**KENYATTA UNIVERSITY**

**SCHOOL OF HUMANITIES AND SOCIAL SCIENCES**

**DEPARTMENT OF GEOGRAPHY**

# EFFECTS OF CLIMATE VARIABILITY ON TEA YIELDS AND ADAPTATION STRATEGIES BY SMALLHOLDER FARMERS IN BOMET COUNTY, KENYA

**By**

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**C50/26080/2013**

**A thesis submitted for partial fulfillment of the requirement for the award of the degree of Master of Arts in Geography, in the School of Humanities and social Sciences,**

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**OCTOBER, 2021**

## DECLARATION

**Student: Declaration**

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

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## DEDICATION

This work is dedicated to my husband Alfred, sons Oscar, Victor and Edgar, daughters Erica and Tresca for their understanding, patience, encouragement and support while pursuing this course.

## ACKNOWLEDGMENTS

It is a pleasure to thank the many people who made this thesis possible. First and foremost, I would like to thank God, who provided me with wisdom, patience and strength required for completing this study. Secondly, I would like to thank my supervisory panel for all the assistance they have given me throughout. I am forever grateful to my supervisors, Dr. Makokha and Dr. Macharia for the guidance they gave me. Their patient encouragement, advice, and insightful criticisms aided the writing of this thesis in many ways.

Family, friends and colleagues have always supported me throughout the study period. My husband Alfred and children Erica, Tresca, Oscar, Victor and Edgar have always given me unprecedented support, encouragement and sacrifice for this work, I truly appreciate. To my parents, Joseph Kauria and Juliana Kauria: I appreciate the support you have continued to give me in pursuit of quality education. To my siblings: it is a pleasure to express my gratitude for the encouragement and unconditional love throughout my journey.

Several colleagues in the Department have been functional in providing the critical mass to make this masters happen. In particular, I would like to thank Mercy Kirui, Margaret Njogu, Michael Murunga, Monica, Albert Mensah, and Beryl for their encouragement. Several other individuals have contributed to this thesis in a number of ways, such as providing data, influencing ideas or data entry. For that, I would like to thank: Anthony Muriithi Naftali (KTDA) and entire staff of KMD. The study would not have been possible without the collaboration of all smallholder tea farmers in Bomet Central sub-County: to them all, I remain so grateful.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **ACCCA** | Advancing Capacity to Support Climate Change Adaptation |
| **AMJ** | April, May and June |
| **CCAFS** | Climate Change Agriculture and Food Security |
| **CIAT** | International Centre for Tropical Agriculture |
| **CPDA** | Christian Partners Development Agency |
| **FAO** | Food and Agriculture Organization |
| **GDP** | Gross Domestic Product |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **JAS** | July, August and September |
| **JFM** | January, February and March |
| **KARI** | Kenya Agricultural Research Institute |
| **KMD** | Kenya Meteorological Department |
| **KTDA** | Kenya Tea Development Agency |
| **MoALF** | Ministry of Agriculture, Livestock and Fisheries |
| **OND** | October, November and December |
| **TBK** | Tea Board of Kenya |
| **TRFK** | Tea Research Foundation of Kenya |
| **UNFCCC** | United Nations Framework Convention on Climate Change |

## OPERATIONAL DEFINITIONS OF TERMS

**Adaptation** This refers to the long term practical steps to mitigate tea farms from the likely disruption and damage that will result from effect of climate variability.

**Climate Variability** This refers to natural changes through which the weather conditions of a place differ from long term average. This variation is indicated by extreme temperature, droughts and changes in rainfall patterns (duration, timing and intensity). In this study climate variability has been operationalized to mean rainfall and temperature variability.

**Smallholder Farmers** This refers to those farmers holding not more than two acres of land under tea farming.

**Tea Yields** This refers to weighted green tea yields in Kgs by smallholder tea farmers who fall under the umbrella of KTDA.

## ABSTRACT

Changes in weather elements such as temperature and rainfall have a strong influence on tea yields. The extent to which climate variability has impacted on tea yields, the main source of livelihood in Bomet Central sub-County is still not documented. To bridge that gap, this study investigated the effects of climate variability on tea yields and the adaptation strategies by smallholder farmers in Bomet Central sub-County, Bomet County. The data used in the study include: observed monthly rainfall and temperature for Bomet Central sub-County obtained from Bomet Water Supply Weather Station and monthly tea yields data for Kapkoros and Tirgaga tea Factories obtained from Kenya Tea Development Agency from 1993–2013. The research was based on a descriptive survey design with a target population of 10,800 tea farmers with a sample size of 130 respondents. Questionnaires were used to collect data on adaptation strategies and determinant factors influencing adaptation strategies from farmers in the study area. Regression analysis and descriptive statistical methods of data analysis were used. Regression analysis was used for time series rainfall, temperature and tea output data over the 21-year period. Descriptive analysis involved computation of frequencies, percentages, mean and standard deviation of the data on adaptation strategies used by smallholder tea farmers. The first objective was to evaluate the effects of rainfall and temperature variability on smallholder tea yields in Bomet Central sub-County from 1993–2013. The results showed that Bomet County experienced a slight increase in rainfall and temperature trend by 6.471mm and about 0.029$^{o}$C respectively per year. Pearson correlation showed that there was a weak positive relationship between rainfall variability and tea yields R=0.122 ($R^2$=0.015) and a strong positive relationship between temperature and tea yields R=0.908 ($R^2$=0.825). The second objective of the study was to determine the adaptation strategies used by smallholder tea farmers in response to climate variability in Bomet Central sub-County. Weed management to reduce competition for moisture (78.9%) and proper drainage systems on long and steep slopes (47.7%) were the most common adaptation strategies. The third objective was to investigate the determinant factors that influenced the adaptation strategies used by smallholder tea farmers in Bomet Central sub-County. Gender, age, education level and household size were vital in facilitating adoption of better and affordable climate variability adaptation strategies which enhances smallholders' tea production. Based on the findings, the study concluded that rainfall variability has negatively affected tea production in Bomet Central sub-County. The study also concluded that there was a positive correlation between temperature and tea yields. Majority of tea farmers have embraced at least one adaptation strategy to climate variability but confirmed that they had never been involved in climate variability adaptation planning beforehand. The study also revealed that education, age and gender significantly influenced a number of these adaptation strategies. The study recommends that farmers be advised to enhance the use mulching, planting drought resistant tea varieties, planting cover crops during young tea stage and regular weeding to mitigate the effects of Rainfall variability. The study also recommends that the County and National Government institutions need to enhance the adaptation strategies used by farmers by providing advice on the need to plant drought resistant varieties such as purple tea so as mitigate the effects of climate variability. Purple tea processing units should also be established in the existing factories to allow farmers earn more profit.

# CHAPTER ONE: INTRODUCTION

## 1.1 Background of the Study

Tea (*Camellia sinensis*) is widely cultivated as a rain-fed plantation crop and its productivity is greatly influenced by environmental conditions. Tea requires a temperature range of 18–25°C and well-distributed annual rainfall of between 1400–2500 mm for optimum production (Nissanka, 2007). In India, unfavorable weather conditions for tea plantations owing to rainfall abrasions (too much and too little) have badly affected the tea plantations in various parts of Assam and North Bengal (Baruah and Bhagat, 2012). Irrigation which was not necessary some few years back has now become utmost essential for tea farms across states particularly in Brahmaputra Valley, the main tea growing region of Assam. Similarly, in Africa, there is a risk of reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national and household livelihood and food security (IPCC, 2014).

Since the introduction of tea in Kenya in the early 20$^{th}$ century, the acreage under cultivation has steadily risen, with the land area under the crop totaling 147,080 hectares by 2007 (TBK, 2008). Tea growing areas in Kenya are divided into two regions defined by the Great Rift Valley, a natural geographical feature that divides the country almost asymmetrically into two major blocks. The East of Rift block comprises Mt. Kenya region, Nyambene hills, and the Aberdare highlands whereas the Kericho region, Mau highlands, Nandi Hills and Kisii highlands form the West Rift block (TBK, 2014). Over the years, tea yields have increased through the development and release of cultivars with high yield and better beverage quality attributes (Republic of Kenya, 2016).

The tea industry is the second leading foreign exchange earner (accounting for about 20% of the total export earnings) amongst agricultural commodities after horticultural crops in Kenya (TBK, 2014). The tea sub-sector provides a source of livelihood to over 3 million people (about 10% of the total population) besides providing support to other sectors of the economy such as infrastructure development (TBK, 2004). Tea in Kenya is also expected to play a great role in achieving Vision 2030 (Kenya's development policy that aspires to achieve a 10% growth annually in gross domestic product from 2012). However, emerging reports indicate that growth in the sector may not be sustained probably due to the abiotic stress factors such as drought, hail, frost and low temperature (Kamunya, 2010; Cheserek, 2011).

Prolonged drought periods are quite common nowadays. For instance, in 1997, 2000, 2003, 2011, late March, 2012 when tea yield losses of over 60 % were recorded (TBK, 2004, 2008; TRFK, 2012). Again, the green leaf deliveries by farmers dropped countrywide from 936.6 million kilogrammes in 2016 to 705.2 million kilograms in 2017 due to prolonged dry spell (TBK, 2018). Majority of the smallholder tea farmers in Bomet Central sub-County have planted most of their land with tea (Bomet County Government, 2013). Assam tea is widely grown by farmers in the area and the clones grown include C51, S15/10, TRFK 31/8, BB/35, TN14/3 and SFS 303/577 (TBK, 2008). Clones S15/10, TRFK 31/8 and BB/35 are susceptible to drought (TRFK, 2012). Hence, due to climate variability coupled with low returns from tea farms, some farmers face food insecurity.

The Tea Research Foundation Kenya (TRFK) has been monitoring climatic data in Kenya since 1958. TRFK observed changes in average temperature increase of 0.016$^{o}$C per year for 52 years which adds nearly to 1$^{o}$C, fall in annual rainfall at 4.82 mm per year totaling 250 mm over the same period and a greater soil water deficit (notably in January, February and March) resulting in significant reductions in tea yields (TRFK, 2012). The occasional dry spells do not support the growth of tea and therefore lead to low yield and hence poor profitability (Mose, 2012).

To reduce the adverse consequences of climate variability, there is need for tea farmers to adopt different adaptation strategies. A study by Smith and Olga (2001) noted that agricultural adaptations embrace a wide range of options. These includes: crop diversification and the timing operations (microlevel options); income diversification and credit schemes (markets responses); developing meteorological forecasting capability, improvement in agricultural market and information provision (adaptive capacity and institutional strengthening); and promoting of new crop varieties (technological developments). Most of these choices represent possible adaptation measures but there is limited evidence that these adaptation options are realistic, or even likely to be implemented. The dependent variable in the study was tea yields in Kgs while the independent variables were rainfall and temperature variability. The adaptation strategies that affect tea yields were the intervening factors in the study.

## 1.2 Problem Statement

Bomet County is experiencing changes in weather elements affecting both the quality and the quantity of tea yields (TRFK, 2012). The persistent cold weather conditions coupled with less rainfall in Bomet, Kisii, and Nyamira have led to a significant reduction of tea yields over the years (TBK, 2012). For instance, tea yields in Bomet dropped by approximately 9% from 27.1 million kilogrammes in 2005 to 24.6 million kilogrammes in 2006 (TBK, 2012).

Smallholder farmers in Bomet Central are more diverse across crops but tea remains to be the main rain fed-crop cultivated throughout the area. There is, however, a scarcity of information on effects of rainfall and temperature variability on the amount of tea yields in the area. There is also uncertainty on what adaptation strategies have been developed by the farmers to ensure sustainable production. Research on effects of climate variability on tea yields and also evaluation of strategies chosen by smallholder farmers to adapt to effects of climate variability has been insufficient (TBK, 2012; TRFK 2012). In addition, factors that influence farmers' decision to adapt to climate variability in Bomet Central sub-County are not known. To address that gap, this study was designed to evaluate the effects of climate variability on tea yields and to determine adaptation strategies employed by smallholder tea farmers in Bomet Central sub-County.

## 1.3 Objective of the Study

### 1.3.1 General Objective

To evaluate the effects of climate variability on tea yields and the adaptation strategies used by smallholder farmers in Bomet Central sub-County, Bomet County.

### 1.3.2 Specific Objectives

To be able to achieve the above objective, the following specific objectives were addressed;

(i) To evaluate effects of rainfall and temperature variability on smallholder tea yields in Bomet Central sub-County from 1993–2013.

(ii) To determine the adaptation strategies used by smallholder tea farmers in response to rainfall and temperature variability in Bomet Central sub-County.

(iii) To investigate the socio-economic determinants of adaptation strategies used by smallholder tea farmers in Bomet Central sub-County.

## 1.4 Research Questions

In order to achieve the above objectives, the study was guided by the following research questions:

(i) What is the relationship between rainfall and temperature variability and smallholder tea yields in Bomet Central sub-County?

(ii) What are the adaptation strategies used by smallholder tea farmers in Bomet Central sub-County?

(iii) What are the determinants of adaptation strategies used by smallholder tea in Bomet Central sub-County?

## 1.5 Study Hypotheses

The study was guided by the following null hypotheses;

(i) There is no significant relationship between rainfall variability and the tea yields by smallholder farmers in Bomet Central sub-County.

(ii) There is no significant relationship between temperature variability and the tea yields by smallholder farmers in Bomet Central sub-County.

(iii) There is no significant relationship between socio-economic determinants and adaptation strategies used in Bomet Central sub-County.

## 1.6 Justification and Significance of the Study

Climate variability poses a big threat to farmers in Bomet County because of their overwhelming reliance on tea farming. IPCC reports also indicate clearly that in developing countries, climate variability is the single most determining factor that endangers agricultural production and it is also predicted to increase further in Eastern Africa (IPCC, 2007). Therefore, it is important to carry out research to establish how smallholder tea farmers in Bomet Central sub-County cope with environmental and socio-economic challenges brought about by climate variability. Rainfall and temperature are the preferred weather elements because they are the major factors that influence the tea yields globally more than any other factor (MoALF, 2017). In addition, rainfall in the county has become more variable, with increase in extremes (both lows and highs) from year to year, which has resulted in increase in drought and flood risk (MoALF, 2017). Food insecurity in the county can be attributed to the occurrence of weather related hazards such as intense rains, drought as well as increase in temperatures (MoALF, 2017). The area has been purposely selected owing to the large number of smallholder tea farmers (TBK, 2012) and also because the Bomet water supply weather station was within the study area for easy collection of rainfall and temperature data. On the other hand, the research period 1993–2013 was selected because data required for the study was readily available from KTDA and Bomet water supply weather station for that period.

The study provides information on appropriate adaptation strategies which could be applied to reduce the negative effects of climate variability. This information could assist the policy makers, donors and researchers in coming up with appropriate research, innovations and development interventions that will improve the livelihoods of the smallholder tea farmers. Also the study could assist the KTDA to find out the level of adaptation to climate variability by tea farmers. This will enable them to organize extensions services to boost on adoption of new skills that will improve the uptake of adaptation strategies and ensure sustainable tea production. This research could also be valuable to TRFK to establish whether the new tea varieties resistant to drought have been planted in the area.

## 1.7 Scope and Limitations

The study examined the effects of climate variability on smallholder tea yields, the adaptation strategies and other socio-economic factors that influence adaptation strategies used by smallholder tea farmers in response to climate variability in the County. It focused on average monthly tea yields in Kgs, average monthly rainfall in mm and average monthly temperature in $^{o}$C. Some of the limitations of this study included tea farmers' unwillingness to give the right information to the researcher. Uncooperative respondent was encountered due to suspicion on the real motives of the researcher. However, working closely with the community leaders and community volunteers helped explain the sole academic purpose of the study to the respondents who were suspicious of the real motives of the study.

In addition, the other factors affecting tea yields like increase in cost of inputs (labour and fertilizer), poor infrastructure, decreasing farm sizes and weather factors were assumed to be insignificant since the study dealt with smallholder tea farmers facing similar challenges.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Introduction

This chapter presents a review of literature that is related to climate variability and adaptation strategies that can be adopted. This enabled the study to develop new knowledge from the gaps identified which if bridged would lead to successful climate variability adaptation.

## 2.2 Climate Variability and Tea Yields

Global weather has become unpredictable and created uncertainty in agricultural production. Studies have shown that an important factor in the annual tea yield is climate variability (Ngetich, et al 2006 (b)). According to Wijeratne et al. (2007), tea yields at low-and-mid altitudes is more vulnerable to adverse effects of climate variability than those at high altitudes in Sri-Lanka. The study established that optimum temperature for tea growing was about 22°C and the optimum rainfall varied from 223–417 mm per month. In addition, a drop of monthly rainfall by 100 mm could reduce productivity of processed tea by about 30–80 kg per hectare. The study also established that a rise in ambient carbon dioxide from 370–600 ppm increased tea yield by 33%–37% depending on altitude. The study noted that, because of climate variability, yields are likely to decrease in low elevations but increase in high elevations. The study carried out field experiments at high and low elevations while current study established the effects of climate variability using regression analysis.

A study done by Bhagat, Baruah and Safique (2010) showed that apart from well-distributed rainfall and the attainment of certain optimum soil and air temperature; wind velocity, sunshine hours, vapour pressure of the atmosphere also influences the performance of the tea crop. In addition, daylength and change of seasons influences many important processes of the tea plant, such as initiation of flowering, induction of vegetative growth, abscission of leaves and fruits or dormancy and germination of seeds. A shift in any of the suitable climatic conditions as a result of climate change or otherwise may lead to poor crop performance. The study failed to capture how extreme weather events like frost and hailstorms affect tea yields.

CIAT (2011) carried out a study to predict climate change for tea growing areas using global models. The study found out that the change in conditions suitable for growing of tea is site-specific. In Uganda, for example, the study showed that the districts such as Bundibugyo, Kyejojo, Bushenyi, Bundibugyo, Masaka and Kanungu will become unsuitable for tea growing by 2050 and farmers will need to plant alternative crops. On the other hand, the districts such as Kisoro and Kabarole will remain suitable for tea but farmers need to adapt their agronomic management to the new climatic conditions that the area will experience. The study also noted that in Kenya, some areas such as Gucha, Kericho, and Nandi will gradually become unsuitable for tea while others like Nyamira Bomet and Kisii will remain stable. On the other hand, conditions of areas such as Meru, Kirinyaga, Embu, Muranga, Nyeri and Kiambu, could increase the probability of growing of tea (CIAT, 2011). The study, however, focused on current and future suitability of tea growing areas but the current study to the analyzed the effects of temperature and rainfall variability on tea yields.

According to Wachira, (2009), there is evidence of climate change in tea growing zones. Since 1958, there is evidence of reduced rainfall, decreased soil water and increased temperatures. In 52 years covered by the study (1958–2010), rainfall in Kericho dropped by 4.82 mm every year while temperature increased by 0.016°C annually. Maximum and minimum temperatures were noted to have increased by between 0.1°C and 2.9°C in the tea growing areas. There was high correlation between tea production and rainfall with reduction of tea yields coinciding with dry periods and increased soil water deficit.

A study done by FAO (2012) noted that the main crops grown in the West of Rift were tea, maize, and bananas while those grown in the East were maize, sweet potatoes, and bananas. The study observed that changes in rainfall patterns and distribution that reduced tea yields were tied to climate variability. Changes that were most notable were in wet and dry seasons which led to frost and shifts in planting season. The study concluded that tea producers may lose up to 30% in cash earnings due to climate variability. The current study provide more detailed information needed on the effects of climate variability on tea yield at a specific location particularly sub-County level and villages for effective adaptation options to be targeted.

Rwigi and Oteng'i, (2009) considered five climatic variables namely; daily mean relative humidity, total weekly radiation, daily mean minimum temperature, daily mean maximum temperature and weekly tea yields. The findings showed that mean minimum temperature and relative humidity highly influenced weekly tea yield. According to the study temperature, rainfall, and their variability are main variables influencing tea yields in Kenya. The authors, however, didn’t look at effect of extreme weather variables like frost and hailstorms on tea yields.

A study by Dutta (2011) on the effects of age, pruning and fertilizer application on tea yield in Netherlands showed that the yield was influenced by fertilizer applications, age of tea plants, leaf area index and also pruning. Similarly, Hicks (2009) pointed out that the factors affecting global tea yields were weather conditions, planted areas, population, age of tea bushes, labour, capital, price of inputs and yield risk. However, there is also need to evaluate climatic variables affecting tea yields in a specific area.

Additionally, Karanga and Bwisa (2014) cited poor road network, high cost of labour and low income from tea produced by farmers as factors which contributed to decline of tea yields in Abothuguci West Division. They concluded that greatest factor which negatively influences the quantity of tea reaching the factory is transportation. The current study seeks to establish the effects of weather variables on tea yield in Bomet central sub-county.

Soy (2010) established that the physical environment played a vital role in rainfall patterns and distribution in tea growing zones in Kenya. He further pointed out that factory production capacity which restricts inflow of green leaf from farmers at peak periods was the major bottleneck in the growing of tea. He argued that there was need for training of farmers and enhancement of production technology both in the field and factory. The author concluded that the poor profitability of the tea sub-sector is largely due to the degradation of the physical environment and low production capacity of both farmers and the factories. The current study seeks to establish the effects of weather variables on tea yield in Bomet central sub-county.

## 2.3 The Adaptation Strategies used by Smallholder Farmers to Climate Variability.

According to FAO (2009), climate variability adaptation strategies are now a matter of urgency. It is necessary that the climate variability adaptation strategies are integrated into development planning programs and projects (World Bank, 2008). Responses aimed at adapting to climate variability may, however, have negative consequences for food security. This is because as a measure taken to increase food security may exacerbate climate variability (CCAFS, 2009). It is therefore important to adopt effective adaptation strategies that can assist farmers adapt to the impact of climate variability. Such adaptation strategies must be sustainable, environmentally friendly, economically viable and easy for farmers to adopt.

Prematilake (2014) recommended that the long-term strategies which should be prioritized to avert impacts of dry conditions are; developing new tea varieties resistant to drought and control of pests and diseases. The author also recommended construction of small ponds, rainwater harvesting, strengthening watershed management, and planting trees on fences, open areas and boarders as important in conserving soil and moisture. The current study enhanced on the findings of this study.

According to De Wit (2006) the adaptation strategies that can be used includes water and soil conservation techniques, changing planting dates, planting varieties of the same crop and increased use of irrigation. FAO (2012) identified the main adaptation strategies employed by the tea farmers in Kenya as growing drought resistant varieties, crop diversification, and planting trees. The study was carried out across 11 countries while the current study evaluated the adaptation strategies used by tea farmers at rural-village level.

In Uganda, Okonya, Syndikus and Kroschel (2013), in their study, found out that the adaptation was affected significantly by size of land owned and gender of the household head. According to the ninety-nine percent of all households interviewed, climate variability had been observed in the last ten years. Floods and drought had the highest effect on production of crops across agro-ecological zones. Storing food, digging drainage channels and income diversification were the adaptation strategies towards extreme events. Others were planting at onset of rains, planting trees and increased pesticide/fungicide application among others. The adaptation strategies established by author was adopted by sweet potato farmers while the current study dealt with adaptation strategies specific to tea farmers.

## 2.4 Socio-economic Determinants of Adaptation Strategies Employed by Smallholder Farmers.

Nhemachena and Hassan (2008) found out that the most vulnerable agricultural practice to climate variability in Africa is mono-cropping. They established that extension services, technology and farm assets are important in assisting African farmers adapt to climate variability. The information obtained from this study was general and covered different activities of farming whereas the current research was limited to tea farming. On the other hand, Fosu-mensah, Vlek and Mansheadi (2010) in their study established that access to credit, soil fertility, land tenure, access to extension services, size of the farm, gender and farming experience were significant determinants in coping with climate variability. Some of the determinants established in the study are not applicable to current study, for instance land tenure, soil fertility and size of the farm. In addition, the study used binomial logit model while the current study used regression analysis and descriptive statistics.

The socio-economic team of Advancing Capacity to Support Climate Change Adaptation (ACCCA, 2010) among smallholder farmers in three drought prone districts in Tigray in Northern Ethiopia established that large farms influence positively tree planting, water conservation and the use of improved varieties. According to the study, livestock ownership by female farmers, extension services, observed change in temperature and access to climate change information has positive impact on adaptation to climate variability. The current study, however, the number of livestock is not included as independent variable. In addition, the study employed a multivariate probit model to analyze data while the current study used regression analysis.

Belaineh, Yared, and Woldeamlak (2012) in their study established that family size, plot size, agro-ecological locations, off-farm income, sex, frequency of extension services and livestock holding are the determinant factors influencing adaptation strategies. Similarly, Coretha and Muchapondwa (2012), in their study showed that, smallholder farmers in Tanzania have observed changes in mean precipitation and temperature and responded to it. Their results on farmers' decision to undertake any adaptation suggests that the possibility of undertaking any adaptation decrease with rainfall and temperature levels in the farming area but increase with education in the household. The current study seeks to establish the determinant factors influencing adaptation strategies specific to smallholder tea farmers.

## 2.6 Conceptual Framework

The study examined the effects of climate variability on tea yields and the adaptation strategies adopted by smallholder farmers in Bomet Central sub-County, Bomet County. The conceptual framework that guided the study was adapted and modified from Bett (2018) as a strategic tool to better understand the interactions between climate variability, tea yields and adaptation strategies used by smallholder tea farmers (Figure 2.1).

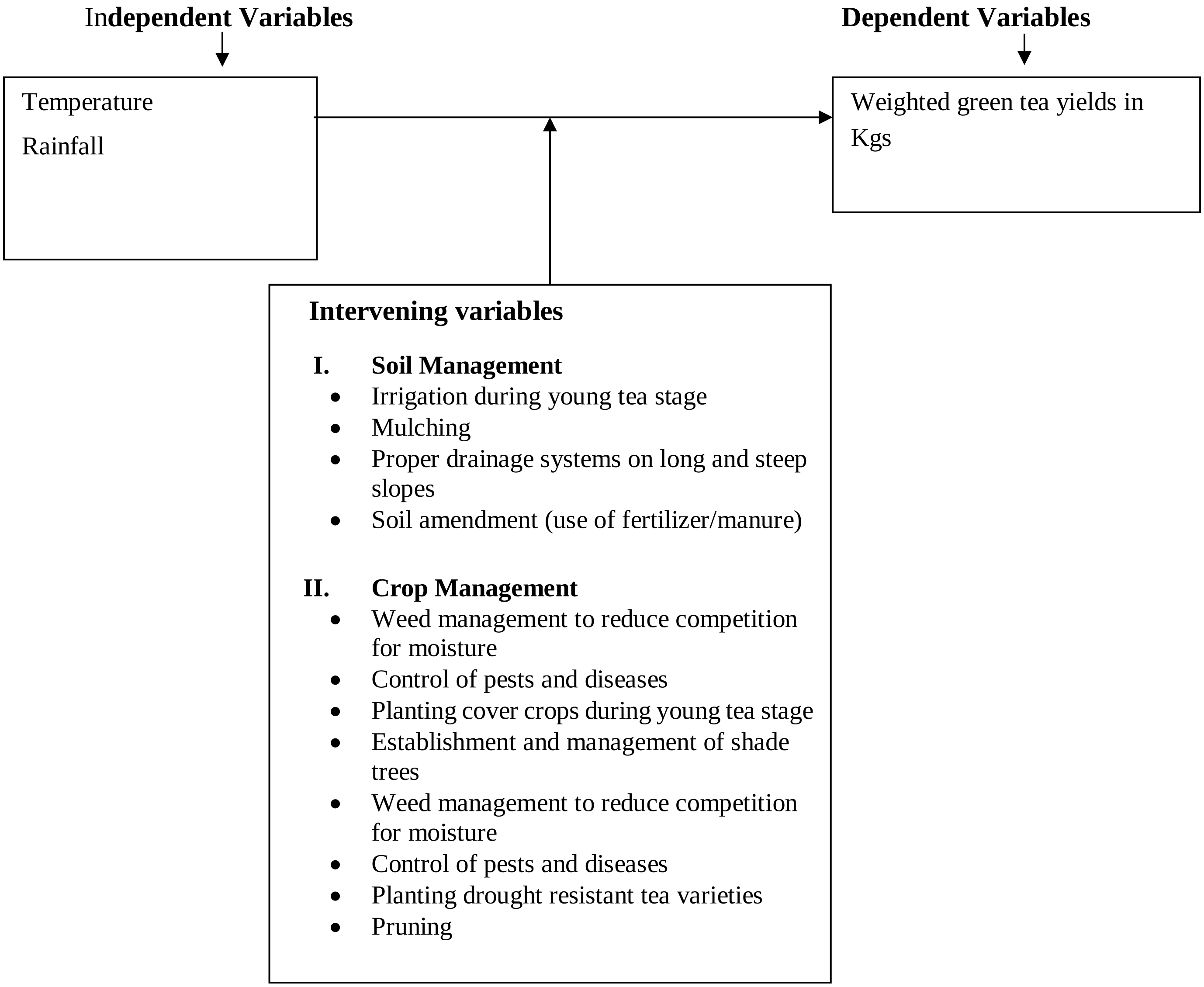


**Figure 2.1: Conceptual Framework**

Showing the Interactions of Independent and Dependent Variables (Adapted and modified from Bett, 2018).

# CHAPTER THREE: RESEARCH METHODOLOGY

## 3.1 Research Design

This study used descriptive research design. Descriptive survey designs are used when objectives are systematic or description of facts and characteristics of a given population or sample of the population or area of interest is factual and accurate (Kothari, 2007). According to Muganda, (2010), the goal of descriptive study is to offer the researcher a profile or to describe relevant aspects of phenomena of interest from an individual organization, industry, and some other perspective. Hence, the descriptive survey helped the researcher to get information on effects of climate variability on smallholder tea yields and the adaptation strategies in the study area.

## 3.2 Study Area

The study area was Bomet Central sub-County which is located in Bomet County. The following areas of the study area were examined;

### 3.2.1 Location and size of the study area

This study was conducted on smallholder tea farmers in Bomet Central sub-County, Bomet County. Bomet County lies between latitudes $0^{o}29'$ and $1^{o}03'$ South and between longitudes $35^{o}05'$ and $35^{o}35'$ East. It is bordered by four counties; Nakuru to the East, Kericho to the North-East, Nyamira to the West and Narok to the South (Figure 3.1). The County is divided into 5 Sub-counties, 25 wards, 66 locations and 177 sub-locations. Bomet Central is the smallest sub-County in Bomet County covering an area of 266 $km^2$ with five assembly wards namely; Silibwet, Singorwet, Ndaraweta, Chesoen and Tarakwa.

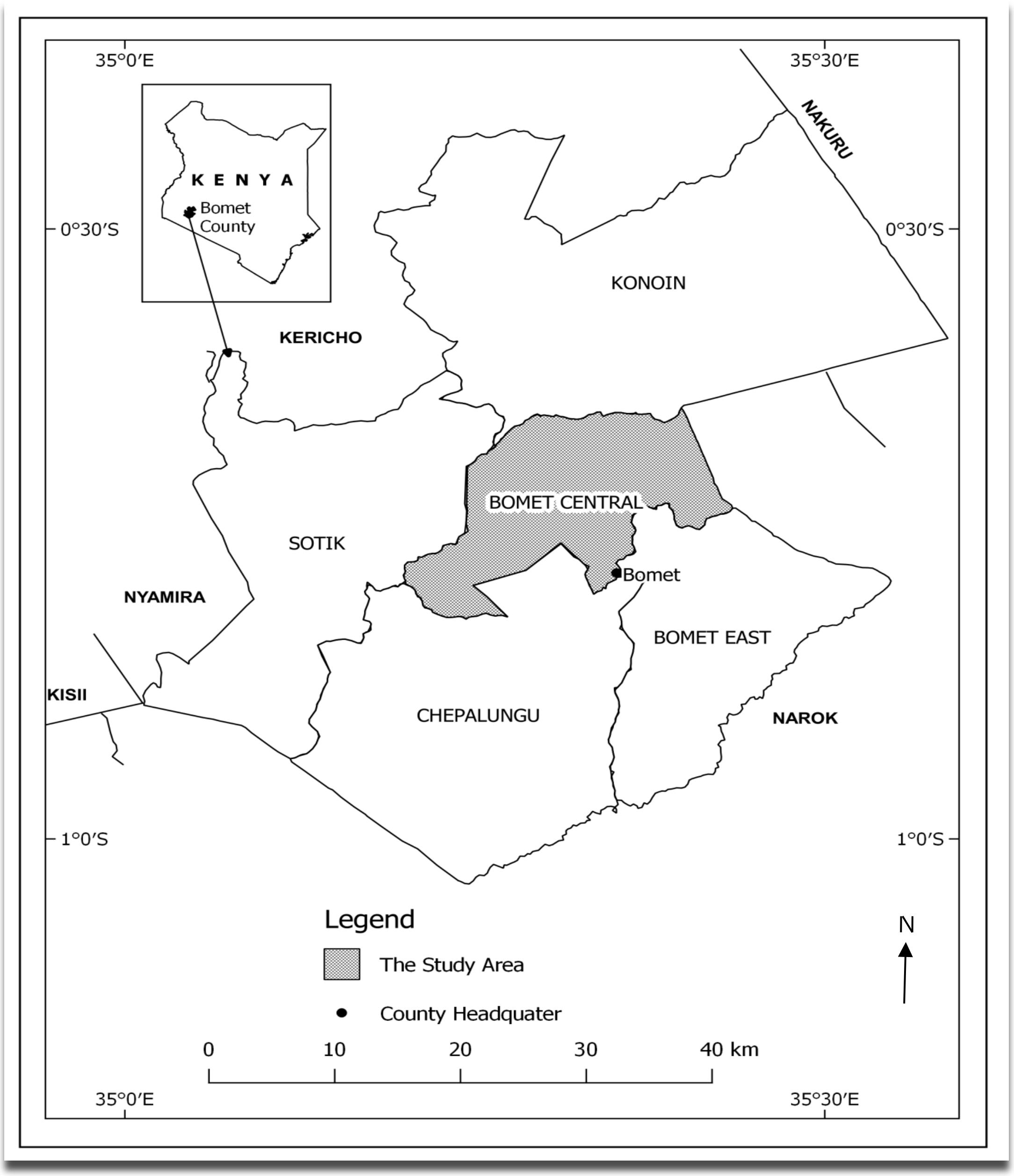


**Figure 3.1: Bomet Central sub-County.**

***Source: Bomet County Government, 2016.***

### 3.2.2 Climate of the study area

The area lies within a region with bimodal rainfall distribution occurring between the months of March to May for long rains and August to October short rains. The annual rainfall averages between 1100–1500 mm per year and a mean temperature of $18^{o}C$ (Bomet County Government, 2013). It is endowed with well-drained, rich and fertile soils but poor husbandry and increasing population have resulted in declining yields and soil erosion.

### 3.2.3 Socio-Economic Activities

Agriculture is the main economic activity for the rural population. The main crops grown are tea, maize, potatoes and beans. Farmers in the sub-County depend greatly on tea farming to support their household income and livelihood. Livestock is kept in the area for milk mainly for household consumption and any excess is sold to cater for the day-to-day running of the families.

## 3.3 Target Population

The target population was smallholder tea farmers in Bomet Central sub-County from which the researcher wished to draw conclusion on the effects of climate variability on tea yields in the study area. Bomet Central sub-County has 10,800 tea farmers supplying their tea to 92 buying centers.

### 3.4 Sample Size and Sampling Technique

A sample size is a subset of the total population that is used to give the general views of the target population (Kothari, 2004). From the total population of 10,800 smallholder farmers in the area, the sample size was determined using a simplified formula provided by Yamane (1967) at 95% confidence level, 5% degree of variability and 9% level of precision. The formula is as shown in equation 1.

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1+N\,(e)^2}} \qquad \text{Equation 1}$$

Where 'n' is the sample size, 'N' is the population size (total smallholder farmers), and 'e' is the level of precision. The above formula required a minimum of 123 but an additional 5% was included to cover for anticipated non-responses and to increase the power of the study giving a total of 130 farmers. Proportionate random sampling technique was used to divide the number of tea farmers living within the study area into 5 sub-groups. The sampling technique was used to ensure a fairly equal representation because number of tea farmers in the wards are not equal. The formula used is shown in equation 2.

$$\textbf{Ward sample size} = \frac{\mathbf{130}}{\mathbf{10,\,800}} \times \textbf{No. of smallholder farmers in the ward} \qquad \text{Equation 2}$$

The proportionate distribution of the respondents per assembly ward were as follows: Silibwet 22, Singorwet 33, Ndaraweta 37, Chesoen 34 and Tarakwa 4 (Table 3.1). Within each ward, the selection of tea farmers was done using convenient and systematic sampling.

**Table 3.1: Sample sizes of the five wards**

| Assembly Wards | No. of Tea farmers in the Ward | Ward Sample Size |
|---|---|---|
| Silibwet | 1,859 | 22 |
| Singorwet | 2,760 | 33 |
| Ndaraweta | 3,090 | 37 |
| Chesoen | 2,790 | 34 |
| Tarakwa | 301 | 4 |
| **Total** | **10,800** | **130** |

***Source: KTDA, 2016***

### 3.5 Research Instruments

The instruments used in this study to collect the primary data were questionnaires which were carried out in the field. Questionnaires were very instrumental for collecting primary data from tea farmers on effects of climate variability on tea yields; the adaptation strategies as well as the determinant factors that influence adaptation strategies used by smallholder tea farmers in the study area. On the other hand, secondary data on the trend of rainfall and temperature for the past 21 years was collected from Bomet Water Supply Weather Station while data on tea yields was collected from KTDA so as to aid in comparison purposes.

### 3.6 Data Collection

Data collection was done from 11th April to 12th July 2016. To obtain primary data, questionnaires were administered to the sampled respondents in the study area. The questionnaires helped in getting information about the adaptation strategies as well as the determinant factors that influence adaptation strategies used by smallholder tea farmers in the study area. Two organizations were targeted as the key sources of secondary data required for the analysis from 1993–2013. Monthly average rainfall data in (mm) and monthly average temperature (°C) data were obtained from Bomet Water Supply Weather Station. At the same time, monthly average tea yields (Kg) for Kapkoros and Tirgaga tea factories were obtained in from Kenya Tea Development Agency for the twenty-one-year period under investigation. This period is long enough to compare the effects of climate variability and smallholder tea production in the area.

### 3.7 Data Analysis

Data obtained from KTDA on the amount of tea yields and data from the Kenya Meteorological Department was collated for further processing and analysis. The questionnaire was edited, cleared, coded and fed into the computer for analysis. Quantitative data were analyzed using regression analysis and descriptive statistics. Regression analysis was used for time series rainfall, temperature and tea output data over the twenty-one-year period.

The linear regression model was given by;

$$\mathbf{V = \beta_{01} + \beta_{11} Y} \qquad \text{Equation 3}$$

$$V = \mathbf{\beta_{02} + \beta_{12} R + \beta_{22} Y} \qquad \text{Equation 4}$$

$$\mathbf{V = \beta_{03} + \beta_{13}R + \beta_{23}T + \beta_{33}Y} \qquad \text{Equation 5}$$

Where V –Tea yields in Kgs

R – Rainfall in mm

T – Temperature in $^{o}C$

Y – The Year.

A structure quadratic regression model was used to evaluate the relationship between tea yield and temperature. This provided the T-test of the variable, R-square and R value. This was given by;

$$V = \boldsymbol{\beta_{04} + \beta_{14}T + \beta_{24}T^2} \qquad \text{Equation 6}$$

Where V – Tea yields in Kgs

T – Temperature in $^{o}C$.

Descriptive analysis involved computation of frequencies, percentages, mean and standard deviation of the adaptation strategies used by smallholder tea farmers. Descriptive analysis was also used to compute moving averages of two weather elements (rainfall and temperature) and tea yield levels for the 21-year period. The inferential statistics were used to make inferences and to draw conclusions on qualitative data such as determinant factors influencing adaptation strategies. The inferential statistics used in this study were chi-square and factor analysis. Chi-square is a statistical method used as a test for comparing variance and non-parametric test (Kothari, 2004). It was used to test the independence of attributes. Factor analysis was done to single out those factors that had significant influence. The technique can reduce a large data set down to a small number of factors which can then be easily characterized and explained. It also determines whether some underlying patterns of relationship exist to facilitate the reducing of the data to a smaller set of factors or components. The Table 3.2 shows a summary of methodology used in this study.

**Table 3.2: Summary of data required and data analysis tools.**

| Objectives | Variables | Data required | Source | Type of data | Data collection tools | Data analysis tools | Statistics required |
|---|---|---|---|---|---|---|---|
| To evaluate the effects of rainfall and temperature variability on smallholder tea yields | Rainfall Temperature Tea yields | Monthly rainfall in mm Temperature in $^{o}$C Monthly green tea leaves in kg | -KMD -TBK | Secondary time series data | Summary Check Sheet | Regression analysis | Parameter estimates (a & b) -Data on: -Rainfall Temperature -Monthly green tea leaves in Kgs |
| To determine adaptation strategies used by smallholder farmers | Adaptation Strategies | Various adaptation strategies used | Smallholder tea farmer | Primary cross sectional data | Questionnaire | Descriptive statistics | Frequencies percentages Mean Standard deviation |
| To investigate determinant factors influencing adaptation | Adaptation Strategies | Determinant factors influencing adaptation strategies | Smallholder tea farmer | Primary cross sectional data | Questionnaire | SPSS -Chi-square - Factor Analysis | - $\chi^2$ -Eigen value |

# CHAPTER FOUR: RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter presents the results of the study based on the data collected from the field. The results are presented in four sections starting with rainfall, temperature, tea yields, adaptation strategies and determinant factors influencing adaptation strategies to climate variability in Bomet Central sub-County.

## 4.2 Variability of Rainfall, Temperature and Tea Yields over Bomet Central sub-County

This section described rainfall and temperature variability and their relationship with amount of tea yield produced in the study area.

### 4.2.1 Rainfall Variability in Bomet County.

Data from Kenya Meteorological Station showed that the amount of rainfall in Bomet Central has been fluctuating between highs of 2172.7 mm in 1997 and lows of 955.0 mm in the year 2005. The rainfall descriptive analysis indicated high variability as in standard deviation from January to December over the years from 1993 to 2013. The maximum standard deviation of rainfall was 105.3 mm in April and minimum standard deviation was 46.1 mm in July. This fluctuation affects the tea yields as registered between 1993 and 2013. The affected months with large standard deviation of tea yields are April and November which are the peak months for first rains and second rains in the study area. The highest mean rains occurred in April for the first rains season with 440.3 mm followed by mean of the second rains which was 359.0 mm and 360.2 mm for November and December respectively (Table 4.1).

**Table 4.1: Rainfall variability in mm in Bomet Central sub-County**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| January | 21 | .3 | 355.9 | 121.60 | 81.71 |
| February | 21 | 4.5 | 236.3 | 96.10 | 68.94 |
| March | 21 | 42.9 | 324.8 | 169.16 | 88.70 |
| April | 21 | 7.0 | 440.3 | 231.52 | 105.31 |
| May | 21 | 30.0 | 275.0 | 173.74 | 81.13 |
| June | 21 | 22.9 | 214.0 | 89.56 | 51.28 |
| July | 21 | 2.5 | 173.5 | 66.73 | 46.10 |
| August | 21 | 0 | 269.1 | 106.62 | 73.00 |
| September | 21 | 26.2 | 259.1 | 111.65 | 60.46 |
| October | 21 | 23.0 | 288.9 | 111.59 | 74.58 |
| November | 21 | 43.7 | 359.0 | 162.56 | 97.54 |
| December | 21 | 17.5 | 360.2 | 117.92 | 89.58 |
| Valid N (listwise) | 21 | | | | |

Source: KMD, 2016

Further analysis was done on total rainfall from 1993 to 2013 and the results showed a major variation as shown in Figure 4.1. There was evidence of low rains in 1993, 1999, 2000 and 2005. High rains were recorded in 1997, 2004, 2011 and 2013. The time series analysis using regression model on annual rainfall and years indicated R = .119 (adjusted $R^2 = 0.014$). This means that only 1.4% of the change in the dependent variable (Annual rainfall) was as a result of the change in the independent/predictor variable (years) while 98.6% are related to other factors (Table 4.2). Linear regression analysis showed that there has been a slight increase of 6.471 mm in rainfall over the years in Bomet County ($R = -11402 + 6.471Y$ where R and Y refers to rainfall in mm and Years respectively) as in Figure 4.1.

**Table 4.2: Regression Model for Rainfall and Time**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -11402.469 | 24760.535 | | -.461 | .650 |
| | Years from 1993-2013 | 6.471 | 12.362 | .119 | .523 | .607 |

a. Dependent Variable: Annual rain in mm

***Source: Computed from field data, 2016***

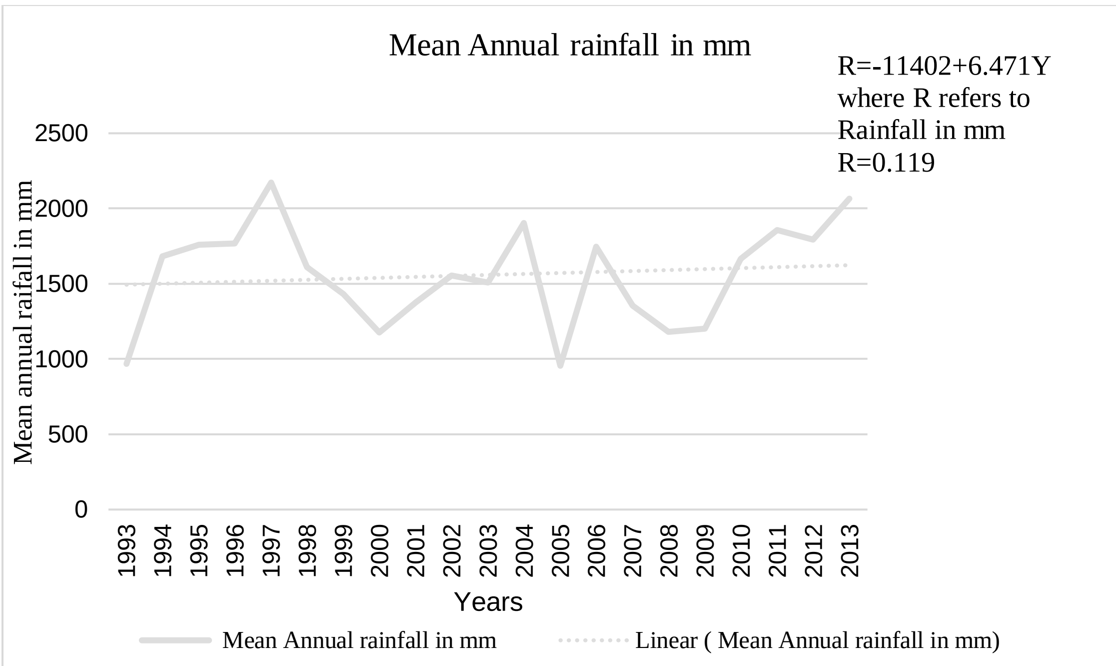


**Figure 4.1: Annual variability of rainfall from 1993–2013 for Bomet Central sub-County.**

***Source: computed from field data, 2016.***

The covariance on rainfall for the years under study was found to be 102.96 mm (Table 4.3). This shows that there was substantial change in rainfall patterns and if not taken into consideration will affect the tea farming in Bomet.

**Table 4.3: Covariance for the year 1993–2013 on rainfall in mm**

| Model | | | Years from 1993–2013 |
|---|---|---|---|
| 1 | Correlations | Years from 1993-2013 | 1.000 |
| | Covariance | Years from 1993-2013 | 102.957 |

a. Dependent Variable: Annual rain in mm
b. Independent Variable: Years

***Source: computed from field data, 2016***

**4.2.2 Temperature Variability from 1993–2013 in Bomet Central sub-County.**

Data from the Kenya Meteorological Station for Bomet water supply weather station showed that the minimum annual average temperature was 17.3$^{o}$C while the maximum annual temperature was 19.0$^{o}$C. The mean temperature was 18.4$^{o}$C (Table 4.4).

**Table 4.4: Descriptive Statistics for Temperature**

| **Average Temperature ($^{o}$C)** | |
|---|---|
| Mean | 18.4 |
| Std. Deviation | .4158 |
| Minimum | 17.3 |
| Maximum | 19.0 |

***Source: computed from field data, 2016.***

Further regression analysis showed that correlation co-efficient was R = .430 and $R^2$ = .185. This revealed that there was a positive relationship between time and the temperature. Thus as years increased from 1993–2013, there was a slight increase in temperature (Table 4.5). This agrees with Ongoma, et al, (2013) who found out that minimum and maximum temperatures have a rising trend in Kenya. This also supported by World Bank, (2016) which found out that between 1960 and 2006 the Malawian annual temperature increased by 0.9°C.

**Table 4.5: Correlation Co-efficient for Temperature with Time**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .430[a] | .185 | .142 | .38512 |

a. Predictors: (Constant), Years from 1993-2013
***Source: computed from field data, 2016***

The time series analysis was T = -39.373 + 0.029Y where T and Y refer to temperature in $^{o}$C and years respectively (Table 4.6). This showed that Bomet County experienced an increase in temperature trend of about 0.029$^{o}$C per year from 1993–2013. The findings by TRFK (2012) in Kericho also corroborate with these findings. TRFK observed changes in average temperature rise at 0.016$^{o}$C per year for 52 years totaling nearly 1$^{o}$C. The regression model relationship can be presented as in Figure 4.2.

**Table 4.6: Regression Model for Temperature and Time**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -39.373 | 27.799 | | -1.416 | .173 |
| | Years from 1993-2013 | .029 | .014 | .430 | 2.077 | .052 |

a. Dependent Variable: Average Temperature

***Source: computed from field data, 2016.***

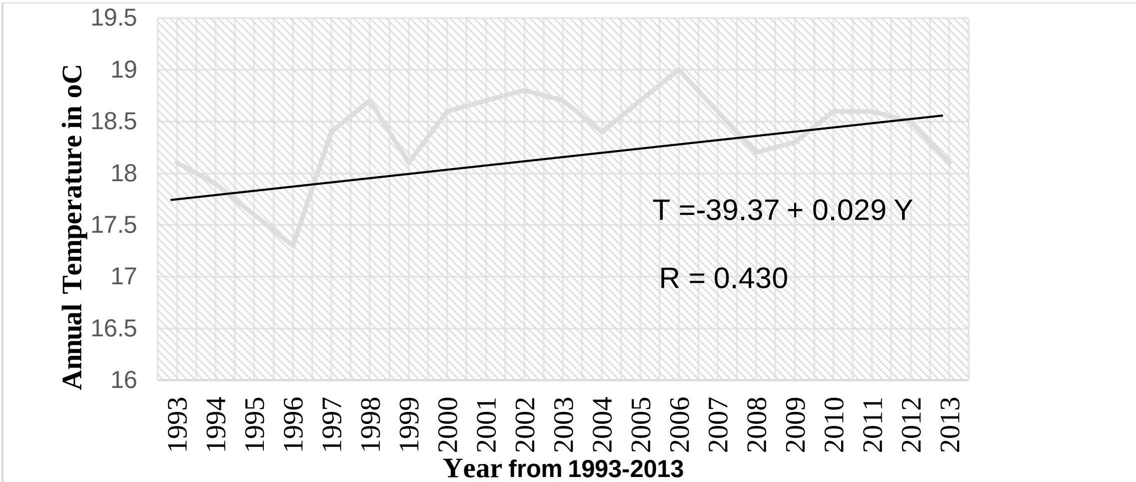


**Figure 4.2: Temperature from 1993–2013 for Bomet Central sub-County.**

***Source: computed from field data, 2016***

Temperature was also analyzed with a moving average of 5 years. This indicated that there was an increase trend in temperature from 1995 to 2004 and gradual decrease from 2004 to 2013 (Figure 4.3).

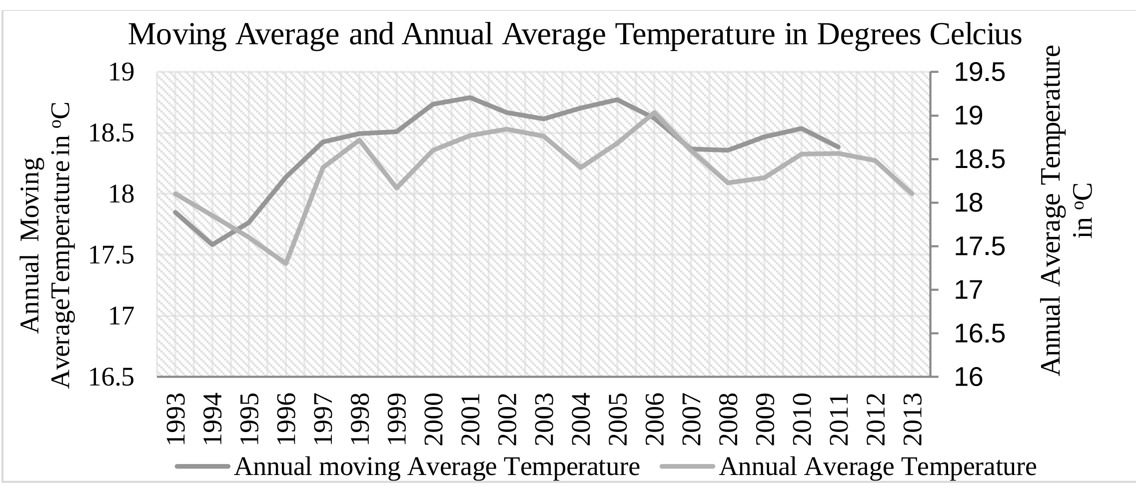


**Figure 4.3: Time series analysis for average temperature over 21 years for Bomet Central sub-County.**

***Source: computed from field data, 2016.***

### 4.2.3 Tea Yields from 1993–2013 in Bomet Central sub-County.

The tea yields analyzed from January to December from 1993–2013 shows a high variability. The maximum standard deviation was 1.38 million Kgs in January and minimum standard deviation was 0.89 million Kgs in February and August. The maximum tea yield was attained in May with 2.47 million Kgs at peak of first rain season and October with 2.47 million Kgs which marks the peak of second rain season (Table 4.7). This indicates that rainfall is a very important factor for tea yields.

**Table 4.7: Tea Yields from January to December over 1993 – 2013.**

| Tea Yields (millions Kg) | N | Sum in millions kg | Mean in Millions | Std. Deviation in millions |
|---|---|---|---|---|
| January | 21 | 50.39 | 2.40 | 1.38 |
| February | 21 | 39.43 | 1.88 | 0.89 |
| March | 21 | 37.42 | 1.78 | 0.90 |
| April | 21 | 45.34 | 2.16 | 0.99 |
| May | 21 | 51.81 | 2.47 | 1.28 |
| June | 21 | 47.21 | 2.25 | 0.97 |
| July | 21 | 45.60 | 2.17 | 0.91 |
| August | 21 | 46.16 | 2.20 | 0.89 |
| September | 21 | 47.43 | 2.26 | 0.92 |
| October | 21 | 51.79 | 2.47 | 1.21 |
| November | 21 | 49.07 | 2.34 | 1.05 |
| December | 21 | 49.21 | 2.34 | 0.96 |
| Valid N (listwise) | 21 | | | |

***Source: computed from field data, 2016***

The regression analysis indicated that there was a growth in tea yields forming a relationship with the number of years. Indeed, most farmers in Bomet Central Sub-County preferred growing tea to other crops. The regression model connecting the tea yields and time is given by:

$$V = -3418611000.511 + 1720076.548Y \qquad \text{Equation 7}$$

Where V refers to tea yields and Y refers to time in years (Table 4.8).

**Table 4.8: Regression Model for Tea Yields Time Series**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -3418611000.511 | 279452279.895 | | -12.233 | .000 |
| | Years from 1993–2013 | 1720076.548 | 139516.227 | .943 | 12.329 | .000 |

a. Dependent Variable: Annual tea yields (Kg)

***Source: computed from field data, 2016.***

The correlation co-efficient R = 0.943 indicated a very strong correlation between the tea yields and years (Figure 4.4). This showed that as the time in years increased from 1993–2013, the tea yields also increased. The coefficient of determinant was $R^2$ = .889 which means that 88.9% of the data was used while 11.1% can be based on other factors that affect the tea yields (Table 4.9).

**Table 4.9: R and R Square values for tea yields with time**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .943[a] | .889 | .883 | 3871418.186 |

a. Predictors: (Constant), Years from 1993-2013

***Source: computed from field data, 2015***

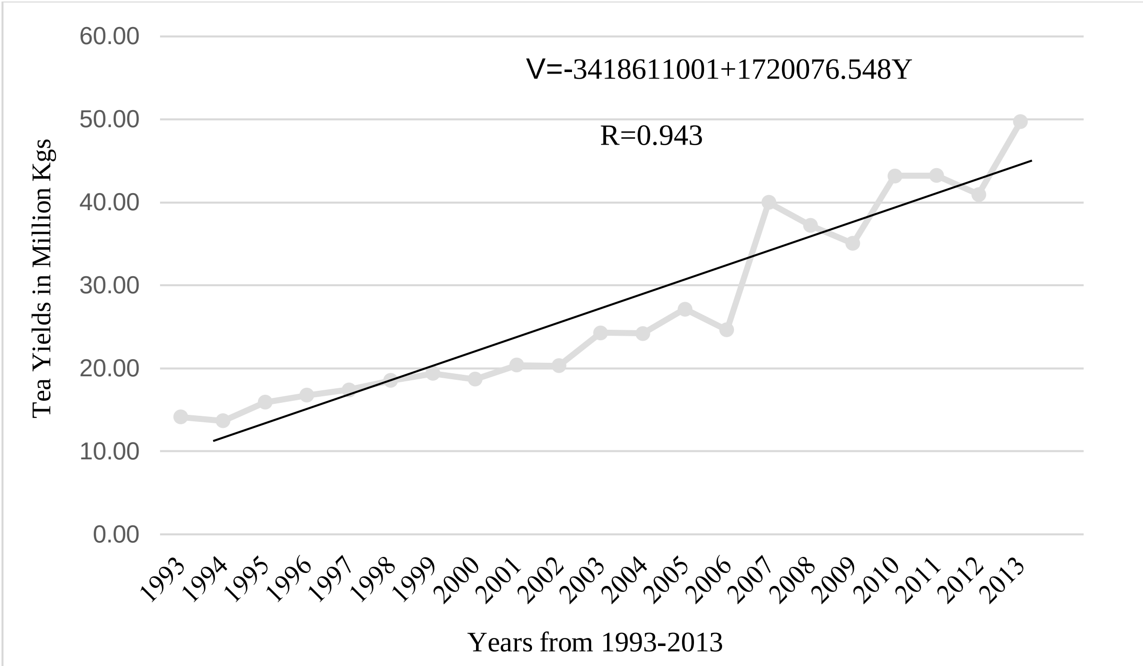


**Figure 4.4: Time series analysis for tea yields from 1993–2013.**
***Source: computed from field data, 2016.***

### 4.2.4 Relationship between Rainfall Variability and Tea Yields from 1993–2013

The Figure 4.5 shows the variability of the tea yields per year in Bomet Central sub-County. There has been an increase in tea yields from 1993–2013 with a marked increase from 2007 to 2013. The technological improvements such as fertilizer inputs and introduction of high yielding cultivars have led to the overall increase in tea yields. However, a significant drop was observed in 1997, 2006, 2009 and 2012 due to dry weather conditions. The loss of tea in the year 1997 was about 12% compared to the 1996 while the loss in the year 2006 was 9% compared to the 2005. There was a remarkable increase of tea yields in year 2013 due to high and well distributed rainfall throughout the year (TBK, 2014). Over the past 21 years, 2013 recorded the highest production level at 432.2 million kilograms countrywide

(TBK, 2014). Comparing the annual rainfall and tea yields in the study area revealed that some years with low annual rainfall still recorded high tea yields (as was the case in 2005 and 2007) (Figure 4.5). This could be attributed to rainfall distribution patterns. Tea yield per hectare is largely influenced by the rainfall distribution rather than total rainfall in the year (Wijeratne *et al*, 2007).

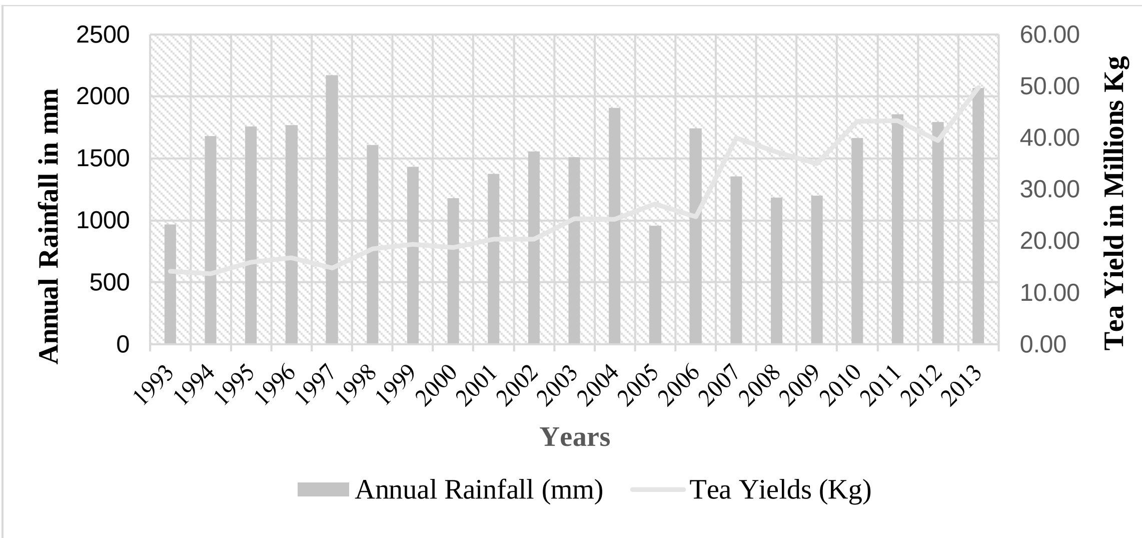


**Figure 4.5: Tea yields (Kg) and Rainfall (mm) over 21 years for in Bomet Central sub-County.**

***Source: computed from field data, 2016.***

The Pearson correlation between the tea yields in Kgs and average annual rainfall in mm indicated weak positive relationship R=0.122 (Table 4.10). This is contrary to the study done by Elbehri (2015) who found out that there was a weak negative relationship between tea yields and rainfall. However, the study conducted by Wanatabe *et al* (2015) agrees with these findings that rainfall significantly influence tea yields. Hence, with an increase in rainfall, there was a slight increase tea yields. Consequently, the study rejected the first research hypothesis that there is no significant relationship between rainfall variability and the tea yields smallholder tea farmers in the study area.

**Table 4.10: Covariance for the year 1993–2013 on rainfall in mm and tea yields in kg**

| | | Annual tea yield (Kg) | Average rain in mm |
|---|---|---|---|
| Annual tea yield (Kg) | Pearson Correlation | 1 | 0.122 |
| | Sig. (2-tailed) | | 0.599 |
| | N | 21 | 21 |
| Average rain in mm | Pearson Correlation | 0.122 | 1 |
| | Sig. (2-tailed) | 0.599 | |
| | N | 21 | 21 |

***Source: computed from field data, 2016***

Further analysis was done on total rainfall and tea yields from 1993 to 2013. The 3 year moving average indicated that between 1993 and 2003 the rainfall declined and from 2003 to 2013 the rainfall trend increased by about 40 mm per year but the tea yields has steadily increased over the years (Figure 4.6).

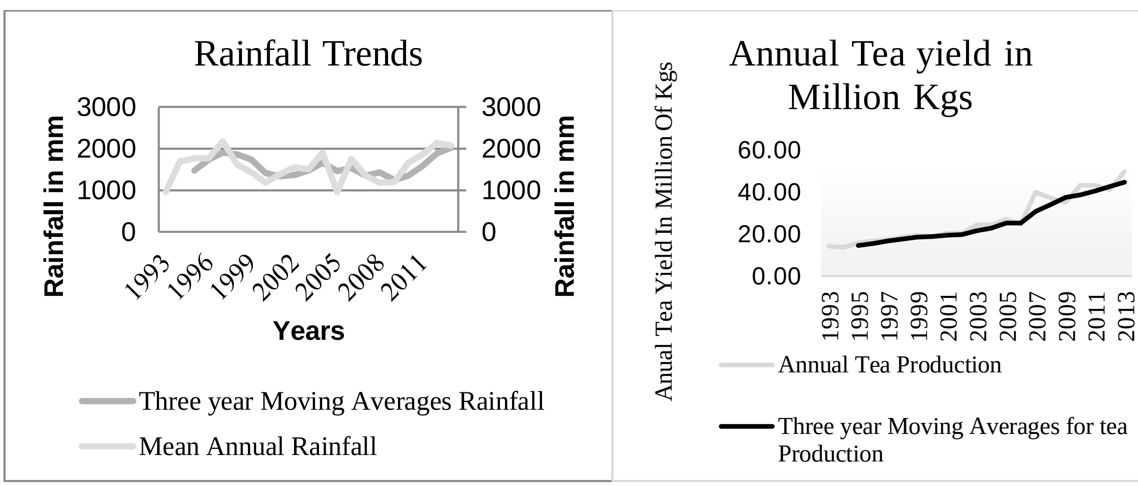


**Figure 4.6: Variability of rainfall and annual tea yields from 1993–2013 in Bomet Central sub-County.**

***Source: computed from field data, 2016.***

A model was attained from analysis where the dependent variable was tea yield and the independent variable was the annual rainfall and number of years under investigation. The model is given by:

**Annual Tea Yields = -3414918214 + 323.859 [Annual rain in mm] + 1717980.889 [Year]** Equation 8

This model indicated that 323.859 Kgs of tea was produced per one mm of rainfall. On the other hand, the year factor produced 1,717,980.889 Kgs of tea and this can be used as a predictor for the further years beyond 2013 (Table 4.11). The regression model indicates that at any time, one can estimate the amount of tea yield produced based on the year of production and the rainfall amount in that given year. This shows that despite the year of production, rainfall plays a major role in production of tea. This results are supported by Hossain et al. (2015) who showed that maximum rainfall with maximum rainy days is required for maximum output tea. Hence, smallholder tea farmers need to use adaptation strategies to reduce the effects of rainfall variability on tea production.

**Table 4.11: Regression analysis between annual tea yields, rainfall and years from 1993–2013**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -3414918213.516 | 288588886.212 | | -11.833 | .000 |
| | Average rain in mm | 323.859 | 2659.087 | .010 | .122 | .904 |
| | Years from 1993–2013 | 1717980.889 | 144309.761 | .942 | 11.905 | .000 |

a. Dependent Variable: Annual tea yields (Kg)

***Source: computed from field data, 2016***

Analysis was done on relationship between tea yields and acreage under tea from 1993 to 2013. The results showed that R = .838 which is a strong positive relationship between tea yields and acreage under tea in Bomet Central sub-County (Figure 4.7). This shows that the number of smallholder tea farmers has been increasing over the years in Bomet Central sub-County. This is mainly brought about by constant payments made on tea and tea bonuses which make farmers to start growing tea in their farms (CPDA, 2008). Hence as the acreage under tea increased, tea yields also increased (Figure 4.8).

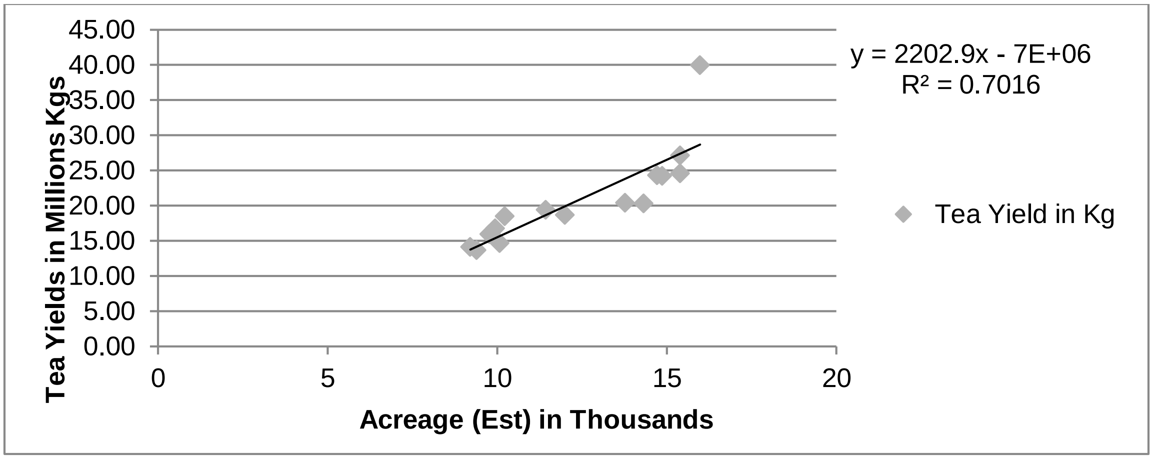


**Figure 4.7: Relationship between Tea yields and Acreage (Estimate).**

***Source: computed from field data, 2016.***

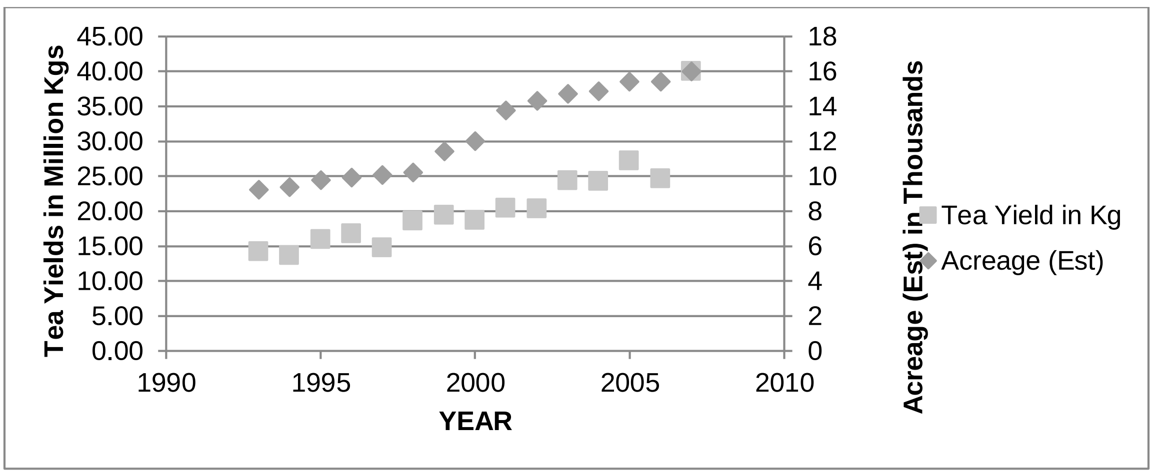


**Figure 4.8: Relationship between Tea yields and Acreage (Estimate).**

***Source: computed from field data, 2016.***

The detrended data for tea yields and rainfall were analyzed using moving average of 3 years. The results showed a negative correlation between the detrended tea yields and rainfall from 1993–2004 and a positive correlation from 2005–2013 (Figure 4.9).

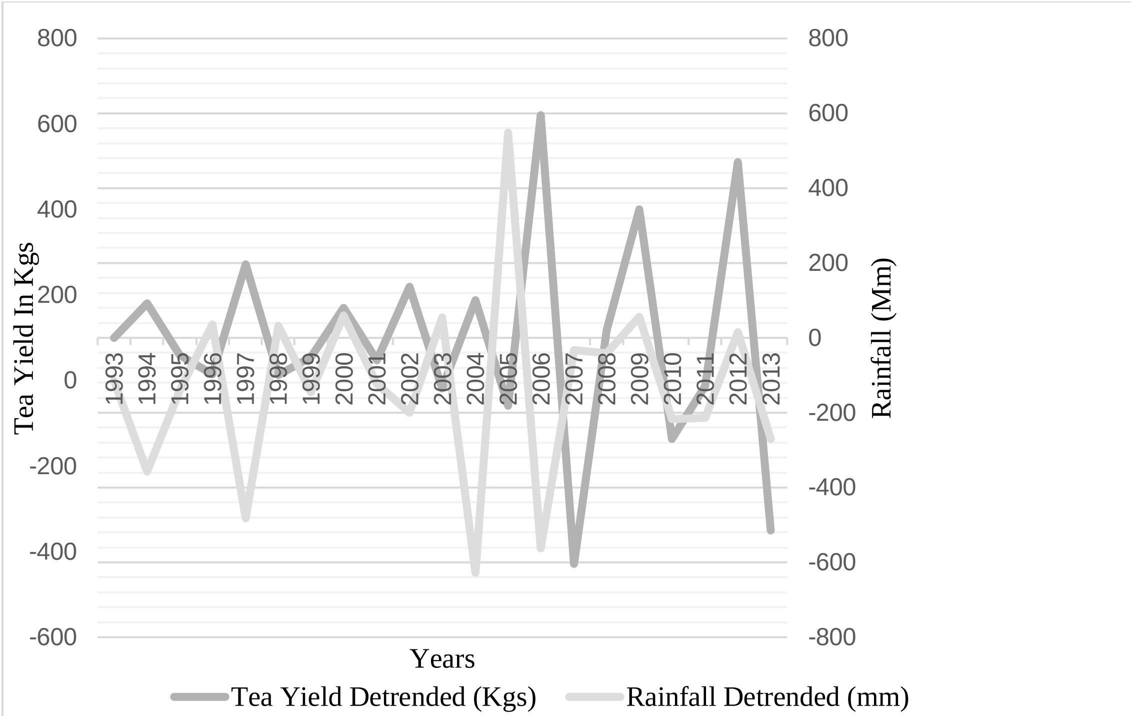


**Figure 4.9: Detrended rainfall (mm) and Tea yield (kg) using 3 year moving average.**

***Source: computed from field data, 2016.***

Similarly, the Pearson correlation between the average quarterly tea yields and rainfall from 2008–2013 indicated weak positive relationship (R=0.306). There was significant relationship between the quarters of tea yields and the rainfall especially first quarter and second quarter (Figure 4.10).

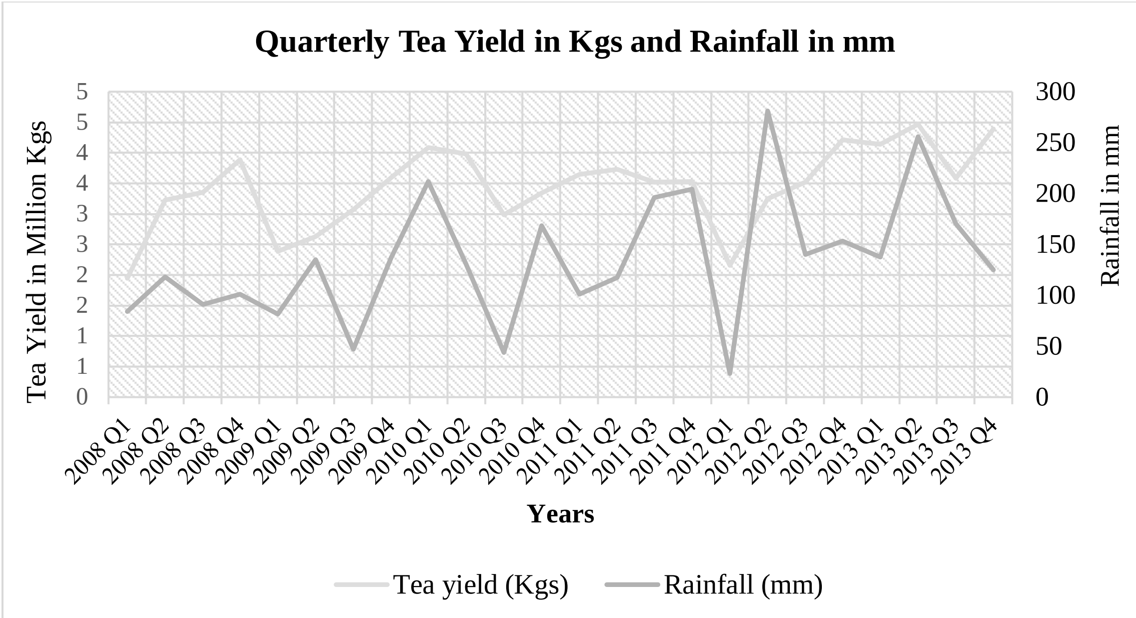


**Figure 4.10: Tea yields in Kg and Rainfall in mm from 1993–2013 in Bomet Central sub-County.**

***Source: computed from field data, 2016.***

Tea and rainfall data were also extrapolated to obtain quarterly report per year of tea yield and seasonal rainfall. Figure 4.11 clearly shows that JFM and AMJ rainfall seasons are the most variable, while the JAS and OND have least variability. There appears to be a slight increase in AMJ, JAS and OND seasonal rains beginning in the year 2010. The study showed that for the period 1993–2013, high rainfall (wet seasons) were experienced in the month of April, May, June (AMJ season). Tea yields also increased significantly beginning in the year 2007 in all the seasons. From the figure, there was a significant relationship between the seasonal rainfall and tea yields in JFM and JAS seasons which are the dry seasons having less than 200 mm of rainfall per quarter.

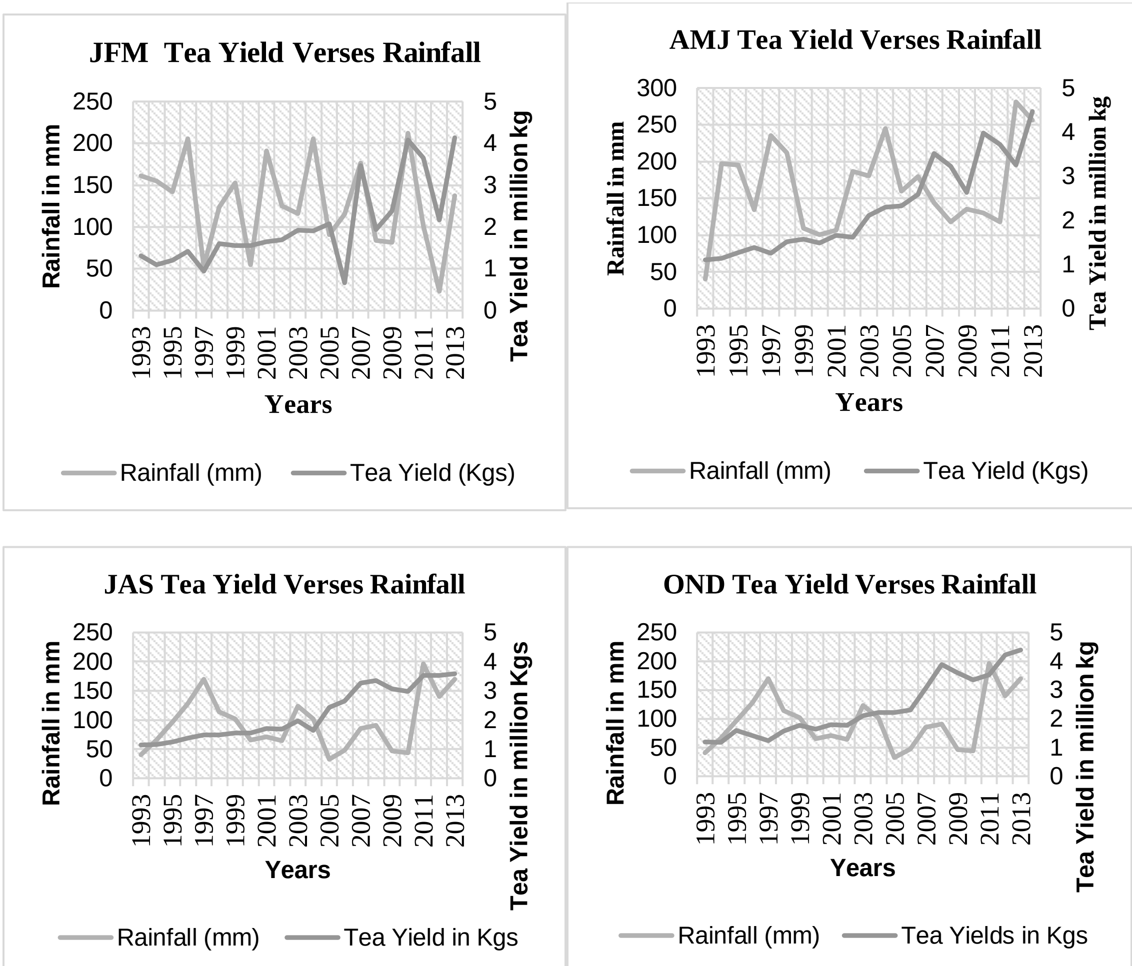


**Figure 4.11: Quarterly tea yields and rainfall from 1993–2013 in Bomet Central sub-County.**

***Source: computed from field data, 2016.***

Analysis on tea yield–rainfall ratio was also done to determine the amount of tea yield per 1mm of rainfall. It was noted that July which marks the end of first rain season recorded the highest tea yield per 1mm of rainfall. April and November which marks the peak of rain seasons, recorded lowest tea yield–rainfall ratio. It means that too much rainfall does not necessarily represent high tea yield return per 1 mm of rainfall increase. This relationship was identified by plotting the tea yield– rainfall ratio against months (Figure 4.12).

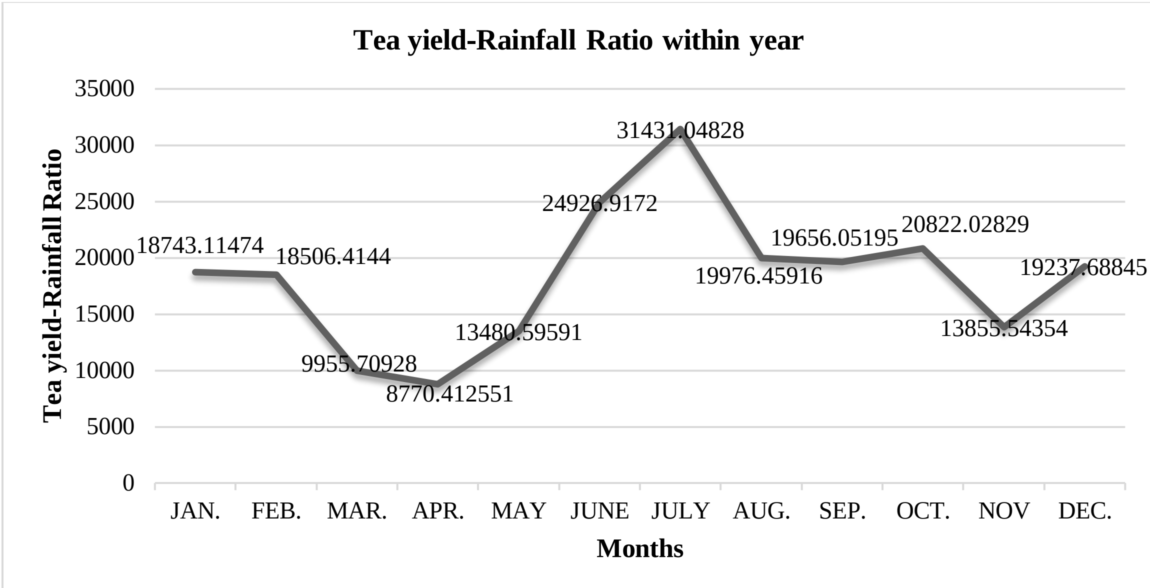


**Figure 4.12: Tea yield–Rainfall Ratio within Year in Bomet Central sub-County from 1993–2013.**

***Source: computed from field data, 2016.***

### 4.2.5 Relationship between Temperature Variability and Tea Yields from 1993–2013

After using a plot graph, curvilinear regression was attained with aid of SPSS Non- linear regression analysis. The data indicated that there was a strong positive relationship between tea yields and changes in temperature (Figure 4.13). This is given by the following quadratic equation.

$$\mathbf{y = -158360226.873 + 17607283.072x - 482192.631}x^2$$

Equation 9

Where, y = Average monthly tea yield in Kgs

x = Average monthly temperature in degrees

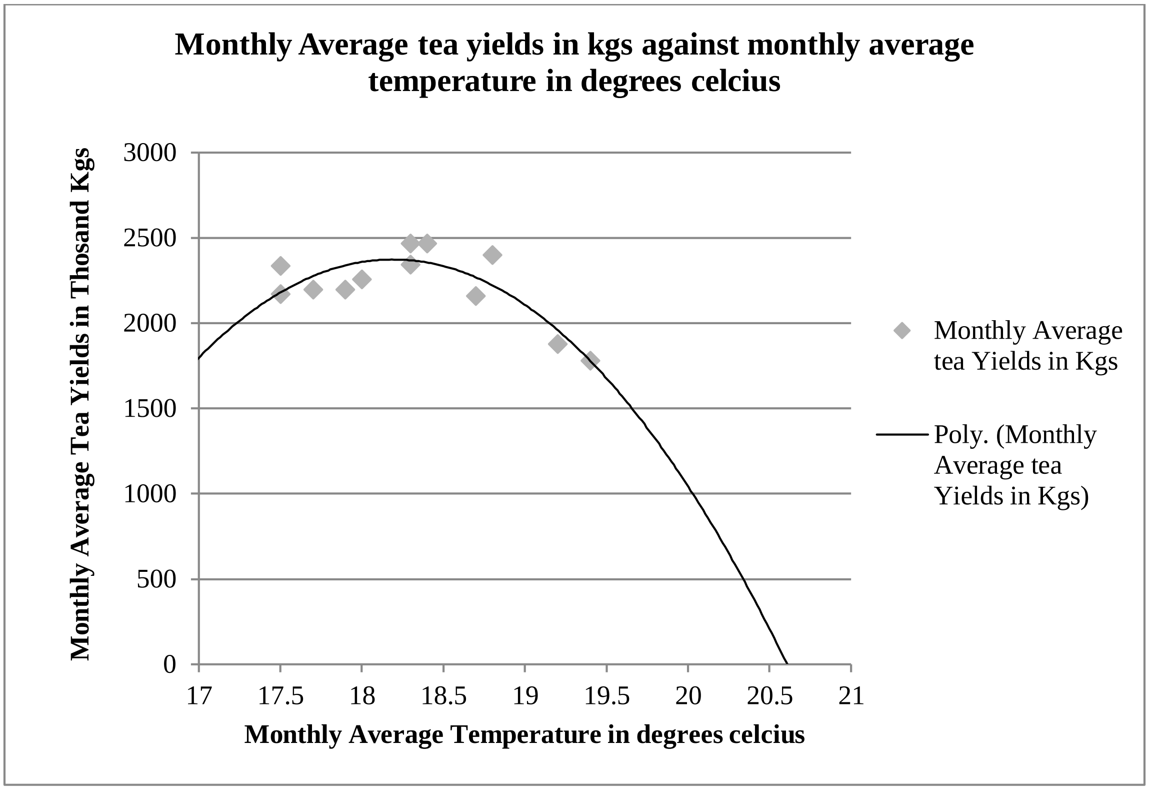


**Figure 4.13: Average monthly tea yield (Kgs) and temperature (oC) from 1993–2013.**

***Source: computed from field data, 2016.***

The Figure 4.13 shows the quadratic relation which indicates that highest tea yields were obtained at an average temperature of 18.3$^{o}$C. High average temperature of 19.5$^{o}$C produced lowest tea yields while low temperature of 17.5$^{o}$C produced moderately high tea yields. There was strong coefficient of determination based on quadratic equation above of $R^2$= 0.825. This showed that 82.5% of variation was caused by temperature and remaining percentage was due to other factors (Table 4.14). This indicated that there exists a strong positive relationship between temperature and yield of tea. Hence, the second hypothesis was rejected that there is no significant relationship between temperature and tea yields in Bomet Central sub-County.

**Table 4.12: Regression of temperature in relation to tea yields from 1993–2013**

Dependent Variable: Average Tea Yields

| **Equation** | **Model Summary** | | | | | **Parameter Estimates** | | |
|---|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 | b2 |
| Quadratic | .825 | 21.164 | 2 | 9 | .000 | -158360226.873 | 17607283.072 | -482192.631 |

The independent variable is Average Temperature.

***Source: computed from field data, 2016.***

The detrended data for tea yields and temperature using moving average of 3 years was done to remove the effects of trend and to show only the differences in values from the trend. The results showed a significant relationship between temperature and tea yields. Tea yields are lowest when temperatures are either lowest or highest especially during dry season. On the other hand, tea yields are highest when temperatures are moderate particularly during the rainy season (Figure 4.14).

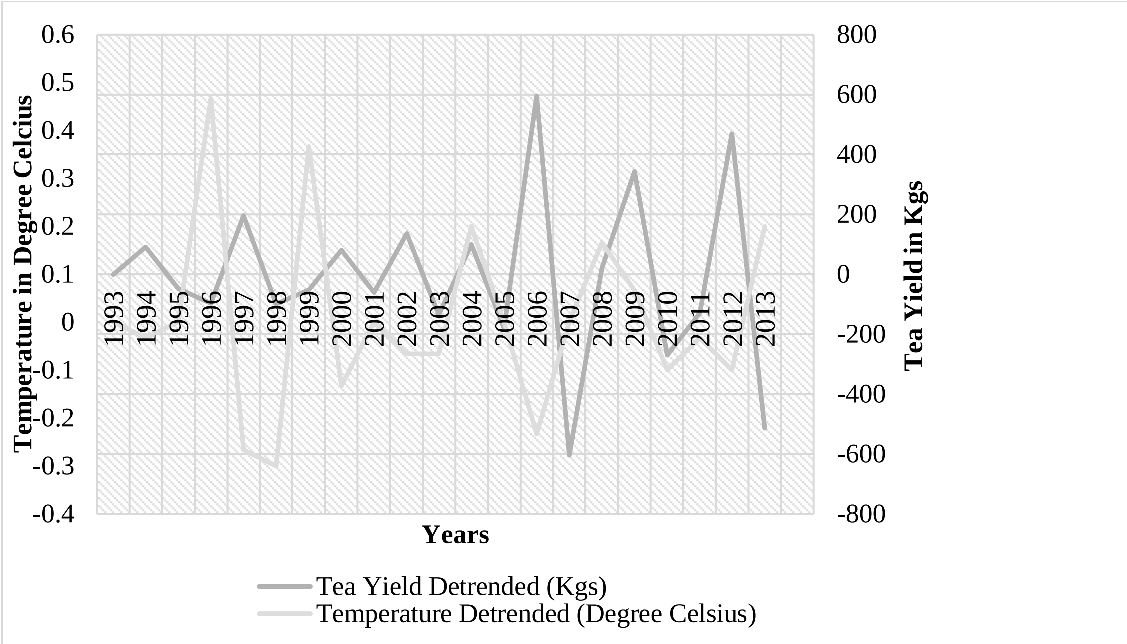


**Figure 4.14: Detrended Temperature (oC) and Tea yield (kg) using 3 year moving average.**

***Source: computed from field data, 2016.***

### 4.2.6 Relationship between Rainfall, Temperature, Years and Tea Yield.

The relationship between tea yields, rainfall and temperature over the number of years of production were analyzed to form a regression model. This indicated a correlation R = .962 which is a very strong positive relationship (96.2%) between total annual tea yield (kg), temperature (ºC) and the annual rainfall (mm) over the number of years of study. The regression model further indicated a co-efficient of determination $R^2$ = .925 which indicates that 92.5% of the data was used and that 7.5% of the data can be attributed to other factors (Table 4.13).

**Table 4.13: Correlation and determination co-efficiency**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .962[a] | .925 | .911 | 3373030.267 |

a. Predictors: (Constant), Average Temperature, Annual rain in mm, Years from 1993-2013

***Source: Computed from field data, 2016***.

ANOVA analysis ($F_{(5\%, 2, 15)}$ = 69.422, p = .000) indicate significant relationship between dependent variable and the independent variables (Table 4.14). This means that the years of growth of tea from 1993–2013, temperature (°C) and annual rain (mm) has significant relationship.

**Table 4.14: ANOVA (Analysis of Variance) for Regression analysis**

| **Model** | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
|---|---|---|---|---|---|---|
| 1 | Regression | 2369525798301012.000 | 3 | 789841932767004.000 | 69.422 | .000[b] |
| | Residual | 193414664089922.800 | 17 | 11377333181760.166 | | |
| | Total | 2562940462390935.000 | 20 | | | |

a. Dependent Variable: Annual tea yield (Kg)

b. Predictors: (Constant), Average Temperature, Annual rain in mm, Years from 1993–2013

***Source: Computed from field data, 2016.***

The model was attained from analysis where the dependent variable was tea yield and the independent variables annual rainfall and years from 1993–2013. The model is given by;

**V = -3661221173.159 - 1135.543R - 5833039.740T + 1895597.898Y** Equation 10

Where V –Tea Yields in Kgs

R – Rainfall in mm

T – Temperature in °C

Y – The year

The model indicated a decrease of 1135.543 Kgs per one mm increase of rainfall, a decrease of 5833039.740 Kgs tea yields per one °C and increase of 1895597.898 Kgs of tea yields with increase of one year. This can be used as a tool of tea yields estimates in future (Table 4.15).

**Table 4.15: Regression analysis on tea yields, rainfall, temperature and time from 1993–2013**

| Model | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (Constant) | -3661221173.159 | 259841000.083 | | -14.090 | .000 |
| Years from 1993-2013 | 1895597.898 | 137578.770 | 1.039 | 13.778 | .000 |
| Annual rain in mm | -1135.543 | 2314.097 | -.034 | -.491 | .630 |
| Average Temperature | -5833039.740 | 2061137.692 | -.214 | -2.830 | .012 |

a. Dependent Variable: Annual tea yields (Kg)

***Source: Computed from field data, 2016.***

The regression model indicated that at any time one can estimate the tea yield based on the year, temperature and the rainfall in that given year. This showed rainfall and temperature variability plays a big role in tea yields. Hence, rainfall and temperature variability need to be moderated by using adaptation strategies.

### 4.2.7 Knowledge on Climate Variability among Tea Farmers in Bomet Central sub-County

Results indicated that climate variability in Bomet Central sub-County characterized by prolonged drought and surprise heavy rainfall. In some parts of the world such as Guinean Coast, climate variability is characterized by increase in total rainfall (Nicholson *et al.*, 2000). Despite the tea farmers experiencing such changes, when asked to indicate their levels of knowledge about climate variability, majority of them (47.7%) indicated that they had minimal knowledge as shown in Figure 4.15.

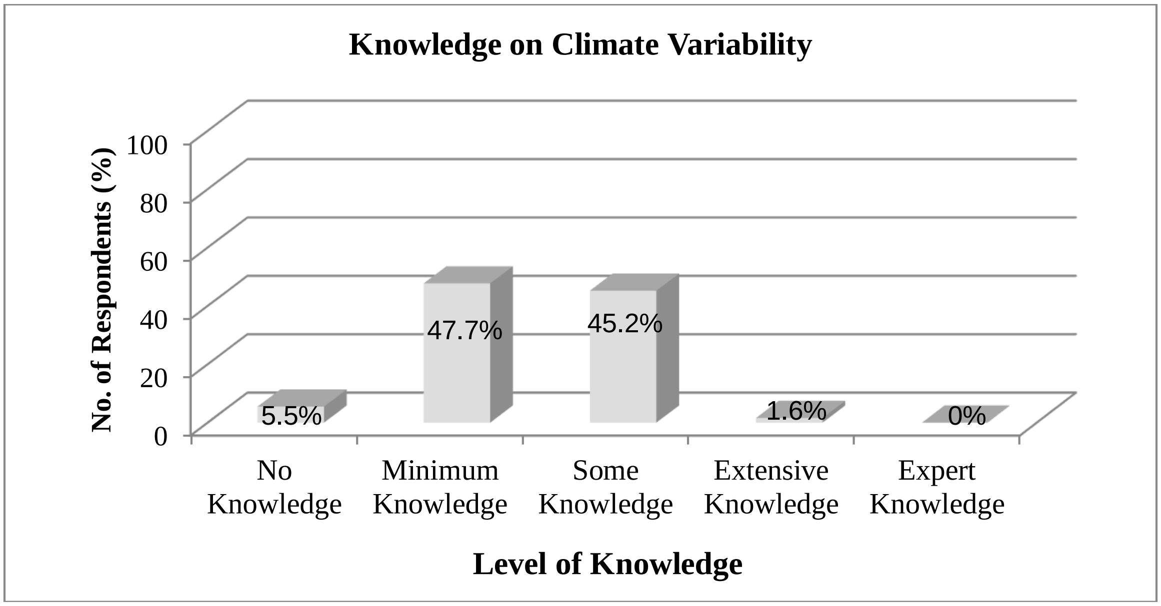


**Figure 4.15: Respondents knowledge on climate variability in Bomet Central sub-County.**

***Source: Computed from field data, 2016.***

The findings in Figure 4.15 could be taken to imply that despite tea being the main rain-fed crop cultivated throughout the area, experts on climate variability have not interacted much with farmers to teach them on climate variability impacts and possible adaptation strategies. Indeed 74.2% of the tea farmers showed that they had never received any professional advice from agricultural officers regarding the effect of climate variability on tea farming (Figure 4.16). Knowledge about climate variability has also been reported to be low among rural farmers of the Niger Delta region of Nigeria (Nzeadibe *et al*., 2011).

One of the major constraints to climate variability adaptation by farmers in the Niger Delta is lack of knowledge on climate variability Nzeadibe *et al*. (2011).

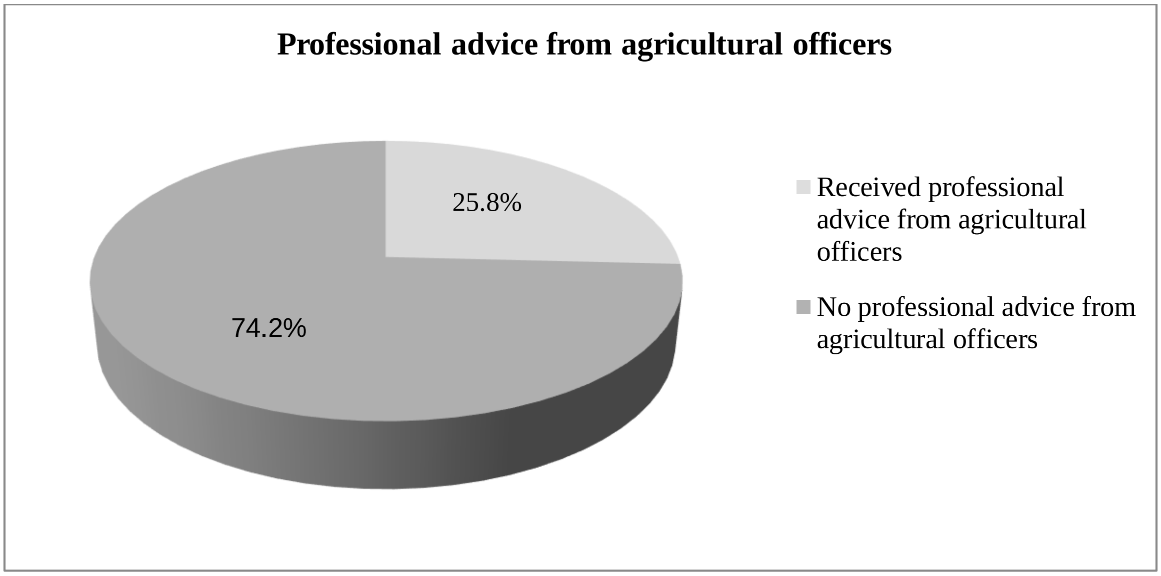


**Figure 4.16: Professional advice from agricultural officers in Bomet Central sub-County.**

***Source: Computed from field data, 2016.***

Maddison (2006) noted that knowledge and recognition of changes of climatic conditions is important. This is because adapting to climate variability requires that a farmer notice first that the climate has changed, and then identify useful adaptations measures and implement them. Antle (2009) established that farmers that are well-informed are capable of using appropriate strategies to adapt their agricultural production to changed climatic condition. The results showed that 87.5% of the tea farmers indicated that they had never been asked to give information on climate variability in the past (Figure 4.17). Gbetibouo (2009) noted that, if farmers have access to extension services, they are likely to understand changes in climatic conditions because extension services provide information about climate.

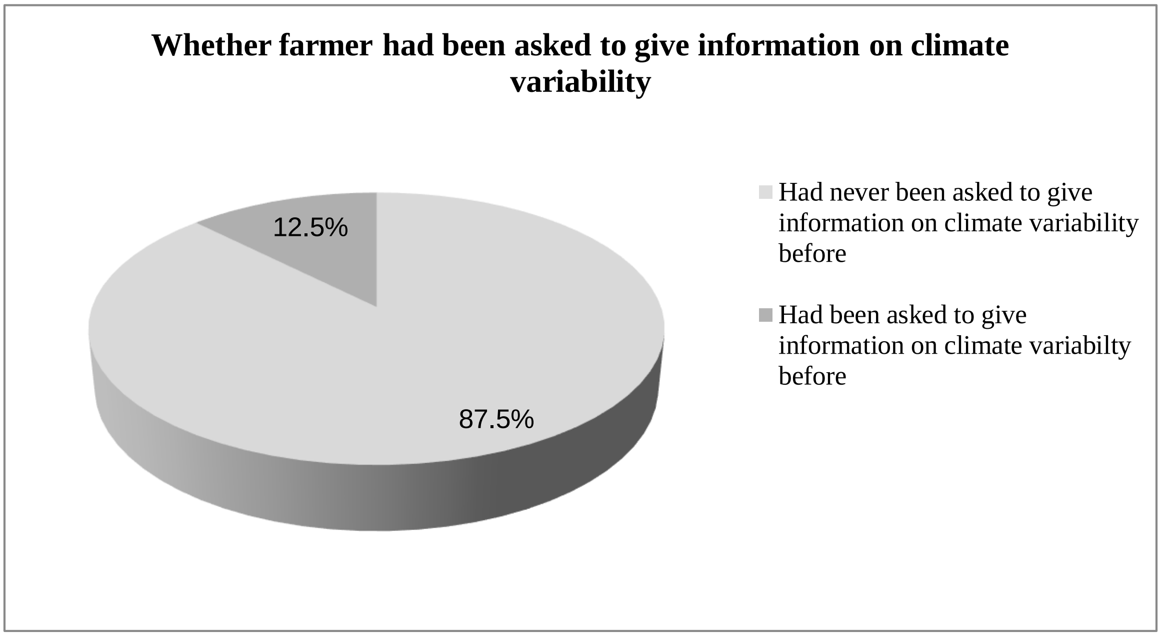


**Figure 4.17: Whether tea farmers had been asked to give information on climate variability in the past in Bomet Central sub-County.**

***Source: Computed from field data, 2016.***

Knowledge about climate variability was found to be significantly influenced by gender ($\chi 2$ = 18.046, df =3, p <0.001). A significantly larger proportion (54.6%) of male respondents reported to have some knowledge about climate variability while most (80.6%) of the female respondents reported having minimal knowledge (Table 4.16).

**Table 4.16: Influence of gender on knowledge about climate variability**

| Gender | No knowledge | Minimal Knowledge | Some knowledge | Extensive knowledge | Total | Df | p-value |
|---|---|---|---|---|---|---|---|
| Male | 6.2%(6) | 37.1% (36) | 54.6%(53) | 2.1% (2) | 100% (97) | 3 | <0.001 |
| Female | 3.2% (1) | 80.6% (25) | 13.1% (5) | 0%(0.0) | 100% (31) | | |

Values in parenthesis are frequencies.
***Source: Computed from field data, 2016***

### 4.2.8 Climatic Variations Experienced by Respondents in Bomet Central sub-County from 1993–2013 and Their Effect on Tea Yields

Majority of the tea farmers had experienced a number of indicators of climate variability during the past 21 years. The experienced climate variability as shown in Table 4.17 included prolonged droughts (95.3%), heavy rainfall (83.6%), hailstorms (79.9%), unpredictable rainfall (78.9%) and changed onset and cessation of rain season (62.5%).

**Table 4.17: Climate variations experienced by respondents in Bomet Central sub-County from 1993–2013**

| **Changes in rainfall** | **No. of Respondents** | **No. of Respondents (%)** |
|---|---|---|
| Unpredictable rainfall | 101 | 78.9 |
| Prolonged drought | 122 | 95.3 |
| severe wet season | 61 | 47.7 |
| Extreme/heavy rainfall | 107 | 83.6 |
| Changed onset and cessation of rain season | 80 | 62.5 |
| Hailstorms | 102 | 79.9 |
| Frost | 26 | 20.3 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

#### 4.2.8.1 Effects of Unpredictable Rainfall on Tea Yields Study Area

Majority (78.9%) of the respondents indicate that rain has become unpredictable in the recent years hence had affected their tea farming plans. For example, unpredictable rainfall has led to uncertainty on when to apply fertilizers (23.4%), low tea yields (42.2%), changes in tea plucking cycle (14%) and also low income (7%) as shown in Table 4.18. The respondents also reported drying of young tea (1%) and untimely weed management (1%).

**Table 4.18: Effects of unpredictable rainfall on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondents (%) |
|---|---|---|
| Uncertainty on when to apply fertilizers | 30 | 23.4 |
| Low yields | 54 | 42.2 |
| Plucking cycle changes | 18 | 14.0 |
| Low income | 9 | 7.0 |
| Drying of young tea | 1 | 0.8 |
| Untimely weed management | 1 | 0.8 |

***Source: Computed from field data, 2016.***

#### 4.2.8.2 Effects of Prolonged Droughts on Tea Yields Study Area

In the case of droughts, majority 95.3% of the respondents felt that prolonged drought had affected their tea production. Majority (87.5%) of the respondents noted that drought has led to very low tea yields and sometimes no plucking of tea at all, 41.4% indicated that there was reduced income during that period (Table 4.19). According to Cheserek *et al*, (2015) droughts decrease the tea yield because the low moisture content decreases photosynthesis, growth and plants survivability. Other effects of drought reported by respondents were increase of pests such as mites (10.2%), drying of tea plants especially young and pruned tea (24.2%) and that green tea produced during the dry season was of poor quality (5.5%).

**Table 4.19: Effects of prolonged droughts on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondent (%) |
|---|---|---|
| Very low yields sometimes no plucking at all | 112 | 87.5 |
| Reduced income | 53 | 41.4 |
| Increase of pests and diseases | 13 | 10.2 |
| Drying of young tea and also pruned tea | 31 | 24.2 |
| Poor quality tea | 7 | 5.5 |
| No pruning of old tea | 13 | 10.2 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

One respondent observed that,

> "The prolonged drought has really affected our tea farming. "In the year 2012, in the months of February and March, we hung our *mesendoik* (traditional tea baskets) because there was no plucking of tea at all".

Most farmers observed that prolonged droughts were experienced in the years 1997, 2000, 2006, 2008, 2009 and 2012 (Table 4.20). In 1997, 2000 and 2006, dry weather conditions in most tea growing areas of the country resulted in some factories having to shut down or operate at far below capacity due to the inadequate supply of tea leaves and revenue (Elbehri, 2015).

**Table 4.20: Years of prolonged drought**

| Year | No. of respondents | No. of respondents (%) |
|---|---|---|
| 1997 | 37 | 28.9 |
| 2000 | 43 | 33.6 |
| 2006 | 56 | 43.8 |
| 2008 | 29 | 22.7 |
| 2009 | 33 | 25.8 |
| 2012 | 42 | 32.8 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

#### 4.2.8.3 Effects of Changed Onset and Cessation of Rain Season on Tea Yields Study Area

Rainfall across the Bomet County has been noted to be unreliable and highly variable in terms of its onset, cessation and amount leading to low tea yields (MoALF, 2017). Majority of the respondents agreed that the rain season has become increasingly variable from year to year. According to 83.6% of the respondents, onset and cessation of the rain season (especially March- April –May season) is highly variable and has affected their tea production (Table 4.21). Rainfall results concur that the changed onset and cessation of rain season is highly variable. According to 69.5% of the respondents, changed onset and cessation of rain season affects tea picking cycle (picking is normally done 3 times per month) while 39.1% noted that this had lowered the yield of tea. Other effects noted by the respondents were uncertainty on when to apply fertilizers (23.4%), less income (3.9%), fluctuation in the number of kilograms picked (3%) and only 3% felt that this variability had no effect. Changing patterns of rainfall and its distribution have already been seen to be problematic for tea yields in Kenya (Cheserek *et al*., 2015). A slight fluctuation in rainfall amount, intensity and onset and cessation time directly influences the agricultural productivity (National Meteorological Service Agency, 2007).

**Table 4.21: Effect of Changed onset and cessation of rain season on tea yields**

| Effect on tea yields | No. of respondents | No. of respondents (%) |
|---|---|---|
| Affect plucking cycles | 89 | 69.5 |
| Lowers tea yields | 50 | 39.1 |
| Uncertainty on when to apply fertilizer | 30 | 23.4 |
| Less income | 5 | 3.9 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016***.

### 4.2.8.4 Effects of Severe Wet Season on Tea yields in the Study Area

According to 23.4% of the respondents, very wet season occur in the area and this has led to high tea yields especially when warm and hence increased income to the tea farmers (21.9%). In addition, 5.5% of the respondents felt that wet season was best for pruning old tea for better yields. Some respondents (17.2%) cited soil erosion as a negative impact of very wet season since heavy rains carried applied fertilizers which led to low yields. Other negative effects included poor bud break (22.9%), poor weed management (6.3%) and road damage which led to delay in delivery of green tea to the factory (6.3%). This is shown in (Table 4.22).

**Table 4.22: Effects of Severe wet season on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondents (%) |
|---|---|---|
| High tea yields especially if warm | 21 | 23.4 |
| High income | 28 | 21.9 |
| Soil erosion carry applied fertilizer | 22 | 17.2 |
| Quality leaves (2 leaves and a bud) reduces if cold/ poor bud break | 29 | 22.7 |
| Facilitate growth of weeds which have negative impact on tea | 8 | 6.3 |
| Best season for pruning | 7 | 5.5 |
| Poor transport/ poor roads leads to wilting of green tea | 8 | 6.3 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

**4.2.8.5 Effects of Extreme/Intensive/Heavy Rainfall on Tea Yields in the Study Area**

Majority of the respondents (79.9%) indicated that heavy rainfall occur in the study area. Heavy rainfall had positive and negative effects on tea yields. Example of positive effect noted by 30.5% of the respondents included high tea yields especially if warm (Table 4.23). However, 50% of the respondents noted that soil is heavily eroded during heavy rains. The runoff water which flows down at a high velocity particularly in sloppy areas results in the loss of top soil layer and also loss of applied fertilizer (25.8%). This is supported by Ali *et al* (2014) who found out that heavy rains erode top soil and carry away fertilizers and other nutrients. Other respondents cited delay in picking tea because of heavy rainfall hence plucking cycle is affected (14.1%). Others cited fast growth of weeds (3.9%), poor transport hence delay in delivery of green tea to the factory (3.1%) and reduced labour

(2.0%). The growth and yield of tea were affected adversely by heavy or scanty or delayed precipitation (Ali *et al*, 2014).

**Table 4.23: Effects of extreme/intensive/heavy rainfall on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondents (%) |
|---|---|---|
| Soil erosion on sloppy areas | 64 | 50.0 |
| High yields | 39 | 30.5 |
| Low yields | 15 | 11.7 |
| Delay in picking tea hence plucking cycle is affected | 18 | 14.1 |
| Applied fertilizer is eroded | 33 | 25.8 |
| Increase of weeds | 5 | 3.9 |
| Too much leaves without desired quality i.e amount of tea leaves and bud reduces | 7 | 5.5 |
| Poor transport hence delay in delivery of green tea to collection centers | 4 | 3.1 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

### 4.2.8.6 Effect of Hailstorm and Frost on Tea Yields in the study area

Tea farmers interviewed noted that there were incidences of hail in Bomet Central with 45.3% of the respondents reporting that hailstorms damages green tea resulting to very low or no yield at all (Table 4.24). They pointed out that hail would completely strip the tea shrubs of leaves and sometimes damages the bush stems depending on storm intensity. According to TBK (2014), hailstorms destroyed tea bushes in Ndaraweta, Singorwet, Mugango and Kiramwok locations in in the study area in August 2013 where some 12,890 Kgs of green tea were lost. Tea farmers had to wait for 2–3 months for the tea bushes to recover from the impact of the hailstorms before again starting to pick their tea leaves. Net loss of green tea leaf due to hail in tea producing counties of western Kenya like Nandi, Kericho and Bomet is estimated at over two million kilograms annually (Bore, 2015).

**Table 4.24: Effects of Hailstorm on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondents (%) |
|---|---|---|
| No plucking for 3 months if hailstones occur and depends on the intensity | 58 | 45.3 |
| Low yields | 33 | 25.8 |
| Damages young tea | 78 | 60.9 |
| No income at all | 16 | 12.5 |
| Reduction of leaf quality | 8 | 6.3 |

Total percentage is more than 100 because of multiple responses, n=128
***Source: Computed from field data, 2016.***

Other effects of hailstones cited by the respondents included damage of young tea 60.9%, reduction of leaf quality (6.3%) and no income at all for at least three months depending on the intensity of the hailstones (12.5%). From the findings, 20.3% of the respondents said that frost had caused withering of tea leaves therefore reducing the tea yields (Table 4.25). This is in agreement with Elbehri (2015) who found out that frost significantly reduces the yields of tea up to 30%. After a frost event, crops cannot be harvested for up to two and three months from the time the frost occurred (Bore, 2015).

**Table 4.25: Effects of Frost on tea yields**

| Effect on tea yields | No. of respondents | No. of Respondents (%) |
|---|---|---|
| Withering of green tea leaves | 26 | 20.3 |

***Source: Computed from field data, 2016.***

## 4.3 Adaptation Strategies to Climate Variability

Findings on Table 4.26 shows that 87.5% of the respondents confirmed that they had never been involved in climate variability adaptation planning before though they were engaging in various adaptation strategies to climate variability. The major adaptation strategies identified included; weed management to reduce competition for moisture, proper drainage systems on long and steep slopes and mulching. Others were, planting cover crops during young tea stage, diversification to other activities, establishment and management of shade trees, planting drought resistant tea varieties and micro credits. Other farmers used irrigation during young tea stage, control of pests and diseases, proper plucking for instance three rounds per month, pruning old tea bushes, covering tea farm with pruned branches to retain water and fertilizer to adapt to climate variability.

**Table 4.26: Adaptation strategies used by tea farmers in response to climate variability**

| Adaptation strategies to climate variability | No. of Respondents | No. of Respondents (%) |
|---|---|---|
| Weed management to reduce competition for moisture | 101 | 78.9 |
| Proper drainage systems on long and steep slopes | 61 | 47.7 |
| Mulching | 54 | 42.2 |
| Planting cover crops during young tea stage | 53 | 41.4 |
| Diversification to other activities | 44 | 34.4 |
| Establishment and management of shade trees | 25 | 19.5 |
| Planting drought resistant tea varieties | 21 | 16.4 |
| Use of micro credits | 10 | 7.8 |
| Control of pests and diseases | 8 | 6.3 |
| Irrigation during Young Tea Stage | 5 | 8.6 |
| Pruning old tea | 5 | 8.6 |
| Covering with pruned branches to retain water and fertilizer | 2 | 3.9 |

Total percentage is more than 100 because of multiple responses, n=128

***Source: Computed from field data, 2016.***

### 4.3.1. Weed Management to Reduce Competition for Moisture

Weed management to reduce competition for moisture was adopted by farmers on large scale. Early and regular weeding was being used by majority (78.9%) of the respondents as the most effective way of dealing with effects of climate variability. This is perceived to be effective in dealing with emergence of stubborn weeds which were not previously known that compete with tea crop for moisture. Some respondents (41%) cited the use of herbicides to get rid of these weeds during the rainy season.

### 4.3.2. Proper Drainage Systems on Long and Steep Slopes

The tea farms of majority (47.7%) of the respondents are on fairly steep slopes. Therefore, during heavy rains, soil is heavily eroded by runoff water which flows down at high speed resulting in loss of top soil layer. To cope with extreme rainfall, the respondents had constructed leader drains to carry excess water away and terraces to conserve soil. They have also planted trees and napier grass along tea farm edges to check on soil erosion (Plate 4.1).

**Plate 4.1: Napier grass grown along the edge of a tea farm to check on soil erosion in Bomet, Singorwet ward**.

***Source: Field (2016).***

### 4.3.3. Mulching

From the results on table 4.26, 42.2% of the respondents used mulching as a measure to cope with climate variability. This is because it was easy to get mulching materials as it is locally available and most of them had local knowledge on how to use it. The materials used as mulch are mainly plant materials. These mulches help to reduce the rate at which moisture is lost from the soil by evaporation, particularly in young and newly pruned tea where a large proportion of the soil is exposed to direct sunlight and drying wind (TRFK, 2002). In addition, mulches reduce run-off and consequently reduce the amount of soil erosion and increase infiltration.

### 4.3.4. Planting Cover Crops

Planting of cover crops mostly beans was used by 41.4% of the respondents (Table 4.26). Tea farmers preferred beans because apart from being utilized as food, the stalks were also used as animal feed. Other cover crops included vegetables, peas and potatoes. The cover crops reduce soil erosion to a minimum at the time when, without the cover crop, soil is most liable to erosion by heavy rain (TRFK, 2002). In addition, the cover crops reduce the loss of organic matter from the soil by heat. However, the research established that the respondents cut down the cover crops at the onset of an extended dry season. If left standing, they will rapidly remove water from the soil and this will worsen the effects of the dry weather (TRFK, 2002). On the other hand, some respondents (16%) spread mulch over the soil after removing cover crops to reduce soil moisture loss by evaporation. Plate 4.2 shows some of the cover crops at a tea farm in Singorwet ward, Bomet central Sub-County.


**Plate 4.2: Cover crops at a tea farm in Bomet, Singorwet ward.**

**A. Cabbages**
**B. Beans**

***Source: Field (2016)***

### 4.3.5. Diversification to Other Activities

The acreages under tea range from 0.3 to 3 acres with a mean of 1.48 acres (Table 4.27). This shows that land used for the purpose of tea are getting smaller and smaller as time goes by due to growth of population and land subdivision due to inheritance. The large numbers of youth who are unemployed join farming and thus straining the resource making them hold small acreage.

**Table 4.27: Size of land under tea**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Size under tea | 128 | .30 | 3.00 | 1.4760 | 1.20317 |
| Valid N (listwise) | 128 | | | | |

***Source: Computed from field data, 2016***

Of the respondents who were interviewed, the researcher established that 12.5% earned less than Ksh 2,000 from tea farming per month, 27.3% earned between Ksh 2,000 and Ksh 3,000, 21.9% earned between Ksh 4,000 and Ksh 5,000 while 6.3% earned over Ksh 12,000 (Table 4.28). From the findings, over three-quarters of the respondents earned less than Ksh 7,000.

**Table 4.28: Average income of respondents per month from tea farming**

| Income (KES) | No. of respondents | No. of Respondents (%) |
|---|---|---|
| Less than 2,000 | 16 | 12.5 |
| 2,000-3,000 | 35 | 27.3 |
| 4,000-5,000 | 28 | 21.9 |
| 6,000-7,000 | 19 | 14.8 |
| 8,000-9,000 | 12 | 9.4 |
| 10,000-11,000 | 10 | 7.8 |
| Over 12,000 | 8 | 6.3 |

***Source: Computed from field data, 2016.***

The number of acreage under tea were correlated with average income and the data obtained showed strong correlation of (R =.853), $R^2$ = 0.728. Hence, the other remaining 27.2% can be attributed to other factors (Table 4.29).

**Table 4.29: Correlation between Income and number Acreage**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .853[a] | .728 | .726 | 2644.24567 |

a. Predictors: (Constant), Size under tea

***Source: Computed from field data, 2016.***

The model is given as: **Income = 885.941 + 3,578 [Acreage under tea].**

The model shows that an acre contributes an income of 3,578 shillings per month (Table 4.30).

**Table 4.30: Regression model for Income against Acreage under tea**

| **Model** | | **Unstandardized Coefficients** | | **Standardized Coefficients** | **T** | **Sig.** |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 885.941 | 372.245 | | 2.380 | .019 |
| | Size under tea | 3578.477 | 195.790 | .853 | 18.277 | .000 |

a. Dependent Variable: Average income per month

***Source: Computed from field data, 2016***.

During the drought period, the tea earnings are very small or none at all. As an adaptation strategy, some respondents 34.4% had diversified to other economic activities (Table 4.26); for instance, livestock keeping (25.8%), beans farming (11.7%), potato farming (5.5%), and motorcycles riding business commonly known as Bodaboda (1.6%) (Plate 4.3). Other activities included salary (10.9%), shop (5.5%), poultry keeping (3.1%) and tailoring (2.3%). Banana farming, bee keeping and fish farming were each practiced by 0.8% of the respondents (Table 4.31). However, more than half of the respondents (65.6%) depended on tea farming as the only source of livehood.

**Table 4.31: Other source of income apart from tea farming**

| Source of Income | No. of respondents | No. of Respondents (%) |
|---|---|---|
| Livestock keeping | 33 | 25.8 |
| Beans farming | 15 | 11.7 |
| Salary | 14 | 10.9 |
| Potato farming | 7 | 5.5 |
| Shop | 7 | 5.5 |
| Poultry keeping | 4 | 3.1 |
| Tailoring | 3 | 2.3 |
| Bodaboda | 2 | 1.6 |
| Banana farming | 1 | 0.8 |
| Bee keeping | 1 | 0.8 |
| Fish farming | 1 | 0.8 |

***Source: Computed from field data, 2016***

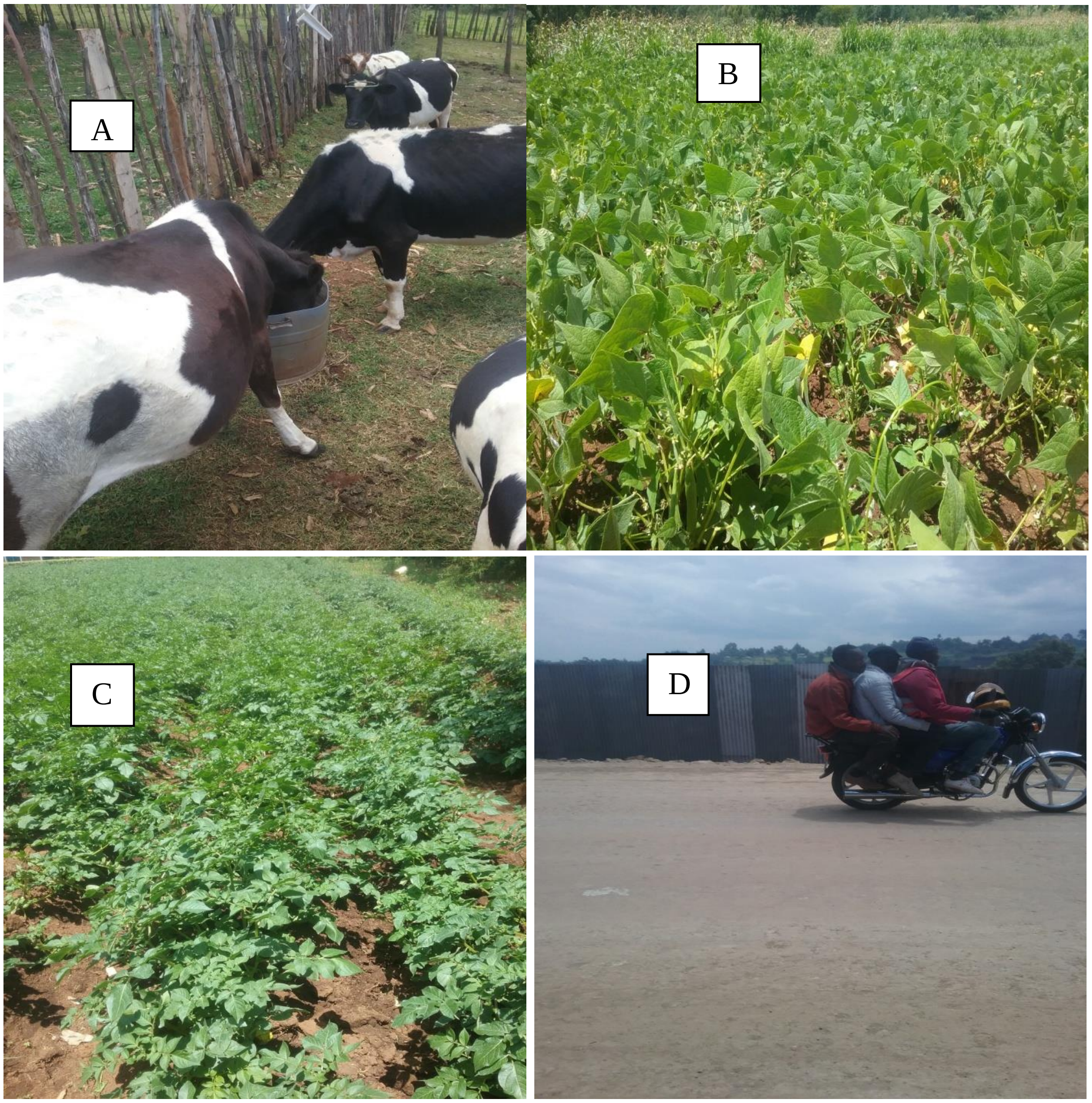


**Plate 4.3: Diversification to other economic activities in Study Area.**

**A. Livestock Keeping** **B. Beans farming**

**C. Potato farming** **D. Bodaboda business**

***Source: Field (2016)***

### 4.3.6. Establishment and Management of Shade Trees

Shade trees had been established only by 19.5% of the respondents (Table 4.26). Shade trees are of no use even though they are properly established unless they are managed timely, for instance, with pollarding or lopping before onset of rains (Prematilake, 2014). However, the research reveals that shade management level is poor in most tea farms which have shade trees. Most of the respondents use forest tree silver oak *Grevillea robusta* in their tea gardens as shade tree plants to assist in moisture retention during hot and humid condition (Plate 4.4). These plants have tap root system therefore no competition for moisture with tea plants. Majority of the respondents had established the border trees to act as wind breaks and to check on soil erosion (Figure 4.18). Other benefits of shade trees include reduced weed growth, reduced frost, carbon sequestration, additional organic matter from leaf litter, minimized wind damage and reduced soil erosion (Prematilake, 2014).

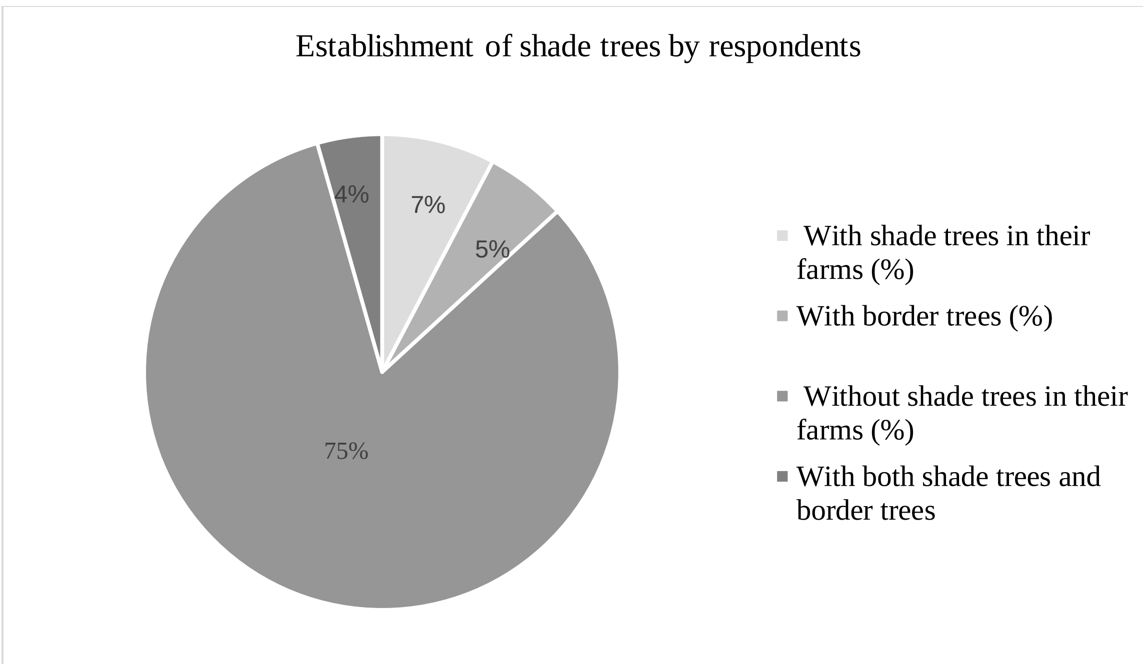


**Figure 4. 18: Establishment of Shade Trees.**

***Source: Computed from field data, 2016***

**Plate 4.4: Shade trees and wind breaks at a tea farm in Bomet, Ndaraweta ward.**
***Source: Field (2016)***

### 4.3.7. Planting Drought Resistant Tea Varieties

The results in Table 4.26 established that minority (14.8%) of the respondents had planted drought resistant tea varieties, for example, the purple tea (TRFK 306/1) (Plate 4.5). This was because purple tea was better able to survive drought episodes through a more conservative use of water. In addition, they are of greater value than other clones. For instance, the variety fetches three to four times more than what is earned from green and black tea (TRFK, 2012). However, majority (85.2%) of the respondents have not planted the purple tea. When asked the reason why they have not planted, one respondent reported that the existing factories in the area do not have a processing unit for purple tea. Instead, it processes it together with green variety and they pay the same amount of money paid for other varieties. In addition, the seedlings of the variety were not readily available in the area.

**Plate 4.5: The purple tea (TRFK 306/1) grown by a farmer in Bomet, Ndaraweta ward.**

***Source: Field (2016)***

### 4.3.8. Irrigation during Young Tea Stage

The results on Table 4.26 showed that 8.6% of the respondents had irrigated their tea during young tea stage. The respondents confirmed that they use watering cans to irrigate the young tea every day during the drought period. Although, irrigation is a viable solution during the dry periods, the respondents cited lack of water as a limitation to this measure. For example, one respondent observed that;

> "Water is very scarce in this area during the dry season. The water available is not enough for our cattle and other domestic activities. We go to the river to fetch water

for household use and for our cattle at night, but we find a long queue. We lack water tanks for harvesting water during the rainy season."

### 4.3.9. Access to credit

From the research, 7.8% of the respondents reported that they had borrowed loans from banks and savings and credit co-operative societies (Saccos). They also cited *merry-go-round* as one source of credit in which members make contributions to one another monthly on rotational basis. Part of the contribution is saved in every round in some cases, so that members can borrow loan at a low interest rate when in need. They reported that the credit was used to enhance adaptation strategies used and do off-farm income activities such as motorcycles riding business (Bodaboda), potato farming, shop, tailoring and poultry keeping. Majority (92.2%) of the respondents reported that they feared borrowing loans because of strict loans policies for applicants in the agricultural sector and lack of proper and accurate information available on credits.

**Table 4.32: Access to credit**

| **Source of Credit** | **No. of Respondents** | **No. of Respondents %** |
|---|---|---|
| Banks | 3 | 2.3 |
| Savings and Credit Societies | 5 | 3.9 |
| *Merry-Go-Round* | 2 | 1.6 |

***Source: Computed from field data, 2016***

### 4.3.10. Other Adaptation Strategies used by farmers in the Study Area

Other adaptation strategies were cited by a few respondents like use of early warning system (10.2%), control of pests and diseases (6.3%) and pruning of old tea bushes (8.6%). Pruning of old tea is done during the rainy season mainly April to June and covering pruned tea farm with prunings (Plate 4.6). The respondents noted that these prunings return nutrients to the soil, reduce soil erosion and conserve moisture (1.6%). Mulch in the form of mature tea prunings and leaf litter, if conserved properly, will confer benefits for several years, depending on the condition of tea at the time of pruning (TRFK, 2002). This is why it is advised that tea prunings should never be removed from tea fields.

**Plate 4.6: Pruned tea covered with prunings at a tea farm in Bomet, Chesoen ward.**

***Source: Field (2016)***

As to whether the adjustments made had improved their tea farming, 87.5% of the respondents agreed that the adjustments had improved their tea farming. The result showed that 95.3% of respondents increase their tea yields by use of fertilizer which is supplied by KTDA once every year while 3.9% of the respondents use manure and 0.8% uses other methods (Figure 4.19).

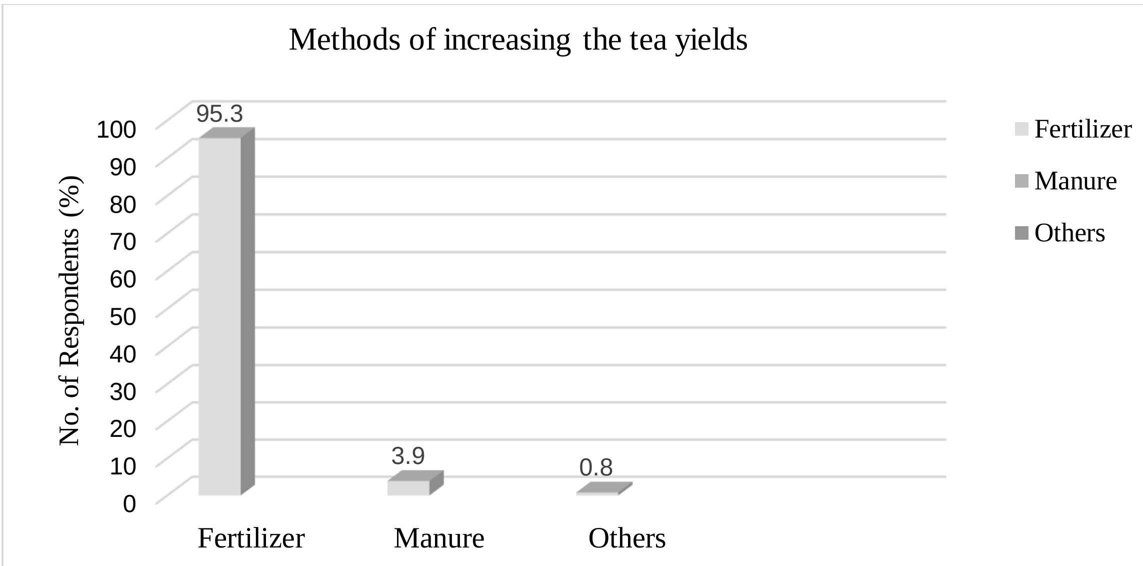


**Figure 4.19: Methods of increasing tea yields in Bomet Central sub-County.**
***Source: Computed from field data, 2016***

**4.4: Socio-economic Determinants of adaptation strategies used by tea farmers in Study Area**

Table 4.33 shows the determinants of adaptation strategies used by tea farmers in Bomet Central sub-County as mentioned by the respondents. These included household size (95.3%), farming experience (87.5%), gender (52.3%), age (38.3%), education level (14.1%), extension services at (13.3%) and use of micro-credit (6.25%).

**Table 4.33: Factors influencing adaptation strategies used by tea farmers in Study Area**

| Determinant factors | Frequency | No. of Respondents % |
|---|---|---|
| Gender | 67 | 52.3 |
| Age of the farmer | 49 | 38.3 |
| Farming Experience | 112 | 87.5 |
| Education Level | 18 | 14.1 |
| Household Size | 122 | 95.3 |
| Extension Services | 17 | 13.3 |
| Use of micro-credits | 8 | 6.25 |

Total percentage is more than 100 because of multiple responses, n=128

***Source: Computed from field data, 2016***

### 4.4.1. Gender of the respondents

Of the respondents interviewed 75.8% were males and 24.2% were females (Fig.4.20). This indicated that majority of the tea farmers in the area are men.

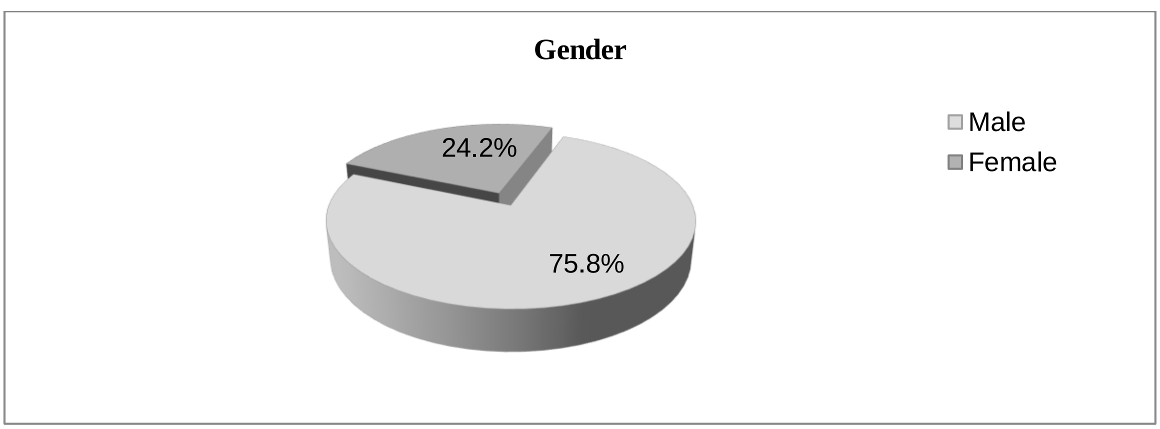


**Figure 4.20: Gender of the respondents.**
***Source: Computed from field data, 2016***

Of the respondents interviewed, majority (89.1%) were married, 9.4% were single and only 1.6% were widows (Figure 4.21). This reveals that most of the tea farms are owned by married farmers.

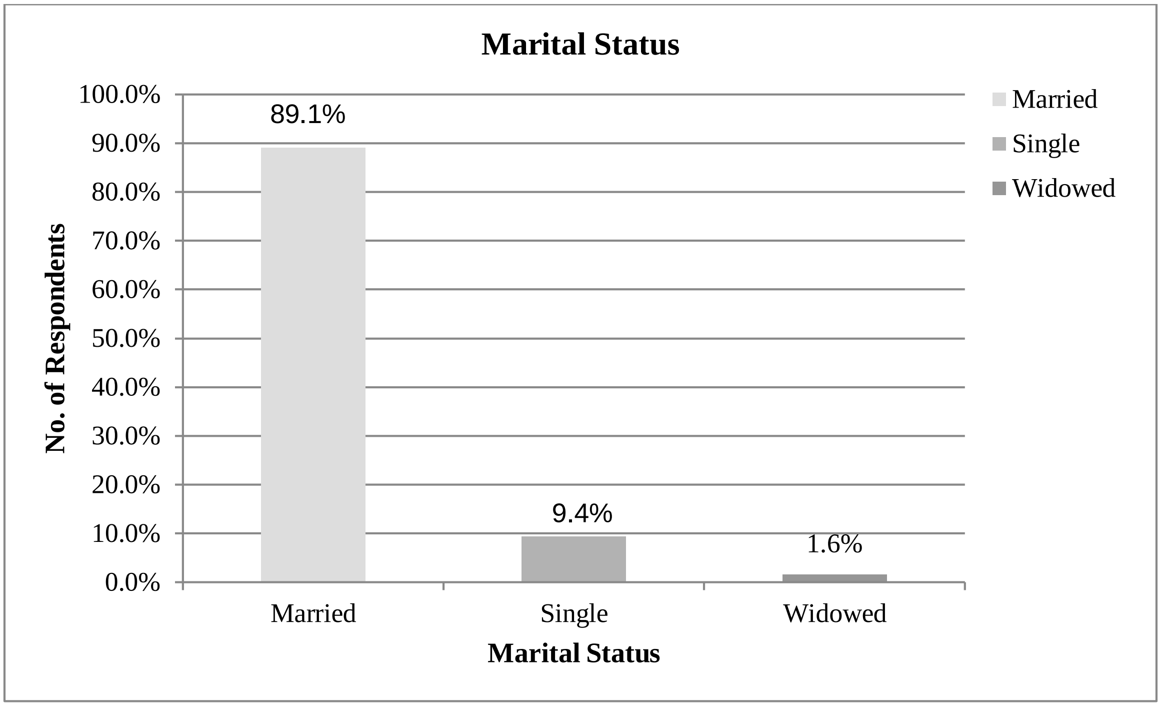


**Figure 4.21: Marital status of the respondents.**
***Source: Computed from field data, 2016***

This study established that the choice of adaptation strategies used was influenced by gender ($\chi^2$=17.098, df=8, P<0.05) whereby men are more likely to use irrigation during young tea stage, diversification to other activities, mulching, establishment and management of shade trees, cover crops and weed management (Table 4.34). On the other hand, women are likely to use early warning system as an adaptation strategy to climate variability. Majority of the respondents (52.3%) reported gender as having contributed to adaptation of climate variability in the study area.

**Table 4.34: Influence of Gender on adaptation strategies**

**Crosstab**

| **Adaptation strategies** | **Gender** | | | | **Total** | |
|---|---|---|---|---|---|---|
| | **Male** | | **Female** | | | |
| | Count | % within Adaptation | Count | % within Adaptation | Count | % |
| Diversification to other activities | 12 | 80.0 | 3 | 20.0 | 15 | 100 |
| Irrigation during young tea stage | 8 | 100.0 | 0 | 0.0 | 8 | 100 |
| Mulching | 34 | 87.2 | 5 | 12.8 | 39 | 100 |
| Planting cover crops during young tea stage | 15 | 75.0 | 5 | 25.0 | 20 | 100 |
| Establishment and management of shade trees | 12 | 57.1 | 9 | 42.9 | 21 | 100 |
| Weed management to reduce competition for moisture | 12 | 70.6 | 5 | 29.4 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 1 | 50.0 | 1 | 50.0 | 2 | 100 |
| Use of early warning systems | 0 | 0.0 | 2 | 100.0 | 2 | 100 |
| Use of micro credits | 1 | 100.0 | 0 | 0.0 | 1 | 100 |
| Total | 95 | 76.0 | 30 | 24.0 | 125 | 100 |

$\chi^2$=17.098, df=8, P<0.05

***Source: Computed from field data, 2016***

### 4.4.2. Age of the farmer

The results indicate 41.4% were of the age of 40–50 years, 35.9% of age 51–60 years and those over 60 years were 22.7% of the sample collected (Figure 4.22). This revealed that there was gradual decline of farming with age group though insignificant as indicated by Chi-square test which, showed that age did not differ significantly ($\chi^2$=2.228, df=2, p=0.328). This is contrary to the average age of a Kenyan farmer which is put at 57 years (Mutai *et al*., 2012). The youth have to be more involved in farming more than the elderly and this can be attributed to unemployment in the country, which was reported at 12.7% in the year 2006 (KNBS, 2007) and at 40% in the year 2009 (Krishnamurthy and Dejan, 2009).

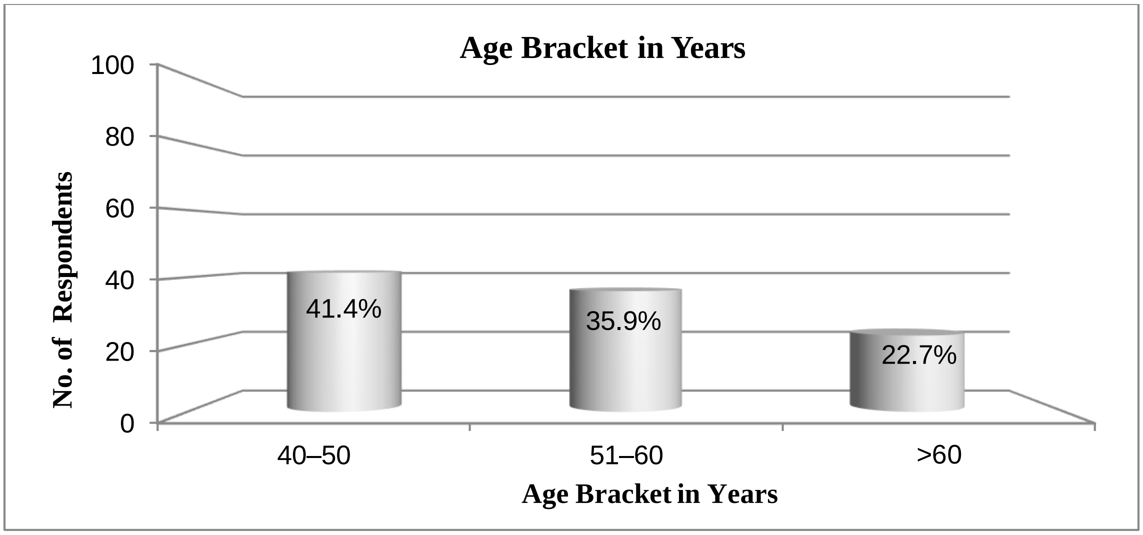


**Figure 4.22: Age distribution of the respondents.**
***Source: Computed from field data, 2016***

As to whether age influenced the choice of adaptation strategies used by smallholder tea farmers, Chi square results indicate that age had a significant influence ($\chi^2$=31.824, df=16, $P< 0.05$) on most of the listed adaptation strategies (Table 4.35). Younger farmers (40–50 years) are more likely to use most of the adaptation strategies except irrigation during young tea stage compared to older farmers (over 50 years). Respondents reported age as having contributed to some extent (38.3%) in adapting to climate variability. This is contrary to a study done by Deressa *et al*, (2009) who established that age did not play a greater role in adaptation to climate variability.

**Table 4.35: Influence of Age on adaptation strategies**

Crosstab

| Adaptation strategies | Age Bracket | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | 40–50 | | 51–60 | | >60 | | | |
| | count | % within Adaptation | Count | % within Adaptation | Count | % within Adaptation | Count | % |
| Diversification to other activities | 8 | 53.3 | 6 | 40.0 | 1 | 6.7 | 15 | 100 |
| Irrigation during young tea stage | 0 | 0.0 | 2 | 25.0 | 6 | 75.0 | 8 | 100 |
| Mulching | 20 | 51.3 | 9 | 23.1 | 10 | 25.6 | 39 | 100 |
| Planting cover crops during young tea stage | 5 | 25.0 | 12 | 60.0 | 3 | 15.0 | 20 | 100 |
| Establishment and management of shade trees | 11 | 52.4 | 8 | 38.1 | 2 | 9.5 | 21 | 100 |
| Weed management to reduce competition for moisture | 5 | 29.4 | 7 | 41.2 | 5 | 29.4 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 1 | 50.0 | 0 | 0.0 | 1 | 50.0 | 2 | 100 |
| Use of early warning systems | 1 | 50.0 | 1 | 50.0 | 0 | 0.0 | 2 | 100 |
| Use of micro credits | 0 | 0.0 | 0 | 0.0 | 1 | 100.0 | 1 | 100 |
| Total | 51 | 40.8 | 45 | 36.0 | 29 | 23.2 | 125 | 100 |

$\chi^2$=31.824, df=16, P<0.05

***Source: Computed from field data, 2016***

### 4.4.3. Farmer's Experience

From the findings majority (52.3%) of the respondents had been farming tea consistently for over 20 years (Figure 4.23). Farmers with few years of farming experience were found to be mainly young who comprises a very low proportion (3.1%). The mean of duration was 22.40 years with minimum of 12 year and maximum of 40 years in tea farming. Both males and females were involved in tea farming throughout the years. Chi-square test showed no significant gender differences in number of years the respondents were involved in tea farming ($\chi^2$=0.459, df=1, p=0.498).

Other researchers (Ndegwa *et al*., 2010 and Ndungu *et al*., 2004) have also shown that males and females equally participate in farming with differences only in the type of farming activities engaged in. Farming activities that are manually demanding, for example land preparation, irrigation and spraying are dominated by males; while females handle activities requiring precision like planting, picking, sorting, grading and packaging (Ndegwa *et al*., 2010).

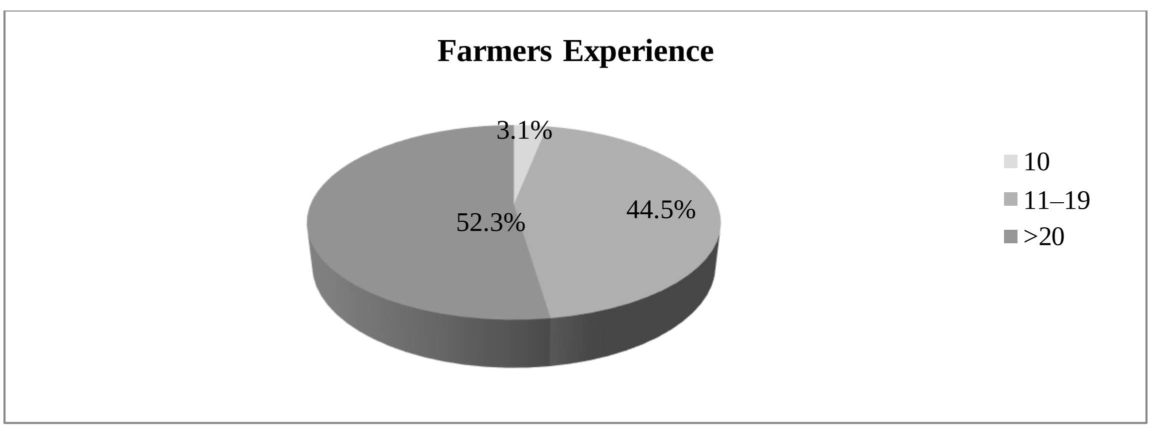


**Figure 4.23: Years of tea farming.**
***Source: Computed from field data, 2016***

As to whether farming experience influence the adoption of adaptation strategies to climate variability, findings revealed that the number of years a tea farmer had in farming tea did not play a significant role ($\chi^2$=13.984, df=16, P>0.05). The results indicate that although farming years in general was insignificant in adopting the adaptation strategies, those with over 20 years' experience in farming tea were in a better position to adopt the adaptation strategies (Table 4.36). Majority (87.5%) of the respondents reported that farming experience influence the use of adaptation strategies to climate variability by smallholder farmers.

**Table 4.36: Influence of Farming Experience on adaptation strategies**

Crosstab

| Adaptation strategies | Farming Experience | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | 10 | | 11–19 | | >20 | | | |
| | count | % within Adaptation | Count | % within Adaptation | Count | % within Adaptation | Count | % |
| Diversification to other activities | 1 | 6.7 | 7 | 46.7 | 7 | 46.7 | 15 | 100 |
| Irrigation during young tea stage | 0 | 0.0 | 0 | 0.0 | 8 | 100.0 | 8 | 100 |
| Mulching | 2 | 5.1 | 17 | 43.6 | 20 | 51.3 | 39 | 100 |
| Planting cover crops during young tea stage | 0 | 0.0 | 12 | 60.0 | 8 | 40.0 | 20 | 100 |
| Establishment and management of shade trees | 1 | 4.8 | 11 | 52.4 | 9 | 42.8 | 21 | 100 |
| Weed management to reduce competition for moisture | 0 | 0.0 | 6 | 35.3 | 11 | 64.7 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 0 | 0.0 | 1 | 50.0 | 1 | 50.0 | 2 | 100 |
| Use of early warning systems | 0 | 0.0 | 1 | 50.0 | 1 | 50.0 | 2 | 100 |
| Use of micro credits | 0 | 0.0 | 0 | 0.0 | 1 | 100.0 | 1 | 100 |
| **Total** | **4** | **3.2** | **55** | **44.0** | **66** | **52.8** | **125** | **100** |

$\chi^2$=13.984, df=16, P>0.05

***Source: Computed from field data, 2016***

### 4.4.4. Education Level

Results of this study showed that majority (44.5%) of the respondents had secondary school education while 41.4% had primary school education (Figure 4.24). As the level of education increased, the number of respondents with such qualifications decreased accordingly with 8.6% having attained college level and only 4.7% university education. The results showed that 0.8% of the respondents never went to school. Chi-square test results revealed significant gender differences in education level attained ($\chi 2=19.695$, df=4, p=0.001). The results showed that significantly more males than females had secondary, college and university education. These low education levels can be attributed to dropout rate which is high at primary level especially for girls (Glennerster *et al*., 2011).

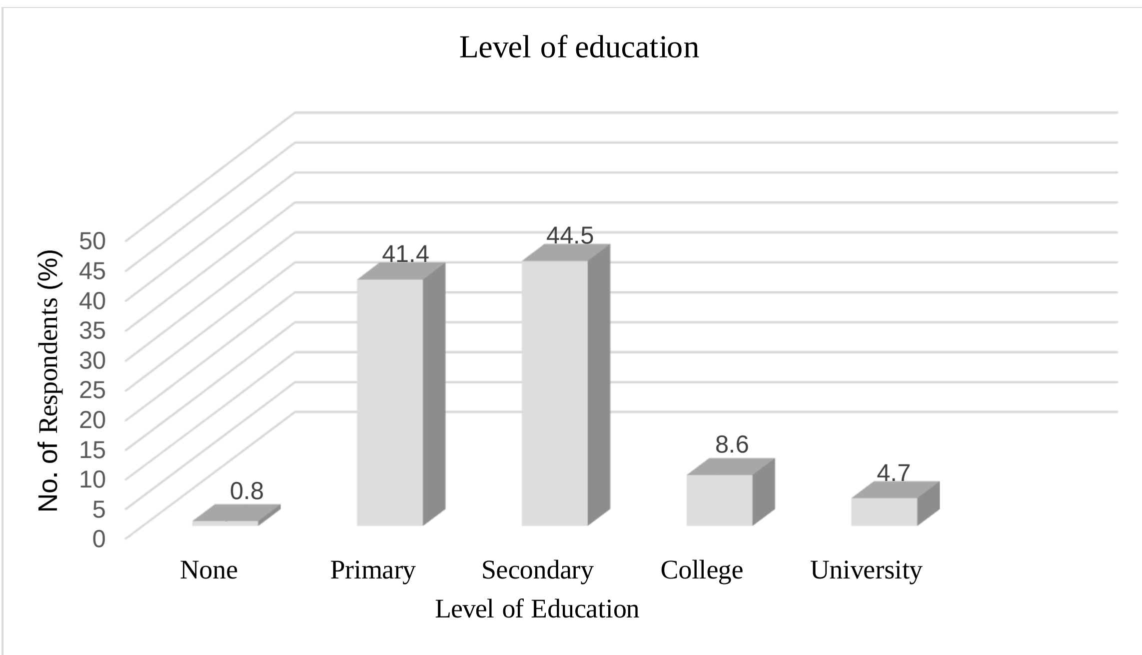


**Figure 4.24: Level of education of the respondents.**

***Source: Computed from field data, 2016***

The researcher established that education had an influence on the choice of adaptation strategies used by the smallholder tea farmers ($\chi^2$=47.660, df=32, P<0.05). The farmers who had more schooling years were likely to diversify to other economic activities than those with less schooling years (Table 4.37). In addition, they are more likely to use mulching and plant shade trees in their tea farms. However, when asked whether education influences the adaptation strategies used by the farmers, majority (85.9%) of the respondents reported that it does not contribute to adaptation of climate variability.

**Table 4.37: Influence of Education Level on adaptation strategies**

Crosstab

| Adaptation strategy | Education Level | | | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | None | | Primary | | Secondary | | College | | University | | | |
| | Count | % | Count | % | Count | % | Count | % | Count | % | Count | % |
| Diversification to other activities | 0 | 0.0 | 4 | 26.7 | 6 | 40.0 | 4 | 26.7 | 1 | 6.7 | 15 | 100 |
| Irrigation during young tea stage | 0 | 0.0 | 4 | 50.0 | 2 | 25.0 | 1 | 12.5 | 1 | 12.5 | 8 | 100 |
| Mulching | 0 | 0.0 | 12 | 30.8 | 25 | 64.1 | 2 | 5.1 | 0 | 0.0 | 39 | 100 |
| Planting cover crops during young tea stage | 0 | 0.0 | 12 | 60.0 | 8 | 40.0 | 0 | 0.0 | 0 | 0.0 | 20 | 100 |
| Establishment and management of shade trees | 0 | 0.0 | 10 | 47.6 | 7 | 33.3 | 0 | 0.0 | 4 | 19.0 | 21 | 100 |
| Weed management to reduce competition for moisture | 1 | 5.9 | 8 | 47.1 | 7 | 41.2 | 1 | 5.9 | 0 | 0.0 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 0 | 0.0 | 1 | 50.0 | 1 | 50.0 | 0 | 0.0 | 0 | 0.0 | 2 | 100 |
| Use of early warning systems | 0 | 0.0 | 1 | 50.0 | 0 | 0.0 | 1 | 50.0 | 0 | 0.0 | 2 | 100 |
| Use of micro credits | 0 | 0.0 | 0 | 0.0 | 1 | 100 | 0 | 0.0 | 0 | 0.0 | 1 | 100 |
| Total | 1 | 0.8 | 52 | 41.6 | 57 | 45.6 | 9 | 7.2 | 6 | 4.8 | 125 | 100 |

$\chi^2$=47.660, df=32, P<0.05

***Source: Computed from field data, 2016***

### 4.4.5. Household Size

The researcher established that the adaptation strategies used by tea farmers in the study area was influenced by household size ($\chi^2$ =29.570, df=16, P<0.05). A household size of 2 is likely to adopt more choices of adaptation to climate variability than household size of more than 3 (Table 4.38).

**Table 4.38: Influence of Household Size on adaptation strategies**

Crosstab

| Adaptation strategies | Household Size | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | 2 | | 3–4 | | >5 | | | |
| | Count | % within Adaptation | Count | % within Adaptation | Count | % within Adaptation | Count | % |
| Diversification to other activities | 9 | 60 | 4 | 26.7 | 2 | 13.3 | 15 | 100 |
| Irrigation during young tea stage | 2 | 25.0 | 3 | 37.5 | 3 | 37.5 | 8 | 100 |
| Mulching | 27 | 69.2 | 8 | 20.5 | 4 | 10.3 | 39 | 100 |
| Planting cover crops during young tea stage | 4 | 20.0 | 12 | 60.0 | 4 | 20.0 | 20 | 100 |
| Establishment and management of shade trees | 16 | 76.2 | 3 | 14.3 | 2 | 9.5 | 21 | 100 |
| Weed management to reduce competition for moisture | 9 | 52.9 | 4 | 23.5 | 4 | 23.5 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 1 | 50.0 | 0 | 0.0 | 1 | 50.0 | 2 | 100 |
| Use of early warning systems | 1 | 50.0 | 0 | 0.0 | 1 | 50.0 | 2 | 100 |
| Use of micro credits | 0 | 0.0 | 1 | 50.0 | 1 | 50.0 | 2 | 100 |
| Total | 69 | 55.2 | 35 | 28.0 | 21 | 16.8 | 125 | 100 |

$\chi^2$=29.570, df=16, P<0.05

***Source: Computed from field data, 2016***

From this study, larger household are more likely to adopt irrigation and also plant cover crops during young tea stage. This resonates with what majority (95.3%) of the respondents reported that household size provided most of the tea farms operations rather than hired labor. Therefore, large households are likely to overcome labour constraints and adopt new farming practices (Marenya and Barrett, 2007).

#### 4.4.6. Extension Services

The research found out that access to extension services does not influence the choice of the adaptation strategies used in the study area ($\chi^2$=9.010, df=8, P>0.05). Majority of smallholder tea farmers lack access to extension services which should increase probability of perceiving and adapting to climate variability (Table 4.39). According to Madisson (2006), farmers are more likely to be aware of changing climatic conditions if they have access to extension services. In addition, they will have knowledge of various management practices that can be used to cope with changes in climatic conditions. Improved farmer access to extension services would therefore have greater impact in enhancing adoption. When asked whether extension services influence adaptation strategies used, majority (86.7%) of the respondents reported that it does not influence since farmers had limited access to extension services done through field days once annually.

**Table 4.39: Influence of Extension Services on adaptation strategies**

| Adaptation strategies | Extension Service | | | | Total | |
|---|---|---|---|---|---|---|
| | No | | Yes | | | |
| | count | % within Adaptation | Count | % within Adaptation | Count | % |
| Diversification to other activities | 11 | 73.3 | 4 | 26.7 | 15 | 100 |
| Irrigation during young tea stage | 5 | 62.5 | 3 | 37.5 | 8 | 100 |
| Mulching | 28 | 71.8 | 11 | 28.2 | 39 | 100 |
| Planting cover crops during young tea stage | 13 | 65.0 | 7 | 35.0 | 20 | 100 |
| Establishment and management of shade trees | 18 | 85.7 | 3 | 14.3 | 21 | 100 |
| Weed management to reduce competition for moisture | 15 | 88.2 | 2 | 11.8 | 17 | 100 |
| Proper drainage systems on long and steep slopes | 1 | 50.0 | 1 | 50.0 | 2 | 100 |
| Use of early warning systems | 2 | 100.0 | 0 | 0.0 | 2 | 100 |
| Use of micro credits | 0 | 0.0 | 1 | 100.0 | 1 | 100 |
| Total | 93 | 74.4 | 32 | 25.6 | 125 | 100 |

$\chi^2$=9.010, df=8, P>0.05

From these results, gender (P<0.05), age (P<0.05) Education (P<0.05) and household size (P<0.05) were significant determinants adaptation strategies adopted. Hence the study rejected the third hypothesis that there is no significant relationship between socio-economic determinants and adaptation strategies used in Bomet Central sub-County.

### 4.4.7. Analysis of the determinants of adaptation strategies used by tea farmers by use of factor analysis

Table 4.40 shows the varimax- rotated principal component analysis of major factors influencing adaptation strategies used by tea farmers in the study area. Four factors were extracted from the result based on the responses of the respondents. The number was decided by leaving out components with corresponding Eigen values of less than one (Figure 4.25). Variables with only factor loadings of 0.4 and above were used in naming the factors. Variables with factor loading of less than 0.4 were not used. The communalities represent the relation between the variable and all other variables. These factors include; factor 1 (demographic data- education, age and gender), factor 2 (external intervention applied by farmers- access to credit, extension services and off-farm income activities), factor 3 (farming experience) and factor 4 (household size).

After rotation, the first factor accounted for 17.9% of the variance, the second factor accounted for 17.2%, the third factor accounted for 14.1% and the fourth factor accounted for 13.7%. The true factors that were retained explained 62.9% of the variance in the eight variable components.

Under factor 1 (demographic data- education, age of the farmer and gender), the factors that loaded high were; education (0.771), age (0.647) and gender (0.624). Mudzonga (2012) also noticed that moving from one category of education to the next increased the probability of the farmer adapting to climate variability. The variables that loaded high under factor 2 (external intervention applied by farmers- access to credit, extension services and off-farm income activities) were; extension services (0.772), access to credit (0.676) and off-farm income activities (0.542). This study done by Fosu Mensah et al (2010) agrees with these findings that access to access to credit, extension services, size of the farm, gender and farming experience were significant determinants in adapting to climate change among other factors positively influenced the farmers to adapt to climate variability.

The factor that determines adaptation strategies as perceived by the respondents in Bomet Central sub-county under factor 3 was farming experience (0.914). Nhemachena and Hassan (2007) found out that the probability of a farmer adapting to climate variability is increased by more farming experience. They noted that the experience of famers increases the probability of uptake of all adaptation options.

The factor that determines adaptation strategies as perceived by the respondents in Bomet Central sub-county under factor 4 was household size (0.881). This is supported by Gbetibou (2009) found out that farming experience, household size, access to credit, access to extension activities and off-farm activities were major factors that enhanced adaptive capacity of farmers to climate variability.

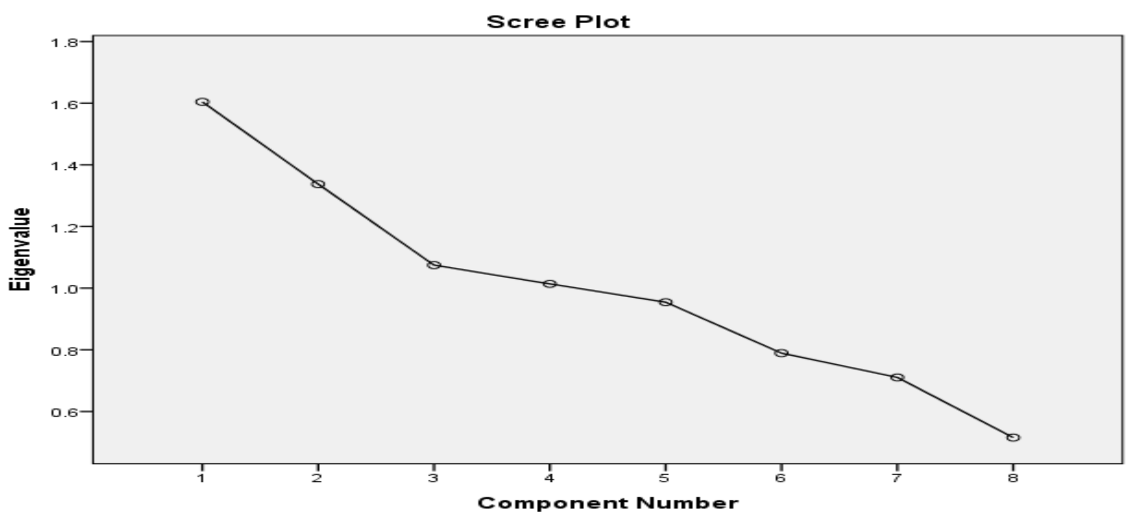


**Figure 4.25: Scree Plot.**

***Source: Computed from field data, 2016***

**Table 4.40: Varimax rotated factors influencing adaptation strategies used by the smallholder farmers in study area**

| Determinant factors influencing adaptation strategies | Component | | | | Communality |
|---|---|---|---|---|---|
| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | |
| 1. Education | .771 | | | | .667 |
| 2. Age | .647 | | | | .696 |
| 3. Gender | .624 | | | | .530 |
| 4. Extension service | | .772 | | | .655 |
| 5. Access to credit | | .676 | | | .479 |
| 6. Off-farm Income activities | | .542 | | | .380 |
| 7. Farming experience | | | .914 | | .845 |
| 8. Household size | | | | .881 | .780 |
| Percentage (%) of Total Variance | **17.9** | **17.2** | **14.1** | **13.7** | |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

***Source: Computed from field data, 2016***

## CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

### 5.1 Introduction

This chapter deals with summary of the findings, conclusion and recommendations of this study and areas of further research. The main objective of this study was to evaluate the effects of climate variability on tea yields and the adaptation strategies used by smallholder farmers in Bomet Central sub-County, Bomet County from 1993–2013. The summary of the findings, conclusion and recommendations outlined in this chapter were based on the primary objectives.

### 5.2 Summary of the findings

The first objective was to evaluate the effects of rainfall and temperature variability on smallholder tea yields in the study area. The study established that in the period 1993–2013, Bomet County experienced a slight increase in rainfall and temperature trend of 6.471mm and about 0.029$^{o}$C respectively per year. Pearson correlation showed that there was a weak positive relationship between rainfall variability and tea yields R=0.122 ($R^2$=0.015). Consequently, the study rejected the first research hypothesis that there is no significant relationship between rainfall variability and the tea yields in the study area.

The study also established that there exists a strong relationship between temperature and tea yields R=0.908 ($R^2$=0.825). Hence, the second hypothesis was rejected that there is no significant relationship between temperature and tea yields in the study area. The quadratic relation indicated that highest tea yields were obtained at average temperature of 18.25$^{o}$C while average temperature of 19.5$^{o}$C and 17.5$^{o}$C produced lowest and moderately high tea yields respectively. In addition, the results showed that there was a very strong positive relationship (96.2%) between total annual tea yield, temperature ($^{o}C$) and the annual rainfall in (mm) over the number of years of study.

The second objective of the study was to determine the adaptation strategies used by smallholder tea farmers in response to climate variability in the study area. The findings established that indeed tea farmers in the study area were engaging in various adaptation strategies to climate variability. The major adaptation strategies identified included, weed management to reduce competition for moisture, proper drainage systems on long and steep slopes and mulching. Others were; planting cover crops during young tea stage, diversification to other activities, establishment and management of shade trees. In addition, planting drought resistant tea varieties, irrigation during young tea stage, pruning old tea bushes, control of pests and diseases, covering tea farm with pruned branches to retain water and fertilizer were used by farmers. The tea farmers agreed that these adjustments had improved their tea farming.

The third objective was to investigate the socio-economic determinants of adaptation strategies used by smallholder tea farmers in Bomet Central sub-County. It was clear that gender, age, education level and household size were vital in facilitating adoption of better and affordable climate variability adaptation strategies which enhances smallholders' tea yields. Hence the study rejected the third hypothesis that there is no significant relationship between socio-economic determinants and adaptation strategies used in Bomet Central sub-County. The factor analysis revealed that the major determinant factors influencing the adaptation strategies used were demographic data (education, age and gender), external intervention applied by farmers (extension services, access to credit and off-farm income activities), farming experience and household size.

### 5.3 Conclusion

Based on the findings, the study concluded that rainfall variability has negatively affected tea yields in Bomet Central sub-County. The covariance on rainfall for the years under study was found to be 102.96 mm. This shows that there was substantial change in rainfall patterns and if not taken into consideration will affect the tea farming in Bomet. The maximum tea yields were attained in May with 2.47 million Kgs at peak of first rain season and October with 2.47 million Kgs which marks the peak of second rain season. A significant drop of tea yields was observed in 1997, 2006, 2009 and 2012 due to dry weather conditions. The loss of tea in the year 1997 was about 12% compared to the previous year while the loss in the year 2006 was 9% compared to the previous year. This indicates that rainfall is a very important factor for sustainable tea production.

The study also concluded that in Bomet Central sub-County, there is an evidence of temperature variability and it had an impact on tea yields. It was noted that there was a positive correlation between temperature and tea yields. However, extreme temperature either hot or cold reduces tea yields and is seen as a major threat to tea farming in Bomet Central sub-County.

The study also concluded that majority of tea farmers have embraced at least one adaptation strategy to climate variability but confirmed that they had never been involved in climate variability adaptation planning beforehand. Hence, there is need to create more awareness through training on climate variability and adaptation strategies to use for sustainable tea farming. The study also revealed that gender, age, education level and household size were significant determinants of the adaptation strategies used by smallholder tea farmers.

## 5.4 Recommendations

(i) The study established that rainfall variability has negatively affected tea yields in Bomet Central sub-County. Hence, the study recommends that farmers be advised to enhance the use mulching, planting drought resistant tea varieties, planting cover crops during young tea stage and regular weeding to mitigate the effects of Rainfall variability.

(ii) The study also recommends that the County and National Government institutions need to enhance the adaptation strategies used by farmers by providing advice on the need to plant drought resistant varieties such as purple tea so as mitigate the effects of climate variability. Purple tea processing units should also be established in the existing factories to allow farmers earn more profit. In addition, crop insurance need to be availed to farmers so as to cushion them against losses brought about by climate variability

(iii) Since education was the major factor affecting adaptation of strategies, the study recommends that extensions services, regular meetings, seminars and workshops be organized regularly to boost on adoption of new skills that will improve the uptake of adaptation strategies.

## 5.5 Recommendation on further research

The following areas should be further researched on;

(i) Further research should be done on effects of other climatic and non-climatic factors on tea yields in Bomet central sub-County.

(ii) Research on the best tea clones suitable for Bomet County with respect to climate variability.

(iii) Research on barriers to climate variability adaptations among smallholder tea farmers in Bomet Central sub-County. This may help in coming up with solutions which will enable them continue producing tea, irrespective of the effects of climate variability.

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## APPENDICES

### APPENDIX 1: QUESTIONNAIRE FOR THE TEA FARMERS

All information given in this questionnaire will be treated with confidentiality. We request for your honest responses.

**Part 1: Personal information**

Please Tick in the box where appropriate and write your responses on the spaces provided

1. Please indicate your age bracket

   [ ] 40-50 years [ ] 50-60 years

   [ ] 0ver 60 years
2. For how many years have you been a tea farmer?
   [ ] 10 years [ ] 11-19 years [ ] Over 20 years

   Specify………….
3. Gender
   [ ] Male [ ] Female
4. Marital status
   [ ] Married [ ] Single
   [ ] Others
   Specify……………………………………
5. Level of education
   [ ] primary [ ] secondary [ ] College
   [ ] University [ ] Others
   Specify…………
6. Size of the farm in acres………………………………….
7. What is number of acres under tea? ......................................................................
8. What is your average income per month from tea farming? Kshs…………………….
9. Do you have any other source of income apart from tea farming?
   [ ] Yes [ ] No
   If yes, which one………………………………………………

**Part 2: Knowledge on climate variability**

10. Please circle the number 1 to 5 that you feel best represents your knowledge on climate variability
    1. No knowledge
    2. Minimal knowledge
    3. Some knowledge
    4. Extensive knowledge
    5. Expert knowledge
11. Have you ever been asked to give information on climate variability before?
    [ ] Yes [ ] No

12. Have you ever received any professional advice (e.g from agricultural officers) regarding the effect of climate variability on your tea farming?
    [ ] Yes [ ] No

    If yes, what was the advice? ..........................................................................................

**Part 3: Effect of climate variability on tea production**

13. What significant changes in climate have you observed in your community over the last 20 years? State its effect on tea production.

| **Changes in rainfall** | **Effect on tea production** |
|---|---|
| Unpredictable rains | |
| Prolonged drought | |
| Very wet season | |
| Changed onset and Cessation of rain season | |
| Extreme/intensive/heavy rainfall | |
| Storms (strong winds and/or hailstones | |
| Others, specify | |

**Part 4: Climate variability adaptation strategies**

14. Have you ever been involved in climate variability adaptation planning before?

[ ] Yes [ ] No

15. Which of the following adaptation strategies to climate variability have your household undertaken?

[ ] Diversification to other activities like maize, beans, potatoes, sorghum, livestock keeping
(Identify the activity……………………………………………………………………)
[ ] Irrigation during young tea stage

[ ] Mulching

[ ] Planting cover crops during young tea stage

[ ] Establishment and management of shade trees

[ ] Weed management to reduce competition for moisture

[ ] Control of pests and diseases

[ ] Proper drainage systems on long and steep slopes

[ ] Use of early warning systems

[ ] Planting drought resistant tea varieties

[ ] use of micro credits

Others,

specify……………………………………………………………………………….

16. Have the adjustments improved your tea farming?

[ ] Yes [ ] No

17. How to do you increase productivity of tea?

[ ] Use of fertilizers [ ] Use of manure or compost

[ ] others, specify……………………………………………

**Part 5: Determinant factors influencing adaptation strategies employed by tea farmers**

18. What factors influence the adaptation strategies employed by tea farmers in the area?
    [ ] Gender
    [ ] Age of the farmer
    [ ] Years of farming Experience
    [ ] Years of education
    [ ] Household size
    [ ] Access to credit
    [ ] Access to extension services
    [ ] Off farm income activities
    [ ] Others, specify……………………………..

THANKYOU.

## APPENDIX 2: RESEARCH AUTHORIZATION LETTER

**NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION**

Telephone: +254-20-2213471,
2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

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

Ref: No. **NACOSTI/P/16/38499/9206**

Date: **4th April, 2016**

Agnes Cherono Milgo
Kenyatta University
P.O. Box 43844-00100
**NAIROBI.**

**<u>RE: RESEARCH AUTHORIZATION</u>**

Following your application for authority to carry out research on ***"Effect of rainfall variability on tea production and coping measures by smallholder farmers in Bomet County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Bomet County** for a period ending **1st April, 2017.**

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

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

**BONIFACE WANYAMA**
**FOR: DIRECTOR-GENERAL/CEO**

Copy to:

The County Commissioner
Bomet County.

The County Director of Education
Bomet County.

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

# APPENDIX 3: RESEARCH PERMIT

APPENDIX 3: RESEARCH PERMIT

THIS IS TO CERTIFY THAT:
*MS. AGNES CHERONO MILGO*
of KENYATTA UNIVERSITY, 0-20400
bomet,has been permitted to conduct
research in *Bomet County*

on the topic: *EFFECT OF RAINFALL VARIABILITY ON TEA PRODUCTION AND COPING MEASURES BY SMALLHOLDER FARMERS IN BOMET COUNTY, KENYA*

for the period ending:
*1st April,2017*

Permit No : NACOSTI/P/16/38499/9206
Date Of Issue : 4th April,2016
Fee Recieved :Ksh 1,000

*Applicant's Signature*

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

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