning	Packaging	Ripening	Processing			
				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%)

rainy season the income reduced. The food security was achieved during rainy season while during dry season food insecurity was felt due to declining yields. This indicates that climate variability has direct impact on farmers' household welfare.

### Effects of climate variability on banana marketing trends

The effect of climate variability on marketing was identified as high market demands, low market prices, and low quality of products depending on seasons. Further we found out that different seasons have significant effect on banana trading. Majority of the respondents in Mukurweini sub-county (50.7%) indicated that during high rainfall seasons bananas were of low quality while in Imenti South sub-county the respondents reported low market demands (50.6%) during the period with high rainfall (Table 4). During the dry season majority of the respondents (36.9%) in Mukurweini and 45.8% in Imenti-South indicated that bananas were of small size and low quality referred to as "seketa" (Table 4). High quality bananas create demand for the products in the market thereby increasing the incomes of farmers. The perceived quality plays a major role in price determination (Dijkstra 1997).

Banana consumption also varies with seasons thus affecting trade. During high rainfall seasons, consumption goes down due to availability of alternative food such as maize and vegetables and consequently low market demands for banana. During hot seasons banana ripening is hastened and there is a high consumption rate due to a high demand on bananas. Extreme weather events, i.e. a large amount of rainfall or extreme temperatures are detrimental to the quality of fresh products. High rainfall and low temperatures delay ripening of bananas while consumption is equally low.

### Adaptation strategies to climate variability in the region

Five adaptation strategies were reported by banana farmers in the region as shown in Table 5. Majority of respondents in Mukurweini Sub-County preferred crop

diversification (36.2%) and planting of drought tolerant banana varieties (32.3%) as their adaptive strategies to climate variability.

In Imenti South, most farmers preferred irrigation (84.9%) as the best option to unreliable and unpredictable rains within the seasons. Crop diversification was preferred as an alternative to providing food for the family. These findings are supported by Shikuku et al. (2017) who observed that inclusion of dual-purpose sweet potato variety in cropping system would be sufficient to offset the negative impacts of climate variability in studies conducted in Machakos County. Some respondents in Mukurweini and Imenti South sub-counties preferred no adaptation strategy – 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 drought-tolerant banana varieties were least preferred (2.0%) (Table 5).

Irrigation as an adaptation strategy has been supported by the studies conducted by MoA (2016), which found that most farmers in Meru County irrigate their banana stems in between seasons due to availability of water and this was much more widespread in the drier parts of Imenti South, specifically in Mitunguu. Use of irrigation in banana production increases the produce per season thus making banana fruit an all year-round crop with constant harvest. In Mukurweini farmers depended on rain-fed system of production thus experiencing challenges brought about by climate variability such as decline in production.

### Dependence of banana production in the study region

Banana production in the study region was primarily aimed at income generation (53.0%) and provision of food (47.0%) as shown in Table 6. In Imenti South and Mukurweini Sub counties, bananas were mainly grown for income generation (fees, cater for medical expenses, source of income, and more profit) and therefore variation in production or in the markets have a serious effect on farmer's livelihood sustainability. This shows that banana harvest plays significant role on the households' welfare.

**Table 4. Effects of climate variability on banana marketing**

Study location	Long rain season				Low rain season			
	High market demands	Low market prices	Low quality of products	Total	High market demands	Low market prices	Low quality of products	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 (10.4%)	127 (50.6%)	98 (39.0%)	251 (100%)	105 (41.8%)	31 (12.4%)	115 (45.8%)	251 (100%)
Total	77 (20.2%)	159 (41.8%)	164 (43.0%)	381 (100%)	149 (39.1%)	69 (18.1%)	163 (42.8%)	381 (100%)

**Table 5. Adaptation strategies among the respondents**

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

**Table 6. 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%)

### Sustainability of the small-scale banana production

Changes in climate and its variability in terms of temperature and rainfall were analyzed annually to understand the sustainability of banana production in the region. As the temperature and rainfall varies the small holder farmers got enlightened on the best adaptation strategies hence sustainable production despite climate variability.

Small-scale banana production in the region is of paramount importance; it ensured sustainable functioning of the households in terms of food security. The production brings income to the households, which serve as a source of income for fees for school going children and caters for medical expenses for the family. The higher is the profit generated by farmers the lower are the associated risks.

Irrigation as an adaptation strategy will promote sustainability among smallholders. Irrigating banana stems in between seasons due to availability of water will ensure constant production throughout the year. Use of irrigation in banana production increases the output per season. Mixed cropping of banana with other crops provides food security for the family hence promoting sustainability among the households.

Post-handling technologies such as cleaning of the banana products, improved packaging and value addition (flour production, crisps, wine juice) and ripening promotes sustainability of the production. These technologies boost market value of the products.

### CONCLUSIONS

This study has revealed 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°C while in Imenti South it was 0.016°C, which translates to 0.2°C and 0.16°C per decade, respectively. These climate trends negatively affect banana productivity in the region hence food insecurity in the region, therefore adaptation measures are critical. The main impact of climate variability on banana sustainability in the study area was decline in banana production as a result of low rainfall incidences leading to a reduced banana production and low quality of products such as small bunches referred to as "seketa". High temperatures lead to damage of banana crops and increased host pests and diseases leading to further decline in yields. These findings agree with other studies, which found that inter-annual unpredictability in precipitation have negative consequences on rural livelihoods especially crop productivity.

High transport cost was the main effect of climate variability during rainy seasons that affected market

aspects of banana value chain development. When mode of transport was considered, it was observed that most of the respondents in Mukurweini (Nyeri County) preferred to use human labour (women carry the load on their backs) and motorcycles commonly referred as "boda boda" both when transporting bananas to the collection point or market centers while in Imenti South (Meru County) most farmers preferred to use motorcycles. In order to make banana transport sustainable it is important to improve the road networks from farms to the collection or market centers. To enhance the market value and sustainability of the production, farmers in Mukurweini sub-county preferred ripening of bananas before delivering to the market while in Imenti South sub-county they preferred cleaning bananas and packaging in crates and sacks thus enhancing their value. During high rainfall seasons, bananas were reported to be of low quality in Mukurweini while in Imenti South we registered low market demand thus increasing wastage and low prices. This implies that there is a need for farmers to embrace value addition, which helps the small holders' farmers to earn more from their products owing to sustainability in banana production.

The most preferred climate adaptation strategy varied between the two study areas with Mukurweini farmers preferring crop diversification and Imenti South farmers opted for irrigation of the banana crop. Therefore, from these finding it can be concluded that climate variability is perceived differently in the region and adaptation measure undertaken by farmers varies within the region. It is worth noting that irrigation as an adaptation strategy on banana production promotes sustainability in the region while crop diversification ensures food security among the households. High-quality bananas create demand on the product in the market thereby bringing more money to the farmers hence promoting sustainable production.

### RECOMMENDATIONS

The study proposes the following areas for further research at banana production level: sustainability of water harvesting on banana production and level of adoption of drought-tolerant varieties and crop diversification among the small holder's farmers in the region. Regarding banana transportation further studies should be conducted on the impact of road network on banana production. At marketing level, the effect of market information on banana production should be studied. The level of adoption of value addition on banana should be studied. Another suggested area of further research is to ascertain the impact of number of rainy days in each year on banana value chain in the region. ■

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