

**AN ASSESSMENT OF THE EFFECTS OF CLIMATE VARIABILITY ON TEA
PRODUCTION IN KERICHO COUNTY: A CASE STUDY OF JAMES FINLAY'S
(KENYA) LIMITED TEA ESTATES, KERICHO, KENYA**

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DECLARATION

This research project is my original work and has not been presented for any degree or certificate in any University.

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DEDICATION

This study is dedicated to my best friend, my lovely wife Chelimo Chelulei and my children Victoria Chepchumba and Audrey Cherop who continued to believe in me and supported me throughout this research project as well as my studies. Their love, care, concern, support, encouragement and enthusiasm inspired me to achieve this goal. I also dedicate this research project to my late father, John Kibet Koskey, who is sadly missed by me.

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LIST OF ABBREVIATIONS AND ACRONMYS

ASDSP	Agricultural Sector Development Support Programme
CBD	Convention of Biological Diversity
DSRS	Department of Survey and Remote Sensing
EER	Environmental Education Research
EMCA	Environmental Management and Co-ordination Act
ENS	Environment News Service
FAO	Food and Agricultural Organization
FD	Forest Department
FOMAWA	Friends of Mau Watershed
GREAEN	Global Response Environmental Action and Education Network
ICIPE	International Centre for Insect Ecology
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
KFWG	Kenya Forests Working Group
KNA	Kenya National Archives
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Services
MENR	Ministry of Environment and Natural Resources
NEMA	National Environmental Management Authority
SUMAWA	Sustainable Management of Watersheds
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
WRM	World Rainforest Movement
WWF	World Wildlife Fund

ABSTRACT

Climate variability may change the frequency and intensity of weather events which will likely challenge human and natural systems than the normal weather change. Agriculture is considered one of the most vulnerable systems than any other system to climate variability in Kenya, there is a particular concern over tea – a critically important sector for the economy, but which is also highly sensitive to climate variability and change. Given its economic importance, tea in Kenya is facing challenges under climate variability and change threats, raising concerns over the long run its viability. Already tea producers are facing reduced and erratic rainfalls, higher rate of hail or frost episodes as well as increasing temperatures that heavily affect yields and productivity levels. Over 500,000 smallholder tea producers are facing increased uncertainty about their future livelihood. It is for this reason that the study sought to assess the impacts of climate variability on Tea production in James Finlay's (K) Limited tea estates in Kericho County, Kenya.

The main objective of this study was to assess the effects of climate variability on Tea production in in Kericho County, Kenya. The specific objectives were to assess the effect of rainfall variability, temperature variations, and climate variability on tea quantity in Kericho County. Also, the study sought to determine the possible adaptation strategies on the impacts of climate variability on tea production in Kericho County. To achieve this goal an assessment of tea production vulnerability to climate variability using a statistical analysis linking historical climate data trends with tea yields in James Finlay's (K) Limited based on time data series was carried out. Data on temperature and rainfall variability was obtained from the Kenya meteorological department stations in Kericho County, while data on tea yields was obtained from the respective tea estates management.

The study found that rainfall variability has a positive and significant influence on tea production in Kericho County. However, rainfall below 1500mm and more than 2500mm can negatively affect tea production. The study found that variation in temperature has a positive and significant effect on tea production in Kericho County. However, temperatures below 19⁰C and above 29⁰C have a negative influence on tea production. Extreme cold conditions (19⁰C) are detrimental to tea production and reduce efficiency of laborers in charge of tea leaves picking. Extreme hot conditions (29⁰C) may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves. The study established that climate change adaptation strategies have a positive and significant effect on tea production in Kericho County. James Finlay's (K) Limited was using crop varieties tolerant to drought, flood and heat, giving higher yield even under extreme climatic conditions.

This study recommends that research institutes such as Kenya Agricultural Research and Livestock Organization (KARLO) and Tea Research Foundation (TRF) should research on better breeds of tea bushes with lower sensitivity to temperature variability. In addition, tea farmers should adopt adaptation strategies such as composting and mulching to prevent loss of water in the soil. In addition, farmers should use other strategies such as installation of drip irrigation to provide water to the seedlings during the dry seasons. Also, the study recommends that the issue of unpredictable rainfall can be addressed by considering other sources of moisture such as use of irrigation. However, for this to happen, cost benefit analysis of the available irrigation technologies must be carried out first.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Climate change and variability is emerging as the most important environmental problem facing modern society today. Rise in atmospheric stocks of greenhouse gases (GHG), including carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), due to human activities have been linked to global climate change and variability(Intergovernmental Panel on Climate Change (IPCC), 1990, 2007). The Fourth Assessment Report of the IPCC (2007) emphasizes that there will be changes in the frequency and intensity of some weather events and extreme climate events which will likely challenge human and natural systems much more than gradual changes in mean conditions. According to this report, it is virtually certain (more than 99% probability of occurrence) that most land areas will have warmer and fewer cold days and nights. It is also very likely that most areas (between 90 to 99 % probability of occurrence) will have warmer temperature, more frequent heat waves and heavy precipitation events, more drought, tropical cyclone and incidence of extreme high sea level (Aberra, 2011).

It is an undisputed fact that the impacts of climate variability can be particularly severe in societies where people are highly dependent on natural resources for their livelihood and also experience the impacts of extreme climate events such as floods, drought and other sources of stress to their livelihoods such as disease, conflict and increased population pressure (Goulden, 2005).

The consequences of climate variability are potentially more significant for the poor in developing countries than for those living in more prosperous nations. Vulnerability to the impacts of climate variability is a function of exposure to climate variables, sensitivity to those variables, and the adaptive capacity of the affected community. Often, the poor are dependent on economic activities that are sensitive to the climate such as agriculture and forestry. Any change in weather and climate conditions could directly impact on productivity levels and thus diminish livelihoods (USAID, 2007).

The threat that climate change and variability poses to climate sensitive economic sectors such as agriculture, forestry, wetlands among other has necessitated the assessment of the potential

impacts of climate at various scales on these sectors in order to reduce their vulnerability and thereby secure the livelihoods of those who depend on them. It is expected that climate variability will be a major driver of the projected change in global climatic variables, especially temperature and precipitation (Schneider, 1992). It is feared that ultimately, this might lead to changes in the productive capacity of agricultural soils and perhaps also bring about frequent occurrences of episodic events such as prolonged heat periods, cold snaps, floods and droughts significantly affecting agricultural productivity (Houghton et al., 1996). The global mean temperature increased by 0.6° C in the last century, and the 1990s were particularly hot years (IPCC, 2001). According to Guwahati (2013), tea production in India is expected to consistently pick up from the month of April, but of late harsh weather condition in the preceding months February and March has been delaying crop production in many tea gardens. Moreover, irrigation, which was something unnecessary and unimaginable few years back, has now become utmost essential for tea gardens across the state, particularly in Brahmaputra Valley, the main tea producing region of Assam.

In Sri Lanka there will be more intense rainfall in future with a prediction perhaps of 10% variability in the length of dry and wet seasons per year in the main tea plantation. The heavier rainfall brings other concerns - mainly soil erosion in higher elevation areas. Lower elevation areas may become less suitable for tea production. But warmer temperatures coupled with the increased rainfall could also make new areas suitable for tea cultivation; mountain areas and wetter zones will likely have increased tea production (Banks, 2011).

Climate variability is wreaking havoc in the world's coffee and tea growing regions and the next decade is likely to see the areas in which these crops are grown rendered unsuitable for cultivation (McDonald, 2009). In the recent past, rising temperatures and changing patterns of precipitation have caused devastating impact in many countries such as Kenya, Uganda, Ethiopia, Brazil, Mexico and Nicaragua. These countries depend on tea and coffee for export (ibid).

The impact of climate variability, as manifested in floods, droughts and unpredictable rains, presents a challenge to most sub Saharan Africa due to their high dependence on climate-sensitive economic activities such as rain-sustained agricultural activities (IPCC 2001). East Africa is also showing signs of climate change. In Uganda, an analysis of the temperature

records shows a sustained warming particularly over the southern parts of the country with the minimum temperature rising faster than the maximum temperature (GoU, 2002). The disappearance of the snow caps on Mount Kilimanjaro and the Ruwenzori peaks provides strong evidence of the climate change and variability in East Africa. The region is already among the most food insecure in the world, and climate variability has the potential to aggravate the problem. Climate predictions for the region indicate that humid areas are likely to become wetter while dry regions are expected to become even drier (Orindi and Eriksen, 2005).

The East Africa countries are highly vulnerable to climate variability due to a combination of factors including: geographic location; structural problems; inadequate infrastructure; and weak institutions. One major cause of vulnerability, however, is the overly strong dependency of the region's population and economies on agriculture. The low use of modern technologies such as improved crop varieties, fertilizers, mechanization and irrigation makes the agricultural sector in the EAC particularly vulnerable to climate variability and climate change.

Kenya Highlands to the West of Rift Valley on attitudes ranging between 1500 and 2700 meters includes such areas as Kericho, Nandi and Cherangani Hills are the major tea growing zones in the country. It is estimated that two thirds of tea production in western Kenya is grown in areas that benefits from ecological functions of Mau complex (TBK, 2009). The tea plantations south west of Mau forest are among the most productive areas in the world. Tea leaves are harvested throughout the year due to evenly distributed rainfall. The three main multinational companies producing tea on large scale in Kericho are the James Finlay's Limited, Unilever Limited and George Williamsons limited. James Finlay's is the largest of the above three mentioned multinational tea companies (Soy et al, 2010).

In the last decade alone, however, the tea growing areas south west of the Mau complex have experienced significant reduction in tea production levels per hector that calls for radical intervention (Soy et al, 2010). Prolonged and frequent drought periods are more evident and the cost per unit of tea produced has increased significantly and consequently the cost of doing business.

1.2 Statement of the Problem

The threat that climate variability poses to climate sensitive economic sectors such as agriculture, forestry and wetlands has necessitated the assessment of the potential impacts of climate variability at various scales on these sectors in order to reduce their vulnerability and thereby secure the livelihoods of those who depend on them. It is feared that ultimately, the drastic and unexpected climatic changes might be the underlying reason behind the frequent occurrences of periodic events such as prolonged heat periods, cold snaps, floods and droughts (Schneider, 1992; Houghton et al., 1996). Studies to bring to the fore the impacts of climate variability in many parts of the world including Africa, Europe, Asia and the Americas (Hulme et al., (1996); Rosenzweig et al., (1995); Alexandrov & Hoogenboom, (2000); Saseendran et al., (2000)) have taken place yet case-focussed studies remain to be conducted in order to reduce blanket generalizations and solutions that often characterize the regional and global assessments of the impacts of climate variability on crop production.

More than anywhere else, understanding the link between climate variability and development is crucial in Africa and especially in sub Saharan Africa, where agriculture and other climate sensitive sectors are the mainstay of most national economies. To date only a few region specific studies on the impacts of climate variations on agricultural and other climate dependent economic activities are still uncertain (IPCC, 1990). A review of the impact of climate change by ICRISAT (2007) shows that there is sufficient evidence to support the conclusion that climate variability and change is real in Kenya, and the sector most likely to be hardest 'hit' is agriculture as a result of significant variability in climatic elements.

Kenyan tea production outputs have fluctuated to levels that have not been experienced since its establishment, while previously consistent year to year tea outputs levels are now varying significantly (Soy et al, 2010). This is making output forecasting and planning a major challenge throughout the tea production chain all courtesy of drastic changes in the prevailing micro climate. In the next decade it is expected that the quality of tea produce in western highlands will decline in some catchments while harvest losses will rise due to unpredictable risks emanating from increasing extreme weather events like frosts, hail and droughts (TBK, 2011). Research emphasis on climate change and variability in Kenya over the recent past have continued to put more emphasis on the future expected impact of climate variability (Ojwang', (2010), Enjobe &

Orborn, (2012), Rwigi & Otengi (2009), Herrero et al (2010) ignoring the need to quantify the actual impacts already experienced by the tea producers. To this extent, it is not clearly documented whether the changes in tea production levels of tea estates in Kericho County can be attributed to the variation in the weather elements or other factors are at play and the extent to which mitigation strategies have influenced the tea yields. It is in this view that the research sought to assess the effects of climatic variability on tea production in James Finlay's (K) Limited in Kericho County.

1.3 Research Questions

- i. Does the rainfall variability in Kericho County affect tea productivity in Kericho County?
- ii. To what extent have temperature variation in Kericho county affected tea production in Kericho County?
- iii. What are the climate variability adaption strategies employed by James Finlay's (K) Limited to improved tea production output?
- iv. What are the possible adaptation strategies on the effects of climate variability on tea production in Kericho county

1.4 Objectives of the study

1.4.1 General objective

The broad objective of the study was to assess the effects of climate variability on tea production in Kericho County.

1.4.2 Specific Objectives

The study was guided by the following specific objectives

- i. To assess the effect of rainfall variability on tea production in James Finlay's (K) limited tea states in Kericho County.
- ii. To establish the effect of temperature variations on tea production in Kericho County
- iii. To assess the effect of climate variability on tea production in Kericho County
- iv. To determine the possible adaptation strategies on the impacts of climate variability on tea production in Kericho County

1.5 Research Hypotheses

- i. Ho: Tea production in James Finlay's (K) Limited has been significantly affected by climate variability in Kericho County.
H₁: Tea production in James Finlay's (K) Limited has not been significantly affected by climate variability in Kericho County.
- ii. Ho: Rainfall variability in Kericho County significantly affect Tea production in James Finlay's(K) Limited
H₁: Rainfall variability in Kericho County does not significantly affect Tea production in James Finlay's (K) Limited
- iii. Ho: Temperature Variation in Kericho County significantly affect Tea production in James Finlay's(K) Limited
H₁: Temperature Variation in Kericho County does not significantly affect Tea production in James Finlay's (K) Limited
- iv. Ho: The climate Variability adaptation strategies employed by James Finlay's (K) Limited are significantly effective.
H₁: The climate Variability adaptation strategies employed by James Finlay's (K) Limited are not significantly effective.

1.6 Significance of the Study

Tea is an important foreign exchange earner in Kenya; therefore, the study provides prudent information on how to ensure that production levels are improved to guarantee increased export hence improved income to the producers. The findings of this study are useful to the tea producing firms which are directly affected by the variations in climatic elements in Kericho. The study will enable the firm management understand the key source of their production challenges and the extent to which the changes in the ecosystem and adaptation strategies employed has influenced their performance all for better management. Apart from the direct stakeholders, the findings of this study are useful to policy makers in such fields as agriculture, environmental conservation and the forestry department. The study will add more information to the body of knowledge on the effects of climatic variability on tea production. To other researchers and academicians, the study will provide information that they can use as literature review.

1.7 Scope of the study

This research study was carried out in Kericho County with a specific focus on the James Finlay's (Kenya) Limited tea estates as the study area. It focused on two climatic elements namely; rainfall, and temperatures. Kericho County was chosen in this study as it produces the highest amount of tea in Kenya and is characterized by large scale cultivation of tea.

The findings were not taken as a representative to all tea producing areas across the country due to the unique ecological systems in every part of the country. However, it can be generalized to tea producing areas in Kericho County with similar climate characteristics. Other factors may also influence tea production such as introduction of new clones which is not captured in this research.

1.8 Study Limitations

Accurate data on key climatic elements (rainfall and temperature) covers a period of 30 years which may be difficult to accurately access since computer use is fairly new in most government agencies. Nonetheless, the researcher sought to obtain data in both hard copies and soft copy so as to increase accessibility of prudent information that was used for developing this study. Moreover, the bureaucracy nature of the James Finlay limited affected the speed of data collection as the transmittal letter from its management allowed the researcher to conduct the study after two weeks thus, delayed the process of data collection.

1.9 Assumptions

The research was based on the following assumptions;

- 1) The information given by James Finlay's (K) limited tea estate managers and the secondary data collected from weather records was true and accurate.
- 2) The tea estate managers are knowledgeable on adaptation measures used by the company, their levels of implementation and their impacts on tea production
- 3) The period of the study was sufficient to allow for exhaustive investigation of the research problem.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The section entailed presentation of literature review related to the main purpose as well as the specific objectives of this study. It also entails presentation of the theoretical and empirical review, conceptual framework and conclusion from the literature review on impacts and adaptation strategies to climate variability.

2.2 Empirical Literature Review

2.2.1 Effects of climate variability on tea production

Recent empirical studies have confirmed that climate variability and change can have substantial impacts on agricultural output (Skoufias *et al.*, 2011). Global weather has become unpredictable and created uncertainty in agricultural production. One of the major impacts of climate variability is the occurrence of severe weather conditions, e.g. hail, frost and drought (Bore, *et al.*, 2011).

Past studies have shown that climate variability is the key factor in the annual tea yield variability. In a study conducted in Bangladesh, Ali et al. (2014) found that the yield of tea is greatly influenced by microclimatic parameter of a region especially rainfall, temperature, humidity and duration of light. In Sri Lanka, Wijeratne (2014) conducted a study on vulnerability of tea production to global climate change and established that increases in temperature, soil moisture deficit, and saturation vapour pressure deficit in the low elevations will adversely affect growth and yield of tea. In another study in Sri Lanka, Seo et al. (2005) analysed the impact of climate change on agriculture productivity using the Ricardian method and five AOGCM experimental models. The model analyse the net revenue per hectare for four most important crops (rice, coconut, rubber, and tea) in the country. The study focused more on the precipitation effect on crop production due to the greater range of precipitation across the country although the limited range of temperature variation allowed only a simple test of temperature impacts in the study. Both the Ricardian method and five AOGCM experimental models showed that the effects of increase in precipitation are predicted to be beneficial to all crops tested and the benefit ranged from 11 % to 12% of the current net revenue of the crops in the model. On the other hand, the impacts of increase in temperature were predicted to be injurious to the economy and the loss

ranged from -18 % to -50 % of the current agricultural productivity (as cited in Lee et al., 2012).

The average productivity of tea plantations in Sri Lanka has shown an overall increase since 1930s even though there have been fluctuations between years. Presently, the national production of tea generally expressed as the quantity of processed or 'made' tea, exceeds 300 million kg a year. The productivity of tea lands is known to be greatly influenced by rainfall and temperature (Wijeratne & Fordham 1996). Previous studies have established strong relationships between the environmental factors and tea yield. Some crop models have also been developed to predict tea yield under varying climatic conditions. Increase in temperature and reduction in rainfall due to global warming could adversely affect the productivity and sustainability of tea plantations in the future (Wijerante & Fordham, 1996).

In Ethiopia, the mean temperature has increased over the past 20 years while rainfall patterns and amounts have changed significantly negatively effecting crop production that accounts for over 45% of its GDP (Abera 2011). In Zambia where agriculture is a key sector, climate variability has a pronounced negative effect on economic growth and is estimated to reduce its GDP growth rate by 0.4 percentage points per year.

Analysis of long-term climatic data for eastern Africa indicates that climate is definitely changing (Mendelsohn, et al, 2000) with an overall tendency towards enhanced temperatures and rainfall. It is projected that rising temperature and changing patterns of precipitation will have devastating impacts for many countries such as Kenya, Uganda, Ethiopia, Brazil, Peru, Mexico and Nicaragua that depends on tea and coffee as a vitally important export (McDonald, 2009).

Evidence of increasing climatic instability in East Africa manifests itself in more frequent and intense weather extremes. In Uganda, the frequency and intensity of droughts and floods have increased significantly. Records of dry and wet years for Uganda between 1943 and 1999 show a marked increase in the frequency of very dry years over the past 30 years, especially in the northern and western parts of the country impacting negatively on its agricultural productivity (Orindi and Eriksen, 2005). Rawhani et. al. (2011) noted that both intra- and inter seasonal changes in temperature and precipitation influence cereal yields in Tanzania. Seasonal

temperature increases by 2°C in their model would reduce average maize, sorghum, and rice yields by 13%, 8.8%, and 7.6% respectively critically impairing food security.

In Kenya, Cheserek, Elbehri and Bore (2015) conducted an analysis of links between climate variables and tea production in the recent past in Kenya and found that air temperature, radiation, rainfall and soil water deficits had an influence on tea yields. According to Mendelsohn *et al.* (2000), climatic variability in Kenya is likely to manifest itself through global warming and sea-level rise and characterized by an increase in mean annual temperature (2.5°–5° C) with a 0 to 25% increase in precipitation. The spin-offs of these changes would include changes in evaporation rates and rainfall patterns resulting in acute water shortages and increased water rights conflicts. In the high rainfall areas, increased flooding and general deterioration of water quality are highly likely changes.

Kenya, like its neighbors' has also suffered a series droughts and floods which have had devastating consequences on its agricultural sector. Climate change is affecting the weather patterns in many East African countries. In Kenya, proven climate changes are already existing, such as delayed; reduced and destructive rainfall as well as increasing temperatures that are affecting heavily the tea production. As the local population is highly dependent on tea production the main source of income for many families is in danger (Adapcc, 2010). Over 70 percent of natural disasters in Kenya are weather-related and their frequency has increased over the years with drought and floods being the main disasters (Omambia et al., 2009).

A study carried out by Omumbo et al (2011) presents evidence of a warming trend in observed maximum, minimum and mean temperatures in Kericho during the period 1979 to 2009 using gold standard meteorological observations. In concluding their study Omumbo et al (2011) noted that the evidence of a warming trend in Kericho point to local factors such as land use change despite the warming trend being consistent with variability and trends that have occurred in correlated global climate processes.

Wachira (2009) in concurrence with the Omumbo's finding noted that tea growing zones evidence of climate variability were presented as reduction in annual rainfall, decreased soil water deficits and increased temperatures. Rainfall around Kericho decreased annually by 4.82mm over the study duration while temperature increased annually by 0.016°C in 52 years.

Both maximum and minimum temperatures were observed to have risen by between 0.1 and 2.9°C. Over the years, radiation was reported to have increased in tea growing areas. High correlation was observed between annual national tea production and rainfall reported in Kericho with reduction in amount of tea produced coinciding with drought periods. Decreased yields were observed with increase in temperature. Soy et al (2009) noted that the unpredictable fluctuations in rainfall pattern is evident over the last decade and occasional long dry spells has become a common occurrence significantly impeding the growth of tea and therefore lead to low production and hence poor profitability.

Studies conducted on climate variability and tea production vary from one country to another. The findings of studies conducted in other countries and different parts of Kenya cannot be generalized to other regions due to differences in types of soil, temperatures, rainfall, humidity and light intensity. This study therefore seeks to assess the effect of climate variability on tea production in Kericho County.

2.2.2 Effect of Rainfall Variability on Tea Production

Water availability is the most critical factor for sustaining crop productivity in rain fed agriculture. Even if a drought-tolerant trait is introduced, water isn't available to crops when there is no water in the soil. Rainfall variability from season to season greatly affects soil water availability to crops, and thus pose crop production risks. There does not seem to be a decisive upper limit to the amount of rainfall under which tea will maintain a vigorous growth. In Sri Lanka certain areas receive as much as 5100 mm of rain yet tea does well. As regards the lower range it is thought that rainfall of less than 1300 mm per annum has a detrimental effect upon tea growth. However, various studies show different effect of rainfall on tea production.

In Bangladesh, Ali et al. (2014) conducted a study on the effects of rainfall variability on tea leaf production in different tea estates. The study found that the yield of tea is greatly influenced by microclimatic parameter of a region especially rainfall, temperature, humidity and duration of light. Scanty rainfall causes irreparable losses because irrigation is seldom used on tea plantations. On the other hand, heavy rains erode top soil and wash away fertilizers and other chemical. An analysis of the results of field experiments with weather data showed that increase highest tea leaf production per hectare lies on 4000mm to 4600mm rainfall. Heavy or scanty or

delayed rainfall adversely affected the growth and yield of tea. It is observed that tea leaf production was slightly increased with increase in total annual rainfall.

In Japan, Ndamani and Watanabe (2015) conducted a study on the influences of rainfall on crop production and suggestions for adaptation in Japan. The results revealed moderate seasonal and irregular annual rainfall concentration. Generally, rainfall in the district starts in May. However, the number of rain days and volume (mm) tend to decrease in June before peaking up in July and August. Correlation between annual rainfall and crop production were negative for all the crops studied, which include tea, sorghum, millet and groundnut.

In Pakistan, Ahmed et al. (2014) carried out a study on the effects of water availability and pest pressures on tea (*Camellia sinensis*) growth and functional quality and found that higher water availability and JA significantly increased the growth of new leaves. The effect of water availability and jasmonic acid (JA) on tea quality varied with individual secondary metabolites. Higher water availability significantly increased total methyl xanthine concentrations of tea leaves but there was no significant effect of JA treatments or the interaction of water and JA. Water availability, JA treatments or their interactive effects had no effect on the concentrations of epigallocatechin 3-gallate. In contrast, increased water availability resulted in significantly lower concentrations of epicatechin 3-gallate but the effect of JA and the interactive effects of water and JA were not significant. These findings point to the fascinating dynamics of climate change effects on tea plants with offsetting interactions between precipitation and pest pressures within agro-ecosystems, and the need for future climate studies to examine interactive biotic and abiotic effects.

Hossain et al. (2015) conducted a study on the effect of rainfall on yield and crop distribution of tea. The results indicated that tea leaf production was slightly increasing in different tea estate of Sylhet district due to increased rainfall. The results also indicated that for maximum production tea needs maximum rainfall with maximum rainy days. In Rural Malawi, Moylan (2012) conducted a study on the impact of rainfall variability on agricultural production and household welfare. The findings revealed that households experiencing a severe negative rainfall shock during the wettest quarter of the 2008/2009 or 2009/2010 agricultural seasons, on average,

suffered from significantly lower crop yields, values of agricultural output, total per capita consumption expenditures, food expenditures and dietary diversity.

In a study focusing on Kenya's tea sector under climate change, Elbehri (2015) found that there is a weak negative relationship between tea yields and rainfall ($1.4 \text{ kg ha}^{-1} \text{ mm}^{-1}$) (Figure 25) at Timbilil Tea Estate. This is due to the low temperatures that accompany the rainy season and depress crop yields. A warm wet season, therefore, is ideal for production. The situation was, however, different at Magura Tea Estate where there was a weak positive relationship between yields and rainfall ($5.5 \text{ kg ha}^{-1} \text{ mm}^{-1}$). This relationship was due to the warm temperatures in the region. Frost bite has a significant potential to reduce tea yields by up to 30percent for three consecutive months. In areas such as Kericho, Sotik and Nandi Hills, the net loss of green tea leaves due to hail was estimated at 2.7 million kg per annum.

In addition, Juma (2014) conducted a study on the effects of Rainfall Variability on Tea Production in Murang'a County. Tea yield data for the period 1995 to 2012 was obtained from the Kenya Tea Development Authority. Climatic data was obtained from the Kenya Meteorological Department. The study found that there was a positive relationship between rainfall variability and Tea Production in Murang'a County.

Studies conducted in Kenya on rainfall variability were limited to specific regions and Counties and hence their findings cannot be generalized to other parts of Kenya. In addition, the studies focused on different period of time that experience different climatic changes. For instance, Juma (2014) study focused on a period ranging from 1995 to 2012 and hence the findings cannot be generalized to the period after 2012.

2.2.3 Effect of Temperature Variability on Tea Production

The elevation of prevailing temperatures has an important effect in modifying transpiration losses. The range in temperature of a particular region is affected by location, for instance an Oceanic area will have totally different temperature characteristic than a tea growing area located in continental climate. The elevation of the land also has a large impact upon the temperature climate of tea growth. Taken together the location and altitude can have a large affect upon temperature climate, for example, the upland districts of Sri Lanka have a similar temperature climate range to that of Highlands of Kenya, which are 450 metres higher in altitude. Tea

requires temperature range of between 19-29degrees Celsius according to Kenya's Tea Research Foundation (Leshamta, 2014).

Temperature variability is the short term deviation from the average temperature such as the occurrence of extremes. Extreme cold conditions detrimental to tea production is frost condition which damages tea leaves, roots and reduces efficiency of labourers in charge of tea leaves picking. Extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves.

Elbehri (2015) conducted a study on Kenya's Tea sector under climate change. The study results indicated that temperature variability has the greatest impact on tea yields. A negative correlation between temperature and tea yields has been observed during dry spells. Output at Timbilil Tea Estate was compared to the national average and it showed a lower monthly average than the national level. Despite the fact that national tea output includes yields from smallholder farms and large plantations with different farm management practices that can affect output, the results indicated that temperature and radiation are key factors that can affect production, including when soil moisture is not limiting. These findings are supported Cheserek, Elbehri and Bore (2015) findings that showed a significant positive relationship between mean air temperature and tea yields (319 kg ha⁻¹m-10C-1) when in Timbilil Tea Estate, Magura in Sotik and Kangaita in Kirinyaga

In Northeast India Dutta (2014) found the possibility of an increase in average temperature by 2⁰C in 2050, while not much variation is observed in the rainfall pattern. A change in tea production period is also expected by 2050 making tea planters look for alternative crops as an adaptive measure to keep the industry on its feet. With such expected impacts on tea production, the planters would need to make changes in their management practices to adapt to the evolving conditions and environment.

In Kenya, Leshamta (2014) conducted a study on the relationship between temperature extremes and tea yields in Kisii, Lake Basin Region of Kenya. The results indicated that seasonal and inter-annual variability of air temperatures have a significant influence on tea yields. In addition, relationship between temperature and tea yields was found in each tea growing zone. In addition, Bilham (2011) in a study on climate change impacts upon crop yields in Kenya, found out that

temperature had more effect upon yield outputs than precipitation and some evidence that temperature thresholds, which severely limit yields, may already have been reached. Further, Rwigi and Otengi (2009) found that the three most important climatic parameters for tea yields in Kiambu are the mean minimum, mean maximum temperature and the terrestrial radiation.

Different parts of the world and different parts of Kenya experience different temperatures during various seasons of the year. Various empirical studies conducted on temperature variability and tea production have been limited to specific countries and regions. For instance, Leshamta (2014) study was conducted in Kisii and hence its findings cannot be generalized to Kericho County. In addition, Bilham (2011) and Rwigi and Otengi (2009) studies focused on the period before the year 2011 and hence their findings cannot be generalized to the period after 2011.

2.2.4 Climate Variability Adaptation strategies

Adaptation to climate change and variability is no longer a secondary and long-term response option only to be considered as a last resort. It is now prevalent and imperative, and for those communities already vulnerable to the impacts of present day climatic hazards, an urgent imperative measures are needed (Cooper, 2013).

Adaptation Strategies are long-term (beyond a single rainfall season) strategies that will be needed for farmers to respond to a new set of evolving climatic conditions that they have not previously experienced. This should be clearly distinguished from coping strategies, which are interventions that have evolved over time through farmers' long experience in dealing with the current known and understood natural variation in weather that they expect both within and between seasons. Pathak et al (2012) identified a number of adaptations strategies available to crop farming in response to climate variability and change.

There is a great variety of possible adaptive responses available to deal with climate variability. These include technological options (such as more drought-tolerant crops), behavioral responses (such as changes in dietary choice), managerial changes (such as different livestock feeding practices), and policy options (such as planning regulations and infrastructural development) (Thornton et al. 2006). In the agricultural sector and specifically crop farming suggests a four

front approach to adopting and managing climate variability at the farm level namely: drought, floods, frost and severe storms and hail stones.

2.3 Theoretical Framework

This study relied on a two front theoretical framework. First is the theory behind climatic change and variability and the second builds a foundation for adaptation strategies adopted. At least four theories of climate change forming the foundations on which climate variability is anchored enjoy some support in the scientific community with the anthropogenic global warming theory being the most prominent. Each theory is plausible and sheds light on some aspects of climate change (Bast, 2012). They are:

1. The anthropogenic global warming theory: The theory holds that man-made greenhouse gases, primarily carbon dioxide (CO₂), are the predominant cause of global warming that occurred during the past 50 years.
2. Bio-thermostat theory: rising temperatures and levels of carbon dioxide (CO₂) in the atmosphere trigger biological and chemical responses that have a cooling effect, like a natural thermostat.
3. Cloud formation and albedo theory: changes in the formation and albedo of clouds create negative feedbacks that cancel out all or nearly all of the warming effect of higher levels of CO₂.
4. Solar variability theory: changes in the brightness of the sun cause changes in cloud formation, ocean currents, and wind that cause climate to change.

To explain the rationale behind climate variability adaptation, Path dependence theory will be used. The concept of path dependency was developed to describe how technologies and social systems could eventually become suboptimal solutions for new and emerging challenges due to norms associated with a particular technological regime and the sunk-in costs of investments in infrastructure for research and development (David 1985). The most important characteristic of path dependency is its *nonergodicity*, a system's inability to detach itself from its past (Martin and Sunley 2006). In other words, a path-dependent system is one where the outcome evolves as a consequence of the system's own history (McGuire 2008). In a climate change and variability setting, the adaptation strategies used by the tea farms is due to their inability to detach

themselves from the weather elements changes but can only develop strategies that evolves from historical climatic occurrences.

2.4 Conceptual Framework

This study sought to assess the effect of climate variability on tea production in Kericho County. The independent variables were rainfall variability, temperature and adaptation strategies. The dependent variable was tea production in Kericho County.

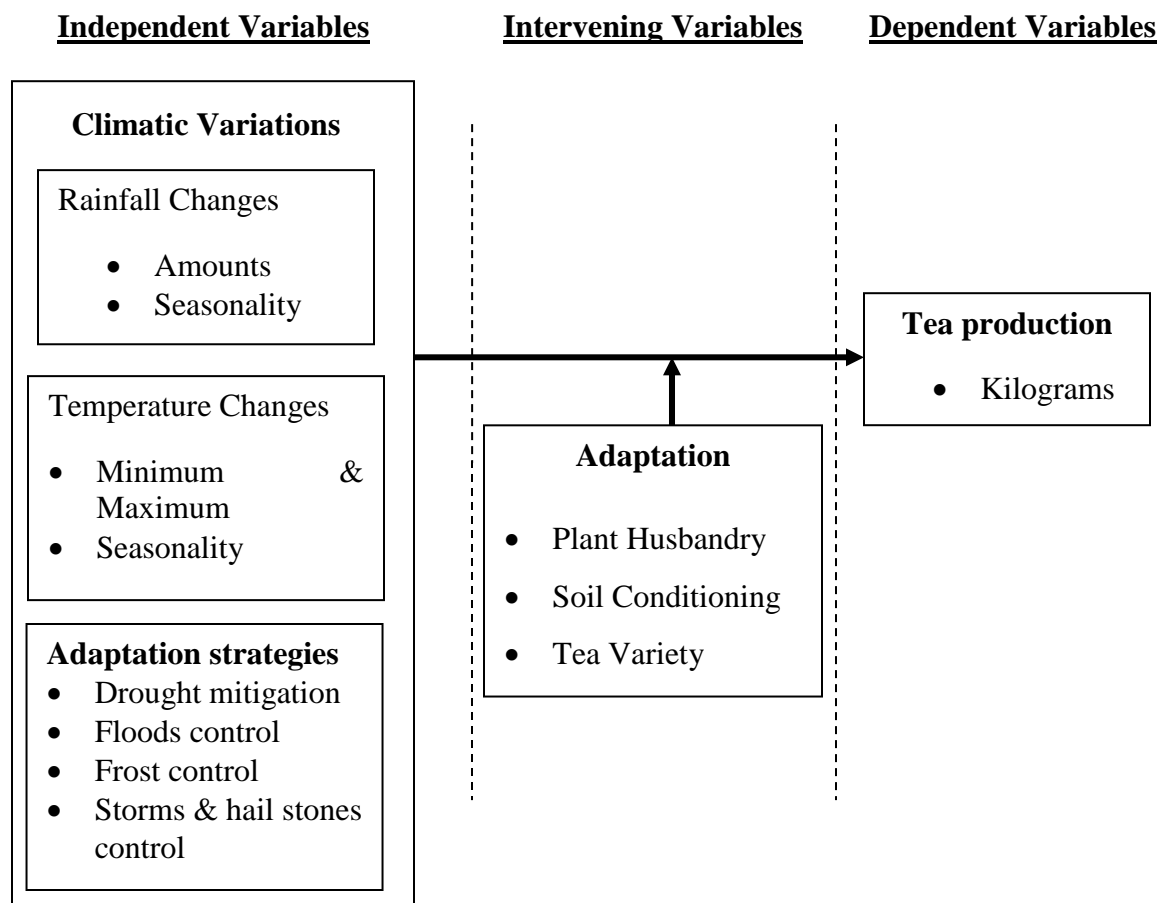


Figure 2. 1: Conceptual Framework

Any significant change in climate in both global and national scale should impact local agriculture. This arises from temperature increase and changes in its geographic distribution, changes in the precipitation patterns that determine the water supply to crops, the evaporative demand imposed on crops by the warmer climate and the available sunshine influencing photosynthesis. What happens to the agricultural economy in a given region, or country, or county, will depend on the interplay of the set of dynamic factors specific to each area.

In middle and higher latitudes, climate change may extend the length of the potential growing season, allowing earlier planting of crops, earlier maturation and harvesting, and the possibility of completing more cropping cycles during the same season. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield. Another important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield.

Agriculture of any kind is strongly influenced by the availability of water. Climate variability and change will modify rainfall, evaporation, runoff, and soil moisture storage. Changes in total seasonal precipitation or in its pattern of variability are both important. The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress.

Extreme meteorological events, such as spells of high temperature, heavy storms, or droughts, disrupt crop production. Heat spells can be particularly detrimental. Similarly, frequent droughts not only reduce water supplies but also increase the amount of water needed for plant transpiration. Higher air temperatures will also be felt in the soil, where warmer conditions are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes that affect fertility.

Altered wind patterns may change the spread of both wind-borne pests and of the bacteria and fungi that are the agents of crop disease. Crop-pest interactions may shift as the timing of development stages in both hosts and pests is altered. A wide variety of adaptive actions may be taken to lessen or overcome adverse effects of climate change on agriculture. At the level of farms, adjustments may include the introduction of earlier or late-maturing crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency.

In response to climatic changes, a major adaptive response will be the breeding of heat- and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Find sources of resistance to changing diseases and insects, as well as tolerances to heat and water stress and better compatibility to new agricultural technologies.

2.5 Conclusion from Literature Review

Although various studies have been conducted on the effect of climate change on tea production, these studies have been limited to specific countries and regions with different temperatures,

rainfall, humidity and soil. From a global perspective, Dutta (2014) conducted a study on climate change and its impact on tea in Northeast India; Ali et al., (2014) carried out a study on the effects of microclimatic parameters on tea leaf production in different tea estates in Bangladesh and Wijeratne (2014) conducted a study on vulnerability of Sri Lanka tea production to global climate change. Nevertheless, the findings of these studies cannot be generalized to Kenya due to differences in climatic conditions, types of tea planted and types of soil in each country.

In Kenya, Cheserek, Elbehri and Bore (2015) conducted an analysis of links between climate variables and tea production in the recent Past in Kenya while Elbehri (2015) conducted a study on Kenya's Tea Sector under Climate Change. However, these studies looked at climatic change for a period less than 10 years. The current study looks at climatic change for 30 years.

CHAPTER THREE: STUDY AREA

3.1 Kericho County Profile: Location and Size

The study area is located within Kericho County approximately 250 km from Nairobi is the country's leading producer of tea and home to the largest tea plantations. Kericho County lies between longitude 35° 02' and 35° 40' East and between the equator and latitude 0 23' South. The county is bordered by Uasin Gishu County to the north, Baringo County to the northeast, Nandi to the northwest, Nakuru County to the east and Bomet County to the south. It is bordered to the South West by Nyamira and Homa Bay Counties and to the West by Kisumu County. The county covers a total of 2,479 km². Kericho is also home to Kenya's biggest water catchment area, the Mau Forest Complex.

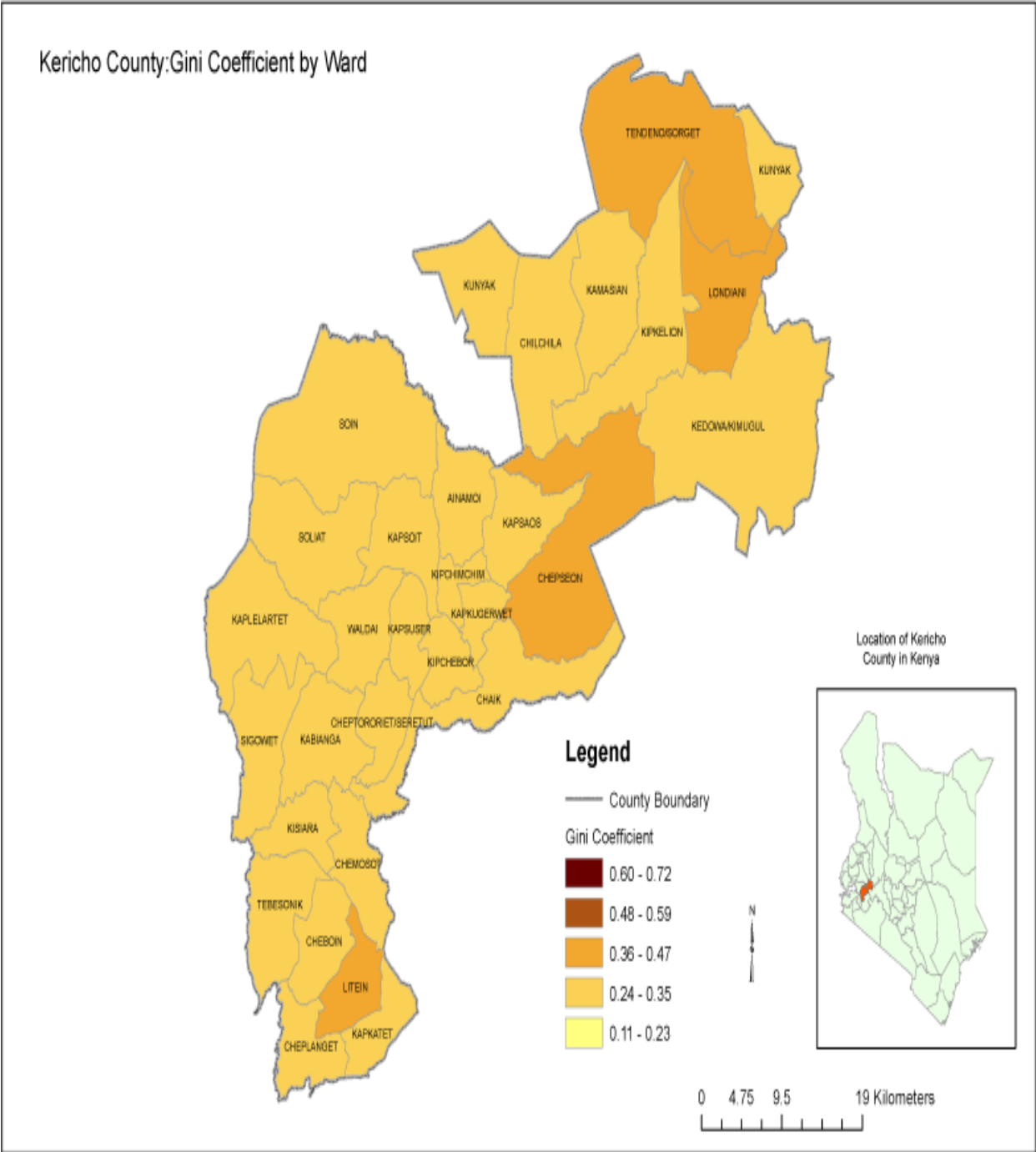


Figure 3.1: A Map of Kericho County

Kericho County covers an area of 2,479 sq. km. Table 3.1 is used to present the distribution of the area according to the administrative units.

Table 3.1: Area Distribution of Kericho County

Constituencies	Sub-County	Division	Area (Sq.km)	No of locations	No of Sub-locations	No of electoral wards
Kipkelion East	Kipkelion East	Londiani Sorget Chepseon	774.4	14	32	4
Soin Sigowet	Sigowet	Soin Sigowet	473.2	13	38	4
Belgut	Kericho West	Kabianga Belgut	337.4	12	27	5
Kipkelion West	Kipkelion West	Kunyak Chilchila Kamasian Kipkelion	333.0	16	35	4
Bureti	Bureti	Bureti Roret Cheborge	321.1	19	53	7
Ainamoi	Kericho East	Ainamoi	239.9	11	24	6
Total			2479.0	85	209	30

Source: County Commissioner's Office, Kericho, 2013

3.1.1 Climatic Characteristics

Kericho County experiences two types of rainy seasons and they include: long rainy season- which are experienced between April and June- and the short rainy seasons are experienced between the month of October and December annually. The driest seasons in Kericho County are experienced in January and February. The temperature as well as precipitation variations are

mainly attributed to change in altitude from one place to another. The county receives relief rainfall, with moderate temperatures of 17⁰C and low evaporation rates. The temperature ranges between 29⁰C and 10⁰C. The rainfall pattern is well distributed such that the central part of the County, where tea is grown, receives the highest rainfall of about 2125 mm per annum while the lower parts of Soin and parts of Kipkelion receive the least amount of rainfall of 1400 mm per annum. The county experiences two rainy seasons: the long rainy season occurs between April and June while the short rainy season occurs between October and December every year. The driest season is mostly from January to February. The variations in the temperatures and rainfall are mainly determined by the altitude of the place. Between the periods July 2010 and June 2011, the county received an average rainfall of 150.1 mm (*Kericho County Development Profile, 2013*).

3.1.2 Physiographic Characteristics

Most part of Kericho County has undulating topography. Generally, the land slopes towards west thus affecting the direction of drainage towards the same direction. Kericho County form a mountainous shelf between Kisumu lower lands and Mau Escarpment. The County has good drainage with a good number of rivers such as Kipchorian, Chemosit, Timbilil, Nyando, Kipsonoi, Itare, Maramara, Malaget among others. Most of the rivers have rapid water falls which can be used in harnessing hydro-electric power. For instance, River Kiptaret, Maramara as well as Itare have rapid water falls.

In relation to ecological conditions, the County lies in Lake Victoria Basin. The type of geology in Kericho County comprised of metamorphic, igneous and volcanic rocks which disintegrate and determine the type of soil in the region. In addition, the County has phonolites as well as intermediate igneous rock within its earth crust. Only a small part of Kericho County has undifferentiated granitic, volcanic, admixture and prolific basement rocks. The hilly topology in most part of Kericho County encourages rapid soil erosion. Nonetheless, the problem is naturally mitigated through the availability of dense vegetation covers in most part of the region, except in a few localities such as Kipkelion, Sigowet and Chilchila and in low laying regions such as Ainamoi and Koitaburot.

3.1.3 Demographic characteristics of Kericho County

The county's population was 758,339 in 2009 as per the national Population and Housing Census. The inter-censal growth rate between 1999 and 2009 was 2.5 per cent per annum. The 2012 population was projected to be 817,402 consisting of 411,730 males and 405,671 females. The male to female ratio is 1:1.01. This population was projected to increase further to 881,064 in 2015 and 926,237 by 2017. There is one town and three major urban centres with population of above 2000 but less than 10,000 namely Kericho, Kipkelion, Londiani and Litein respectively. According to the 2009 population and housing census, their respective populations were as follows: Kericho 42, 039 consisting of 22,199 males and 19,830 females; Kipkelion 3,629 comprising of 1,799 males and 1,830 females; Londiani 5,437 composed of 2,672 males and 2,765 females and Litein 6,061 consisting 2,990 and 3,071 females respectively. In 2012, the population is projected to be 45,302, 3,912, 5,860 and 6,533 for Kericho, Kipkelion, Londiani and Litein respectively.

Bureti Constituency was the most populated in 2012 with a population of 180,706 followed by Ainamoi with a population of 155,553. Belgut has a population of 145,151 while Kipkelion East has a population of 126,272. Sigowet/Soin has a population of 113,312 while Kipkelion West is the least populated with a population of 96,408. (KNBS 2009).

3.1.4 Economic Activities

Agriculture is the main backbone of the county's economy because there are both cash and food crops that are grown in both large and small scales. Besides, there are also livestock activities that are being undertaken within the county. Some of the crops such as tea and sugarcane are also grown by multinational companies. The county is actually food secure due to the good climatic conditions and agricultural ecological zones.

3.1.5 Land availability and Use in Kericho County

The size of land holding varies across sub-counties. The average farm size for small scale farmers is 0.9 ha while for large scale farmers is 14 ha. The large scale farms are dwindling due to land fragmentation. Land resources in most part of the county are utilized for farming, which comprises both food and cash crop farming and livestock rearing. The county produces both cash and food crops. The main crops grown include tea, coffee, sugarcane, potatoes, maize, beans,

Pineapples, horticulture (tomatoes, vegetables among others). The land under both food and cash crops is 79,200 ha consisting of 45,200 ha for food crops and 34,000 ha for cash crops. On the contrary, dairy and beef cattle, sheep, goats and poultry are the types of livestock bred across the whole county.

However, large tracks of land are mainly held by multinational companies such as tea and flower farms which are mainly concentrated within Belgut, Kipkelion East and Kericho East sub-counties. A larger percentage of the land is held by private individuals who use it mainly for the production of small scale cash crops, food crops and rearing of livestock. About 80 percent of the county is arable while the remaining 20 percent is non-arable.

The county has seven gazetted forests comprising of the South Western Mau Forest Reserve that occupies a total area of 32,700 ha, Makutano Forest covers 5,474.09 ha, Tendeno Forest (723.80ha.), Kuresoi Forest (7,366.80 ha.), Londiani Forest (9,015.50 ha.), Malagat Forest Station (3,137.90 ha.) and Sorget Forest Station(6,856.60 ha.). Private forests within the county are mainly owned by James Finlay Tea and Unilever Tea. The forests are situated in Londiani and within the tea estates (ASDSP, 2013).

3.1.6 James Finlay's (Kenya) Limited

Finlay's was founded in 1750. As a wholly owned subsidiary of the Swire Group, the company has extensive tea and horticultural interests in Kenya, South Africa, Sri Lanka and China, complemented by global trading, packaging and extraction activities. Its primary markets are in the UK, USA, Asia and increasingly continental Europe.

James Finlay's (Kenya) Limited tea estates lies 35° 15' 16" to the East and 0° 22' 09" South of equator next to Kericho town. Its altitude is 2,000 m above sea level on deep rich loam soils which are high in organic content and produces an average of 23 million kilograms of made tea every year. The following Estates and Factories are under the James Finlay's. The researcher will cover all the 13 estates with each estate manager being the key source of the required tea production patterns data for the study.

Table 3.2: James Finlay’s (K) Limited Tea estates in Kericho County

	Factory name	Size in Hectares
1	Kitumbe Factory	500 Hectares
2	Tenduet Factory	450 Hectares
3	Kapsongoi	600 Hectares
4	Chemase Factory	650 Hectares
5	Chomogonday Factory	450 Hectares
6	Tuluet Factory	800 Hectares
7	Chemasingi	650 hectares
8	Cheptabes	650 Hectares
9	Changana Factory	650 Hectares
10	Marinyin Estate	600 Hectares
11	Chemamul Estate	450 Hectare
12	Kimulot Factory	600 Hectares
13	Bondet Estate	450 Hectare.

Source: James Finlay’s Research Centre

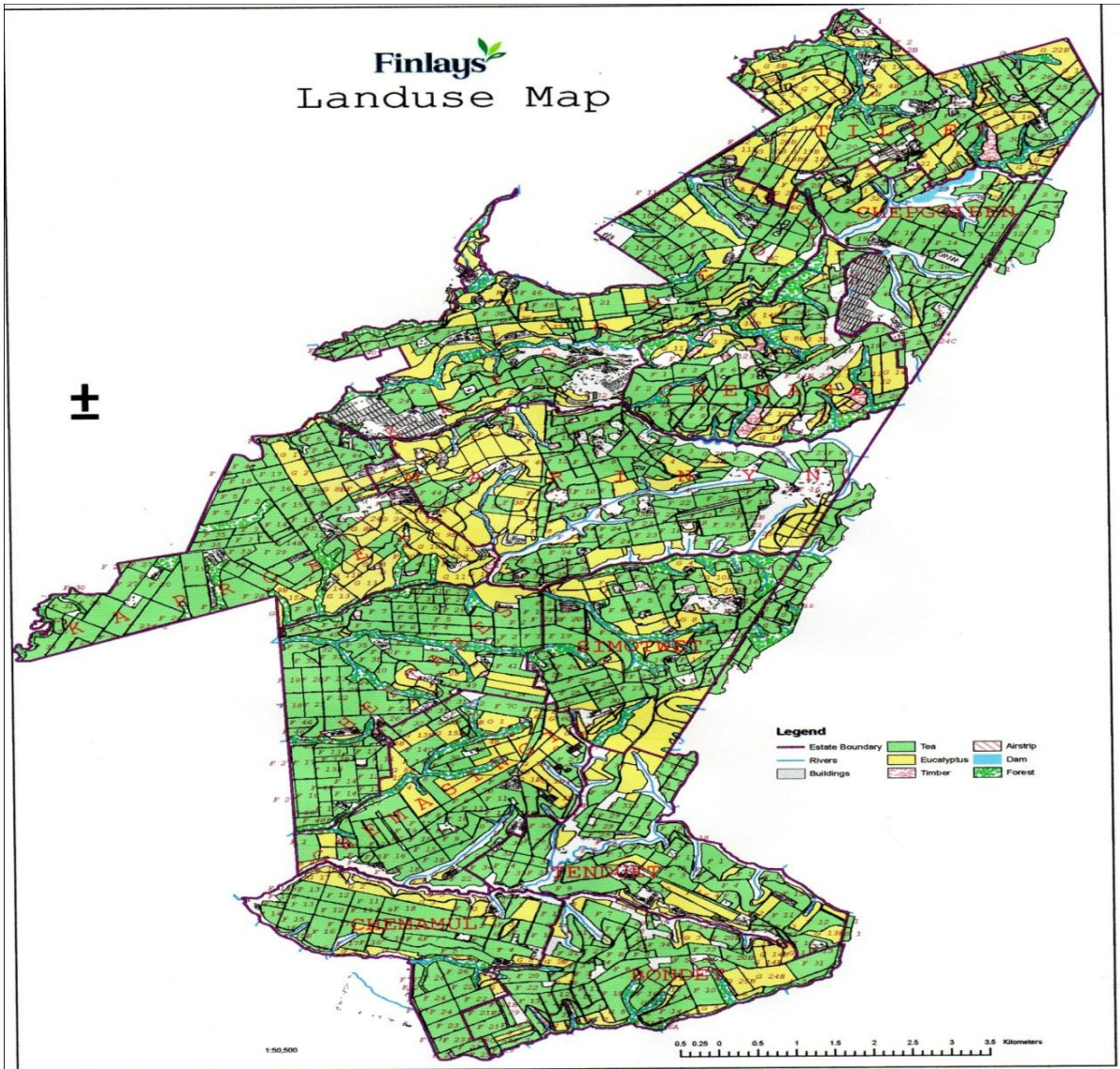


Figure 3.2: Land Use Map of James Finlay’s (K) Limited

Source: James Finlay’s Research Centre

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This section highlights the methodology adopted for the study, research design, and target population, sampling design, data collection instruments and analysis adopted for the study.

4.2 Research Design

A survey method was adopted during the study. A case study design is detailed and thorough investigation of a single unit done so as to gain an in-depth understanding of the aspect under investigation (Mugenda, 2003). In this design, the researcher used both primary and secondary data obtained from two organizations within Kericho county; the Kenya meteorological station, Kericho and James Finlay (K) Limited tea estates.

4.3 Target Population

The target population was James Finlay (K) Limited tea estates Managers and it was selected due to its size and consistency in its record keeping systems and was the source of tea production data for the 30 year period under investigation. Adaptation strategies employed by the company were also obtained. All the 13 estate managers and respective heads of the relevant departments concerned with the custody of the above information were the target for collection of the information.

4.4 Sample Size

Variability in climatic conditions can significantly be determined when specific weather elements are examined continuously over a period of time. The period is usually selected according to the following criteria (IPCC-TGICA, 2007): namely (1) representative of the present-day or recent average climate in the study region, (2) sufficiency of the duration to encompass a range of climatic variations, including a number of significant weather anomalies (e.g. severe droughts or cool seasons), (3) a period for which data on all major climate variables are available.

4.5 Data Collection Instruments

To ensure accurate and comprehensive data was collected in line with the objectives of the study, check sheets and researcher designed questionnaires were employed. The tabular data capture

Check sheets was specifically designed to allow for recording of daily records for the three weather elements and computation of the relevant monthly averages and totals. The use of the check sheet was necessitated by the need to maintain the highest level of accuracy during the data collection process and to facilitate ease of preliminary analysis. Questionnaires were the key tool for collecting primary data on adaptation strategies employed by the management of James Finlay's (K) Limited. Questionnaires were used to collect data from the 13 estate managers in James Finlay's (K) Limited. The target data collected and the specific data collection instrument that were employed are as indicated on the table 4.1 below.

4.6 Sampling Procedure

In order to meet the above criteria, subjective sampling was used to select the most recent 30 year period (1988-2017) from where monthly total rainfall, Average temperature and humidity data were collected. For comparative purposes, corresponding period's green leaf tea outputs in kilograms were obtained from James Finlay's (K) Limited production records. The unit of analysis was James Finlay's (K) Limited.

Table 4.1: Data Collection Instruments, Variables and Sources

Variable	Data required	Source	Type of Data	Data collection Tool
Rainfall	Monthly Rainfall in mm	Meteorological Department(Kericho Station)	Secondary	Summary Check Sheet
Temperature	Monthly average temperatures in Degree Celsius	Meteorological Department(Kericho Station)	Secondary	Summary Check Sheet
Adaptation strategies	Mitigation Interventions	James Finlay estate Managers	Primary	Questionnaire
Tea Production	Monthly Green tea leaves Kilograms	James Finlay (K) Ltd Records	Secondary	Summary Check Sheet

Source: Researcher Design

The researcher sought approvals and guidance from the relevant personnel of both the meteorological department and James Finlay’s management in accessing the relevant data. High degree of accuracy was emphasized during the data collection process to maintain the authenticity of the information collected.

4.7 Autocorrelation Test

Autocorrelation in this study was tested by use of Durbin–Watson statistic and this enabled the researcher to detect the presence of autocorrelation. Statistically, Durbin–Watson statistic is a statistical test used in detecting autocorrelation in regression analysis residuals. Durbin–Watson statistic can assume values ranging from 0 to 4. The rule of the thumb in this test statistic is that values between 1.5 and 2.5 ($1.5 < d < 2.5$) implying that there exists no autocorrelation in the data. In this study, Durbin–Watson statistic was 1.769, which lies between 1.5 and 2.5. This implies that there was no autocorrelation in the data set.

Table 4.2: Durbin–Watson statistic

Model	Durbin-Watson
1	1.769

4.8 Diagnostic Tests

To determine whether the data was from a normal distribution, diagnostic tests such as test of normality (Shapiro Wilk Test), Multicollinearity Test (Variance Inflation Factor) and Autocorrelation Test (Durbin–Watson statistic) were conducted.

4.8.1 Tests of Normality

Normality test was conducted so as to determine whether the data was from a normal distribution. Normality test was conducted by utilizing of Shapiro Wilk Test. The null hypothesis in Shapiro Wilk Test is that data in a particular variable can be characterized as normally distributed. Therefore, when using an alpha level of 0.05 (95% confidence interval) and the p-value happens to be less than 0.05, then the null hypothesis is rejected, implying that the data is not normally distributed. If the p-value happens to be higher than 0.05, then the null hypothesis fails to be rejected. From the findings, tea yield (p-value=0.831), precipitation (p-value=0.122) and temperature (p-value=0.346), were normally distributed. This is because their p-values were less than the significance level (0.05).

Table 4.3: Tests of Normality

	Shapiro-Wilk		
	Statistic	Df	Sig.
Yield	.980	30	.831
Precipitation	.941	30	.122
Temperature	.962	30	.346

4.8.2 Multicollinearity Test

Multicollinearity Test was used to determine whether independent variables in a data set are highly correlated with each other. Linear regression makes an assumption that there exists no multicollinearity or there is little multicollinearity in data set. Multicollinearity often exists when independent variables in a data set are highly correlated with each other. Variance inflation

factor was utilized in this study to test the multicollinearity of the data. A VIF of more than 10 is considered severe and necessitates further investigations.

Table 4.4: Collinearity Statistics (Variance Inflation Factor)

	Tolerance	VIF
Rainfall	.989	1.011
Temperature	.989	1.011

4.9 Data Processing and Analysis

The researcher used correlation and multiple regression analysis during this study. Correlation analysis was used in this study to determine the relationship between the dependent and independent variables. Both descriptive and inferential methods of data analysis were used. Descriptive analysis involved computation of averages as well as means of the two weather elements and tea outputs over the 30 year period. Inferential analysis involved testing the four hypotheses of the study as a basis for deriving relevant conclusions. Otherwise, multiple regression analysis was used to determine the level to which the two weather elements explains the variability in tea output.

The regression model was;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Whereby Y = Tea output

X_1 = Rainfall

X_2 = Temperature

X_3 = Adaptation strategies

ε = Error Term

β_0 = Constant Term

$\beta_1, \beta_2, \beta_3$ = Beta Co-efficient

Table 4.5: Data analysis tools

Objective	Independent Variable	Dependent Variable	Analytical procedure
Effects of rainfall variability on tea production	<ul style="list-style-type: none"> • Rainfall (mm) • MAM & OND distribution 	Tea leaves production (Kgs)	Descriptive: <ul style="list-style-type: none"> • Moving averages Inferential: Correlation & multiple regression analysis
Effects of temperature variability on tea production	Temperatures in Degree Celsius	Tea leaves production (Kgs)	Descriptive: <ul style="list-style-type: none"> • Moving averages Inferential: Correlation & multiple regression analysis
Adaptation strategies	Mitigation Interventions Methods	Tea leaves production (Kgs)	<ul style="list-style-type: none"> • Frequencies • multiple regression analysis

The decision on whether to accept or reject the hypothesis was based on the P-values generated through the help of statistical tool (SPSS version 22). If $P > 0.05$, the hypothesis was rejected. The direction and strength of the relationship between the individual elements and tea output was examined using Pearson's correlation based on a two tailed test at 95% level of significance. Statistical Package for Social Sciences (SPSS) Version 22 software was used to perform the analysis. Tables, bar graphs and pie charts with relevant descriptive was used for presentation.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Introduction

This chapter covers data analysis and discussion of the findings as per the purpose and objectives of the study. The purpose of the study was to assess the effects of climate variability on tea production in Kericho County. The study sought to determine the influence of rainfall variability, variation in temperature, climate variability and climate change adaptation strategies on tea production in Kericho County.

The target population of this study was the 13 estate managers working in James Finlay's (K) Limited in Kericho County. Out of 13 questionnaires that were distributed, 12 were filled and returned to the researcher. This gives a 92.31% response rate. Secondary data on precipitation, temperature and tea yield covered a period of 30 years starting from 1988 to 2017.

5.2 General Information

The estate managers were asked to indicate their highest level of education. From the findings, 66.7% indicated that they had undergraduate degrees and 33.3% indicated that they had postgraduate degrees. This implies that most of the estate managers in James Finlay's (K) Limited had undergraduate degrees.

Table 5. 1: Respondents' Highest Level of Education

	Frequency	Percent
Post graduate degree	4	33.3
Undergraduate degree	8	66.7
Total	12	100.0

5.3 Effect of Rainfall Variability on Tea Production

The first aim of this study was to assess the effect of rainfall variability on tea production in James Finlay's (K) limited tea states in Kericho County.

5.3.1 Trend of Precipitation and Tea Yields

The results in Figure 5.1 show that Precipitation in James Finlay's (K) Limited has been fluctuating over the years. Between the year 1988 and 2012 rainfall in James Finlay's (K) Limited was ranging from 141mm to 207mm per Year. However, in the year 2013 and 2014 it increased to 453.133mm and 727.145mm, respectively. In the year 2015 the precipitation was 690.212mm, which increased to 712.912mm in 2016 and 700.212mm in 2017. This implies that the rainfall (precipitation) in James Finlay's (K) Limited was increasing over the years.

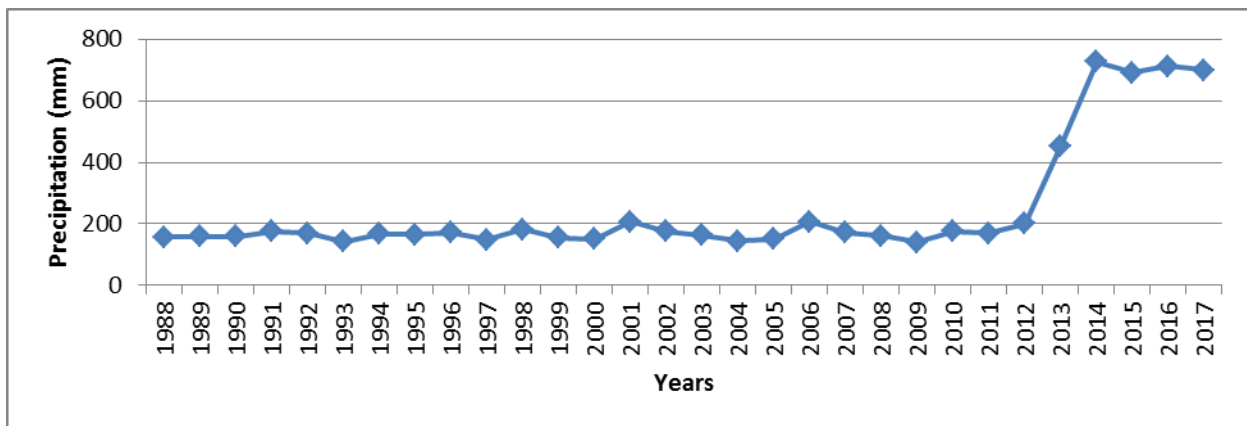


Figure 5. 1: Trend of Precipitation

Source: Research Data (2018)

According to the findings, as shown in Figure 5.2, the yield of tea has been fluctuating over the years. Between the year 1988 and 1991, the yield of tea increased from 3178 Kgs/Ha to 3728 Kgs/Ha. This figure then decreased to 3625 Kgs/Ha in 1992 before decreasing to 4115 Kgs/Ha in the year 1993. In 1997, tea yields slightly decreased to 2793 Kgs/Ha, increased to 3924 Kgs/Ha in 1998 and decreased to 2960 Kgs/Ha in 2000. Between the year 2000 and 2005, tea yield increased to 4124 Kgs/Ha. During the same period of time temperature slightly increased and then began decreasing. The yield decreased to 3516 Kgs/Ha in 2006, but with the same period of time temperature increased. The yield then increased to 4165Kgs/Ha in 2007 and then decreased to

3737 Kgs/Ha in 2009. In the year 2010, the tea yield increased to 4931 Kgs/Ha, but later decreased to 4034 Kgs/Ha in 2012, before increasing to 4596 Kgs/Ha in 2014. Within the same period, tea yields decreased to the year 2012, but later increased upto the year 2014. In the year 2015, tea yield decreased to 4073 Kgs/Ha but later increased to 5091 Kgs/Ha in 2016. In the year 2017, teal yield was 4893. However, while the precipitation significantly increased between the year 2012 and 2015 tea yields did not experience a significant increase.

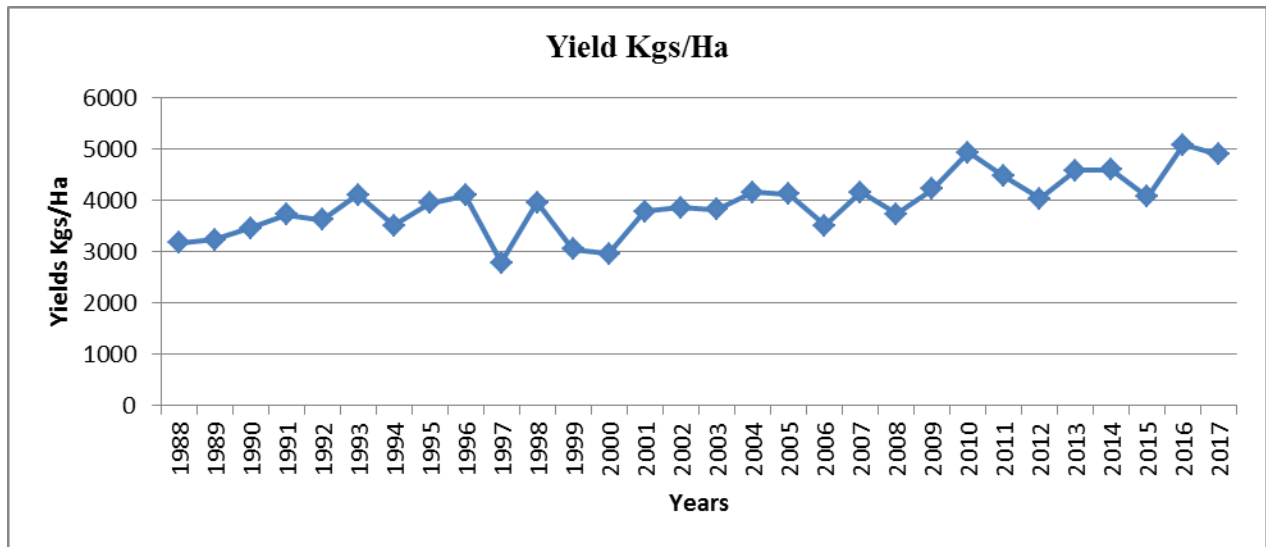


Figure 5. 2: Trend of Yields

Source: Research Data (2018)

5.3.2 Rainfall Variability and Tea Production

The estate managers were requested to indicate their agreement level with different statements on rainfall variability and tea production. Where 1 was used to represent strongly disagree, 2 represented agree, 3 represented neutral, 4 represented agree and 5 represented strongly agree. From the findings, all the estate managers (100%) strongly agreed with the statements indicating that variability in rainfall affects soil-water availability to tea crops; and frost bite significantly reduces tea production and yields. Generally, changes in rainfall affect soil water availability to tea crops; and frost bite tremendously reduced the level of tea yields. This is because lack of rainfall leads to the drying of tea bushes. In addition, 83.3% of the estate managers agreed while 16.7% strongly agreed with the statement indicating that heavy rainfall destroys tea bushes. Heavy rainfall leads to the carrying away of important nutrients in the soil. In addition it leads to

the destruction of tea leaves. Further, 83.3% of the estate managers agreed while 16.7% moderately agreed with the statement that scanty rainfall causes irreparable losses to tea plantations. Lack of rainfall in tea plantations may lead to the drying up of tea bushes. Similarly, 83.3% of the estate managers strongly agreed while 16.7% agreed with the statement that heavy rains lead to the erosion of top fertile soil and hence wash nutrients and other vital chemical in the soil which enhance crop yield.

Table 5. 2: Effect of Rainfall Variability on Tea Production

	1	2	3	4	5	Mean	Std. Deviation
Variability in rainfall affects soil-water availability to tea crops	0.0	0.0	0.0	0.0	100.0	5.000	.000
Heavy rainfall destroy tea bushes	0.0	0.0	0.0	83.3	16.7	4.166	.389
Scanty rainfall causes irreparable losses to tea plantations	0.0	0.0	16.7	83.3	0.0	3.833	.389
Heavy rains lead to erosion of top soil and wash away available fertilizers and other chemicals	0.0	0.0	0.0	16.7	83.3	4.833	.389
Frost bite significantly reduces tea production and yields	0.0	0.0	0.0	0.0	100.0	5.000	.000

5.3.3 Correlation Analysis for Rainfall and Tea Yield

The study used Pearson correlation coefficient to assess the association between rainfall variability and the tea production in James Finlay’s (K) Limited. From the findings, there is a significant association between rainfall and tea production in James Finlay’s (K) Limited ($r=0.575$, $p\text{-value}=0.001$). This implies that rainfall variability has an influence on tea production in James Finlay’s (K) Limited. Therefore, increase in the rate of precipitation would lead to an increase tea production. However, excess rainfall (more than 2500mm) leads to destruction of tea bushes and carrying away of important nutrients and fertilizers in the soil.

Table 5. 3: Correlations Coefficients

		Yield Kgs/Ha	Rainfall
Yield Kgs/Ha	Pearson Correlation	1	
	Sig. (2-tailed)		
Rainfall	Pearson Correlation	.575**	1
	Sig. (2-tailed)	.001	

** . Correlation is significant at the 0.01 level (2-tailed).

5.3.4 Regression Analysis for Precipitation and Tea Production

The study further sought to examine the relationship between rainfall variability in Kericho County and tea production in James Finlay’s (K) Limited. The null hypothesis was;

H₀: Rainfall variability in Kericho County does not significantly affect tea production in James Finlay’s (K) Limited

The r-squared for the relationship between rainfall variability in Kericho County and tea production in James Finlay’s (K) Limited was 0.330. This shows that rainfall variability in Kericho County can explain 33% of the tea production in James Finlay’s (K) Limited.

Table 5. 4: Model Summary for Rainfall variability and Tea Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.575 ^a	.330	.306	479.39054

a. Predictors: (Constant), Precipitation

As shown in Table 5.5, the p-value (0.000) was less than the level of significance (0.05) and the F-calculated (13.815) was more than the F-critical (4.20) implying that regression model can be used in predicting the influence of rainfall variability on tea production in James Finlay’s (K) Limited.

Table 5. 5: ANOVA for Rainfall variability and Tea Production

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3174877.809	1	3174877.809	13.815	.001 ^b
	Residual	6434828.057	28	229815.288		
	Total	9609705.867	29			

a. Dependent Variable: Yield Kgs/Ha

b. Predictors: (Constant), Precipitation

The results show that rainfall variability in Kericho County has a significant influence on tea production in James Finlay’s (K) Limited as shown by a regression coefficient of 1.730. This implies that a unit increase in rainfall would lead to a 1.730 increase in tea production in James Finlay’s (K) Limited. Therefore, we can reject the null hypothesis that “rainfall variability in Kericho County does not affect tea production in James Finlay’s (K) Limited”.

Table 5. 6: Coefficients for Rainfall variability and Tea Production

Model		Unstandardized Coefficients		Standardized	T	Sig.
		B	Std. Error	Coefficients Beta		
1	(Constant)	3494.495	145.019		24.097	.000
	Precipitation	1.730	.465	.575	3.717	.001

a. Dependent Variable: Yield Kgs/Ha

5.3.5 Discussions on the Effect of Rainfall Variability on Tea Production

The study found that rainfall variability has a positive and significant influence on tea production in Kericho County. These findings concur with Ndamani and Watanabe (2015) argument that rainfall significantly influences tea production. In addition, Hossain et al. (2015) finds that rainfall increase led to an increase in the production of tea in various estates in Sylhet district. The findings also agree with Juma (2014) findings there was a strong and positive association between rainfall variation and production of tea in Murang’a County.

However, even though an increase in rainfall leads to an increase in tea production, excess rainfall (more than 2500mm) leads to a decrease in the production of tea. The study found that variability in rainfall affects availability of water in the soil and hence availability of water to tea

crops. These findings concur with Ali et al. (2014) findings that variability in rainfall in different seasons significantly influences availability of water to the tea crops and hence it poses a great risk to crop production. The study established that frost bite significantly reduces tea production, growth rate and yields. This is in agreement with Elbehri (2015) findings that frost bite significantly reduces the yields of tea by up to 30 percent for about three months following each other.

In addition, the study established that heavy rainfall destroys tea bushes. The findings agree with Juma (2014) findings that excess rainfall in terms of floods significantly influences tea production. Further, the study revealed that scanty rainfall causes irreparable losses to tea plantations. These findings concur with Ndamani and Watanabe (2015) argument that low rainfall leads to irreparable losses since irrigation is rarely used in tea plantations. Similarly, the study revealed that heavy rains lead to erosion of the top soil thus washing away available fertilizers and many other chemicals and nutrients. The findings relates to Ali et al. (2014) findings which stated that high amount of rainfall result to increase in the rate of soil erosion hence wash away nutrients in the soil such as fertilizer.

5.4 Effect of Variation in Temperature on Tea Production

The second goal of this study was to establish the effect of variation in temperature on tea production in James Finlay's (K) limited tea states in Kericho County.

5.4.1 Trend of temperature

From the findings in Figure 5.3, the minimum temperature was ranging from 10⁰c to 11⁰C for the period starting from 1988 to 2017. In addition, the maximum temperature was within 24⁰C and the average temperature was ranging from 17⁰C and 18⁰C. This implies that the temperature was stable in James Finlay's (K) Limited for the period ranging from 1988 to 2017.

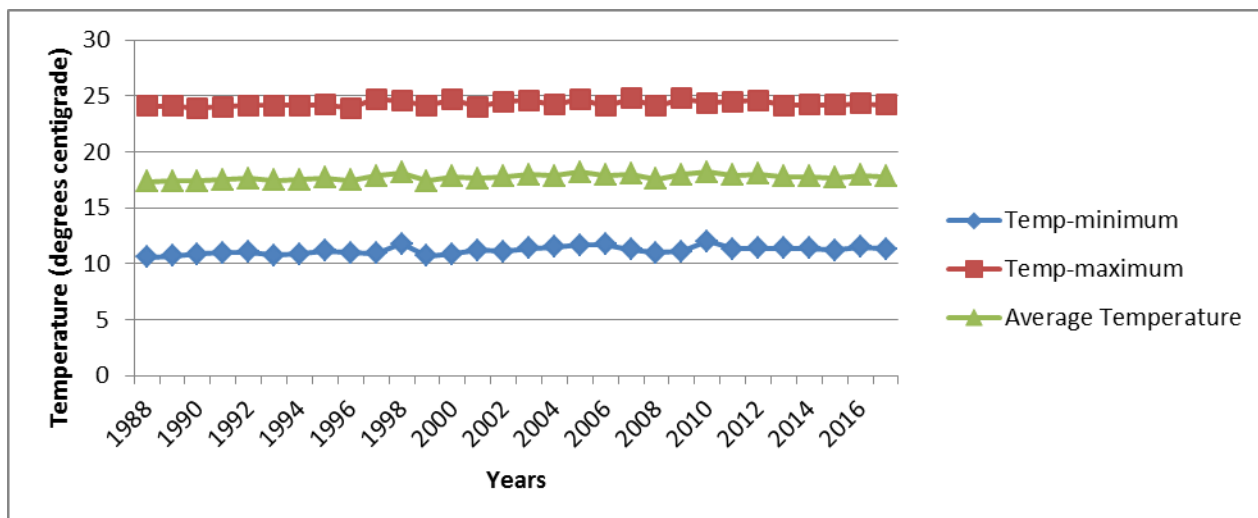


Figure 5. 3: Trend of Temperature

Source: Research Data (2018)

According to the results, as shown in Figure 5.4, the yield of tea has been fluctuating over the years. Between the year 1988 and 1991, the yield of tea increased from 3178 Kgs/Ha to 3728 Kgs/Ha. This figure then decreased to 3625 Kgs/Ha in 1992 before increasing to 4115 Kgs/Ha in the year 1993. In 1997, teal yields slightly decreased to 2793 Kgs/Ha, increased to 3924 Kgs/Ha in 1998 and decreased to 2960 Kgs/Ha in 2000. Between the year 2000 and 2005, tea yield increased to 4124 Kgs/Ha, decreased to 3516 Kgs/Ha in 2006, increased to 4165Kgs/Ha in 2007 and then decreased to 3737 Kgs/Ha in 2009. In the year 2010, the tea yield increased to 4931 Kgs/Ha, but later decreased to 4034 Kgs/Ha in 2012, before increasing to 4596 Kgs/Ha in 2014. In the year 2015, tea yield decreased to 4073 Kgs/Ha but later increased to 5091 Kgs/Ha in 2016. In the year 2017, tea yield was 4893. Just like temperature, tea yields had no significant during the study period and were experiencing fluctuations.

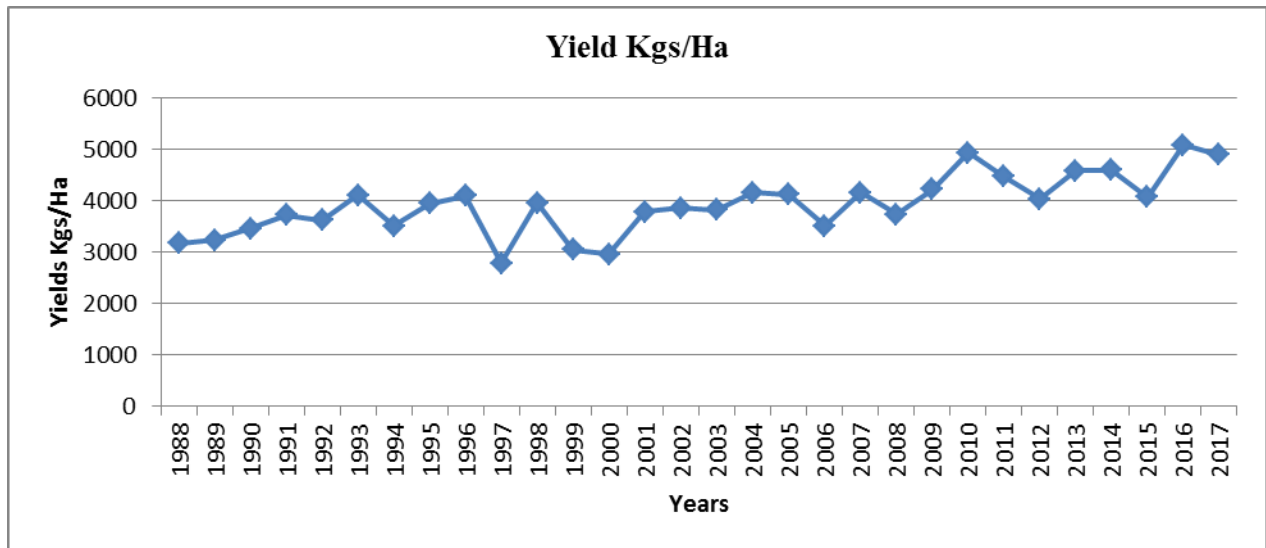


Figure 5. 4: Trend of Yields

Source: Research Data (2018)

5.4.2 Variation in Temperature and Tea Production

The study participants were asked to indicate their agreement level on some of the statements relating to variation of temperature and tea production. Where 1 denotes strong disagree, 2 denotes agree, 3 denotes neutral, 4 denotes agree and 5 denotes strongly agree. According to the findings, 50% of the estate managers strongly agreed and 50% agreed with the statement that temperatures have an important effect in modifying transpiration losses. These findings imply that temperatures have an important effect in modifying transpiration losses. In addition, 83.3% of the estate managers agreed while 16.7% were neutral on the statement indicating that extreme cold conditions were detrimental to tea production. This implies that extreme cold conditions were detrimental to tea production. Further, 66.7% of the estate managers were neutral while 33.3% agreed with the statement that extreme cold conditions reduce efficiency of laborers in charge of tea leaves picking. This basically shows that extreme cold conditions reduce efficiency of laborers in charge of tea leaves picking. Also, 66.7% of the estate managers strongly agreed while 33.3% agreed that extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves. These findings imply that extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves.

Table 5. 7: Effect of Variation in Temperature on Tea Production

	1	2	3	4	5	Mean	Std. Deviation
Temperatures have an important effect in modifying transpiration losses	0.0	0.0	0.0	50.0	50.0	4.5000	.52223
Extreme cold conditions detrimental to tea production	0.0	0.0	16.7	83.3	0.0	3.8333	.38925
Extreme cold conditions reduce efficiency of laborers in charge of tea leaves picking	0.0	0.0	66.7	33.3	0.0	3.3333	.49237
Extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves	0.0	0.0	0.0	33.3	66.7	4.6667	.49237

5.4.3 Correlation Analysis for Temperature and Tea Yield

The study used Pearson correlation coefficient to assess the association between the dependent variable (tea yield) and the independent variables (variation in temperature). As shown in Table 5.8, the results also show that there is a positive association between variation in temperature and tea production in James Finlay's (K) Limited ($r=0.492$, $p\text{-value}=0.006$).

Table 5. 8: Correlations Coefficients

		Yield Kgs/Ha	Temperature
Yield Kgs/Ha	Pearson Correlation	1	
	Sig. (2-tailed)		
Temperature	Pearson Correlation	.492**	1
	Sig. (2-tailed)	.006	

** . Correlation is significant at the 0.01 level (2-tailed).

5.4.4 Regression Analysis for Temperature and Tea Production

The main goal of this study was to establish the relationship between temperature and tea production in James Finlay's (K) Limited. The null hypothesis was;

H₀: Temperature Variation in Kericho County does not significantly affect Tea production in James Finlay's (K) Limited.

As indicated in Table 5.9, the r-squared for the relationship between temperature variability in Kericho County and tea production is 0.242. This implies that temperature can explain 24.2% of tea production in in James Finlay’s (K) Limited.

Table 5. 9: Model Summary for Temperature and Tea Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.492 ^a	.242	.215	510.00118

a. Predictors: (Constant), Temperature

The findings in Table 5.10 show that the p-value (0.000) was below the significance level (0.05) and the F-calculated (8.946) was more than the F-critical (4.20) and hence the model can be used in predicting the influence of temperature viability on tea production in James Finlay’s (K) Limited.

Table 5. 10: ANOVA for Temperature and Tea Production

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	2326872.185	1	2326872.185	8.946	.006 ^b
1	Residual	7282833.681	28	260101.203		
	Total	9609705.867	29			

a. Dependent Variable: Yield Kgs/Ha

b. Predictors: (Constant), Temperature

As shown in table 5.11, temperature variation has a significant influence on tea production in James Finlay’s (K) Limited as shown by a regression coefficient of 1131.615. This implies that a unit increase in temperature would lead to 1131.615 increase in tea production in James Finlay’s (K) Limited in Kericho County. Hence, the null hypothesis which stated that “variation in Kericho County does not affect tea production in James Finlay’s (K) Limited” can be rejected.

Table 5. 11: Coefficients for Temperature and Tea Production

Model		Unstandardized Coefficients		Standardized	T	Sig.
		B	Std. Error	Coefficients Beta		
1	(Constant)	-16160.284	6715.661		-2.406	.023
	Temperature	1131.615	378.341	.492	2.991	.006

a. Dependent Variable: Yield Kgs/Ha

5.4.5 Discussions on the Effect of Variation in Temperature on Tea Production

The study found that variation in temperature has a positive influence on tea production in Kericho County. These findings are in line with Cheserek, Elbehri and Bore (2015) findings that the mean air temperature has a significant effect on tea yields. However, Elbehri (2015) argues that temperature negatively influences tea production and yields, which is normally observed during dry seasons. The elevation of prevailing temperatures has an important effect in modifying transpiration losses. Tea requires temperature range of between 19-29degrees Celsius. This implies that temperatures below 19⁰C and above 29⁰C have a negative influence on tea production.

The study also found that temperatures have an important effect in modifying transpiration losses. These findings are in line with Leshamta (2014) findings that temperature variability is the short term deviation from the average temperature such as the occurrence of extremes. In addition, the study revealed that extreme cold conditions are detrimental to tea production and reduce efficiency of laborers in charge of tea leaves picking. The findings agree with Leshamta (2014) argument that eextreme cold conditions detrimental to tea production is frost condition which damages tea leaves, roots and reduces efficiency of labourers in charge of tea leaves picking. Also, the study found that extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves. These findings concur with Elbehri (2015) extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves.

5.5 Effect of Climate Change Adaptation Strategies on Tea Production

The fourth goal of this study was to determine the possible adaptation strategies on the impacts of climate variability on tea production in Kericho County. The estate managers were requested to indicate the level of adoption of climate change adaptation strategies in James Finlay's (K) Limited. Where I denotes implemented, P denotes planned, E denotes effective/necessary (but not planned yet) and NR denotes not relevant/ necessary. According to the findings, all the estate managers (100%) indicated that they were using different varieties of crops that are tolerant to heat, drought and flood, leading to increased yields even under extreme climatic conditions. They also indicated that they were using mulching and complete ground cover cropping; as well as growing resistant/tolerant tea varieties to withstand the adverse effect of changes in climatic conditions.

In addition, 83.3% of the estate managers indicated that they implemented an inclusion of other crops, and other economic activities to support tea production; were using forecasting of weather for crop management planning; and combined chemical, biological and physical methods of pest management.

Further, 83.3% of the estate managers reported that they had changed planting dates (late or early sowing) in an effort to prevent or avoid heat stress while 16.7% indicated that though it was effective and necessary they were not planning to use this strategy. Also, 83.3% of the estate managers indicated that they implemented strategies such as crop rotation, zero tillage, and residue covering of soil while 16.7% indicated that although it was effective and necessary they were not planning to use it.

Moreover, 66.7% of the estate managers indicated that they covered risks of climatic extremes while 33.3% indicated that they planned to. Further, 50% of the estate managers reported that they used organic fertilizer, avoiding the utilization of chemical pesticides, 33.3% indicated that they planned to while 16.7% indicated that though it was effective and necessary but they were not planning to use it.

Table 5. 12: Climate Change Adaptation Strategies

	I	P	E	NR
Different crops tolerant to heat, drought and floods leading to higher yield even under changing climatic conditions	100.0	0.0	0.0	0.0
Mulching, complete ground cover cropping	100.0	0.0	0.0	0.0
Changing the planting date (late or early sowing) to avoid heat stress	83.3	0.0	16.7	0.0
The inclusion of other crops, or other economic activities that support tea production	83.3	16.7	0.0	0.0
Growing resistant/tolerant tea varieties that can withstand the adverse impacts of climate change	100.0	0.0	0.0	0.0
Combination of chemical, biological and physical methods of pest management	83.3	16.7	0.0	0.0
Insurance to cover risks of climatic extremes	66.7	33.3	0.0	0.0
Utilization of organic sources of nutrients, thus avoiding the utilization of chemical pesticides	50.0	33.3	16.7	0.0
Crop rotation, zero tillage and increasing residue cover of soil	83.3	0.0	16.7	0.0
Weather forecasting, specifically extreme events, for the management and planning of crops	83.3	16.7	0.0	0.0

5.5.1 Correlation Analysis for Climate Change Adaptation Strategies and Tea Yield

The study used Pearson correlation coefficient to assess the association between the independent variables (climate change adaptation strategies) and the dependent variable (tea production). In addition, the result show that there is a significant association between climate change adaptation strategies and tea production in James Finlay's (K) Limited ($r=0.653$, $p\text{-value}=0.000$).

Table 5. 13: Correlations Coefficients

		Yield Kgs/Ha	Climate change adaptation strategies
Yield Kgs/Ha	Pearson Correlation	1	
	Sig. (2-tailed)		
Climate change adaptation strategies	Pearson Correlation	.653**	1
	Sig. (2-tailed)	.000	

** . Correlation is significant at the 0.01 level (2-tailed).

5.5.2 Climate Change adaptation strategies and Tea Production

The study sought to examine the effectiveness climate change adaptation strategies employed by James Finlay's (K) Limited. The null hypothesis was;

H₀: The climatic variation adaptation strategies employed by James Finlay's (K) Limited are not significantly effective.

From the findings, as shown in Table 5.14, the results show that the r-squared for the relationship between climate variability adaptation strategies and tea production in James Finlay's (K) Limited was 0.808. This implies that climate variability adaptation strategies can explain 80.8% of tea production in James Finlay's (K) Limited.

Table 5. 14: Model Summary for climate Variability adaptation strategies and Tea Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.899 ^a	.808	.789	198.71948

a. Predictors: (Constant), Climate change adaptation strategies

From Table 5.15, the F-calculated (42.140) was more than the F-critical (4.84) and the p-value (0.000) was less than significance level (0.05). This implies that the model was fit in predicting the influence climate variability adaptation strategies on tea production in James Finlay's (K) Limited.

Table 5. 15: ANOVA for Climate Variability Adaptation Strategies and Tea Production

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	1664070.692	1	1664070.692	42.140	.000 ^b
1	Residual	394894.308	10	39489.431		
	Total	2058965.000	11			

a. Dependent Variable: Yield Kgs/Ha

b. Predictors: (Constant), Climate change adaptation strategies

The results show that the climate variability adaptation strategies have a significant influence on tea production in James Finlay's (K) Limited as shown by a regression coefficient of 1282.402.

This implies that a unit increase in the use of climate variability adaptation strategies would lead to a 1282.402 increase in tea production in James Finlay’s (K) Limited. Therefore, we can reject the null hypothesis indicating that “the climate variability adaptation strategies employed by James Finlay’s (K) Limited are not effective”.

Table 5. 16: Coefficients for climate Variability adaptation strategies and Tea Production

Model	Unstandardized		Standardized	T	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
(Constant)	-1075.246	716.118		-1.501	.164
1 Climate change adaptation strategies	1282.402	197.551	.899	6.492	.000

a. Dependent Variable: Yield Kgs/Ha

5.5.3 Discussion on Climate Change Adaptation Strategies and Tea Production

The study revealed that climatic variation adaptation strategies have a positive and significant effect on tea production in Kericho County. Cooper (2013) argues that currently, adaptation to climatic variation is no longer a long-term response option or a secondary option. Currently, it is imperative and prevalent and for communities that are directly affected by changing climatic conditions, urgent and considerable measures are required

The study found that James Finlay’s (K) Limited was using different crops tolerant to heat, drought and floods leading to higher yield even under changing climatic conditions. The study also revealed that James Finlay’s (K) Limited was growing tolerant/resistant tea varieties to withstand the adverse impacts of climate change. These findings are in line with Pathak et al (2012) findings that farmers have opted for different crop varieties that can tolerate heat, flood and drought.

In addition, the study established that James Finlay’s (K) Limited was using mulching and complete ground cover cropping. The study found that James Finlay’s (K) Limited was using inclusion of other crops, and other economic activities to support tea production. These findings are in line with Elbehri (2015) argument that farms have responded to climate change by using

an integrated farming system strategy that involves the inclusion of fishery, livestock and crop in a farming system to ensure the sustenance of livelihood, specifically for poor farmers.

The organization was also using forecasting of weather for crop management planning. These findings are in line with Cooper (2013) findings that farmers were adopting improved weather-based agro-advisory in response to climate change through weather forecasting, specifically extreme events to ensure crop planning and management. The study found that the organization combined biological, chemical and physical methods of pest management. The findings agree with the statement of Bilham (2011) that farmers had started adopting an integrated pest management strategy that involves the combination of biological, chemical and physical pest management methods.

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

6.1 Introduction

This chapter, gives a summary of findings and conclusions which were drawn from the findings. Recommendations were also made as per the purpose and objectives of the study. The purpose of the study was to assess the effects of climate variability on tea production in Kericho County. The study sought to determine the influence of rainfall variability, variation in temperature, climate variability and climate change adaptation strategies on tea production in Kericho County. To achieve the objectives of the study, the discussion on key findings, conclusion and recommendations have been made in relation to the research questions.

6.2 Summary of the Findings

This section presents the summary of the findings as per the objectives of the study. It specifically covers the effect of rainfall variability on tea production; effect of variation in temperature on tea production; and effect of climate change adaptation strategies on tea production.

6.2.1 Effect of Rainfall Variability on Tea Production

The study found that rainfall variability has a positive as well as significant influence on tea production in Kericho County. However, even though an increase in rainfall leads to an increase in tea production, excess rainfall (more than 2500mm) leads to a decrease in the production of tea. The study found that rainfall variation affects the availability of water in the soil for tea crops. In addition, the study established that heavy rainfall destroys tea bushes. Further, the study revealed that scanty rainfall causes irreparable losses to tea plantations. Similarly, the study revealed that heavy rains lead to erosion of the top soil and washing away of fertilizers and other vital nutrients in the soil.

6.2.2 Effect of Variation in Temperature on Tea Production

The study found that variation in temperature has a positive and significant effect on tea production in Kericho County. The elevation of prevailing temperatures has an important effect in modifying transpiration losses. Tea requires temperature range of between 19-29degrees

Celsius. This implies that temperatures below 19⁰C and above 29⁰C have a negative influence on tea production. The study also found that temperatures have an important effect in modifying transpiration losses. In addition, the study revealed that extreme cold conditions are detrimental to tea production and reduce efficiency of laborers in charge of tea leaves picking. Also, the study found that extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves.

6.2.3 Climate Change Adaptation Strategies and Tea Production

The study also revealed that climatic variation adaptation strategies have a positive and significant effect on tea production in Kericho County. The study found that James Finlay's (K) Limited was using drought resistance crops varieties and flood resistant crops resulting to increase in farm yield even under harsh climatic conditions. The study also revealed that James Finlay's (K) Limited was growing tolerant/resistant tea varieties to withstand the adverse climate change impacts. In addition, the study established that James Finlay's (K) Limited was using mulching and complete ground cover cropping. The study found that James Finlay's (K) Limited was using inclusion of other crops, and other economic activities to support tea production. The organization was also using forecasting of weather for crop management planning. The study found that the organization combined biological, chemical and physical pest management methods.

6.4 Conclusions

The study concludes that climate variability (rainfall and temperature) has a positive effect on tea production in Kericho County. However, climate variability can have a negative effect on tea production when the measures of climate such as rainfall and temperature go to the extreme. For instance more frequent and intense weather extremes like increased temperatures and increased frequency floods negatively influence tea production.

The study also concludes that rainfall variability has a positive and significant influence on tea production in Kericho County. However, rainfall below 1500mm and more than 2500mm can negatively affect tea production. Excess rainfall lead to destruction of tea bushes erode top soil

and wash away fertilizers and other chemical. On the other hand, scanty rainfall causes irreparable losses because irrigation is seldom used on tea plantations.

The study further concludes that variation in temperature has a positive and significant effect on tea production in Kericho County. However, temperatures below 19⁰C and above 29⁰C have a negative influence on tea production. Extreme cold conditions (19⁰C) are detrimental to tea production and reduce efficiency of laborers in charge of tea leaves picking. Extreme hot conditions (29⁰C) may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves.

The study concludes that climate change adaptation strategies have a positive and significant effect on tea production in Kericho County. The study found that James Finlay's (K) Limited was using crop varieties tolerant to drought, flood and heat, giving higher yield even under extreme climatic conditions. James Finlay's (K) Limited was growing tolerant/resistant tea varieties to withstand the adverse impacts of climate change. In addition, the organization was using inclusion of other crops, and other economic activities to support tea production. Also, the organization combined physical, chemical and biological methods of pest management.

6.5 Recommendations

The study found that extreme (both high and low) temperatures negatively affect tea yield in Kericho County. This study recommends that research institutes such as Kenya Agricultural Research and Livestock Organization and Tea Research Foundation should research on better breeds of tea bushes with lower sensitivity to temperature variability.

The study found that extreme rainfall like frequent drought and floods have a negative effect on tea yield in Kericho County. The study recommends that tea farmers should adopt adaptation strategies such as composting and mulching to prevent loss of water in the soil. In addition, farmers should use other strategies such as installation of drip irrigation to provide water to the seedlings during the dry seasons. In addition, to reduce the risk of flooding, farmers should plant tea in slightly sloppy areas. This is because tea plants are not tolerant to flooded soils conditions.

The study found that extreme cold conditions (like excessive rains) reduce efficiency of laborers in charge of tea leaves picking. The study therefore recommends that large tea farms should

adopt the new technology of using machines to pick tea as this requires on a few human resource.

The study found that extreme hot conditions may increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves. The study therefore recommends that farmers should use pesticides to deal with pest infestation during the dry seasons. This should be done by combining physical, chemical and biological methods of pest management.

In addition, the issue of unpredictable rainfall can be addressed by considering other sources of moisture such as use of irrigation. However, for this to happen, cost benefit analysis of the available irrigation technologies must be carried out first.

Due to the uncertainty that comes with extreme conditions (drought and floods) that are more recurrent than in the past, the study recommends that farmers should consider insurance covers to take care of risks of climatic extremes.

6.6 Areas for Further Research

This study was limited to the effects of climate variability on tea production in Kericho County. Having been limited to One County, the findings of this study cannot be generalized to other Counties producing tea in Kenya. The study was limited to two components of climate: rainfall and temperature. Thus, other studies should be conducted on the effect of humidity and sunshine on tea production in Kericho County. Therefore, a comparative study should be conducted on climate variability in tea producing Counties like Nyeri, Murang'a, Kiambu and Kisii among others. In addition, the findings of this study cannot be generalized to other types of farm products. This is because different crops require different climatic conditions. Therefore, further studies should be conducted on the effect of climate variability on the production of other farm products like flowers, maize beans, millet, sorghum and even animal products.

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APENDIX II: QUESTIONNAIRE

Demographic information

What is your job position in James Finlay's (K) limited tea states?

What is you highest level of education?

- No formal education []
- Primary education []
- Secondary education []
- Undergraduate education []
- Post graduate education []

Effect of Rainfall Variability on Tea Production

To what extent do you agree with the following statements on rainfall variability and tea production? (Key: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree).

	1	2	3	4	5
Variability in rainfall affects soil-water availability to tea crops					
Heavy rainfall destroy tea bushes					
Scanty rainfall causes irreparable losses to tea plantations					
Heavy rains lead to erosion of top soil and wash away available fertilizers and other chemicals					
Frost bite significantly reduces tea production and yields					

Effect of Variation in Temperature on Tea Production

To what extent do you agree with the following statements on variation in temperature and tea production? (Key: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree).

	1	2	3	4	5
Temperatures have an important effect in modifying transpiration losses					
Extreme cold conditions detrimental to tea production is frost condition which damages tea leaves and roots					
Extreme cold conditions reduce efficiency of labourers in charge of tea leaves picking.					
Extreme hot conditions may add heat stress to tea leaves, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves					

Climate Change Adaptation Strategies

Please indicate by ticking the appropriate response box, the current level of the following adaptation strategies in your estate.

I: Implemented. P: Planned E: Effective/necessary (but not planned yet) NR: Not relevant/ necessary

Adaptation measure	Description	I	P	E	NR
Climate-ready crop varieties :	Crop varieties tolerant to drought, flood and heat giving higher yield even under extreme climatic conditions				
Changing of the dates and seasons of planting:	Changing the dates and seasons of planting (late or early sowing) in an effort to avoid heat stress				
Growing variety of crops:	Growing of resistant/tolerant varieties of tea varieties to withstand the adverse climate change impacts				
Farming system integration:	Inclusion of other crops and other economic activities for supporting tea production				
Technologies for saving water	Mulching as well as complete ground cover cropping				
Pest management integration:	Combination of biological, physical and chemical pest management methods				
Insuring of crops	To cover risks of climatic extremes				
Improved weather-based agro-advisory :	Weather forecasting, particularly extreme events, for the planning and management of crops				
Organic farming:	Utilization of organic sources of nutrients as well as avoiding the utilization of chemical pesticides				
Conservation agriculture:	Crop rotation, zero tillage as well as residue covering the soil				
Rainwater harvesting:	Ensuring the reduction of run-off loss and recharge to groundwater				
Others					