# ADOPTION OF PURPLE TEA FARMING AS A COPING MECHANISM TO CLIMATE VARIABILITY AND CHANGE

# A CASE STUDY OF KERICHO COUNTY KENYA

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# Adoption of Purple Tea Farming as a Coping Mechanism to Climate Variability and Change a Case Study of Kericho County Kenya

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## DECLARATION

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

Signature ……………………………. Date ………………………………………

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This thesis has been submitted for examination with our approval as University supervisors

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## DEDICATION

This work is dedicated to my parents Mr. and Mrs. Kimtai, who laid a foundation for me to pursue my education. To my grandparents and aunties who have always stood with me in prayers and who taught me that with perseverance, humility and honesty I can achieve a lot.

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## LIST OF ACRONYMS

| | |
|---|---|
| **C** | Carbon |
| **$CO_2$** | Carbon dioxide |
| **Co.** | Company |
| **CDE** | County Director of Environment |
| **CPDA** | Christian Partners Development Agency |
| **CTC** | Cut Tear and Curl |
| **EATTA** | East Africa Tea Trade Association |
| **EPZA** | Economic Processing Zone Authority |
| **FAO** | Food and Agricultural Organization |
| **FFS** | Farmers Field School |
| **GHG** | Green House Gases |
| **GOK** | Government of Kenya |
| **HIV/AIDS** | Human Immune Virus/ Acquired Immunodeficiency Syndrome |
| **IPCC** | Intergovernmental Panel for Climate Change |
| **KTDA** | Kenya Tea Development Agency |
| **NEMA** | National Environment Management Authority |
| **NGO** | Non-Governmental Organization |
| **RGR** | Relative Growth Rate |
| **SOM** | Soil Organic Matter |
| **SPSS** | Statistical Package for Social Sciences |
| **STI** | Sustainable Trade Initiative |
| **TAR** | Third Assessment Report |
| **TBK** | Tea Board of Kenya |
| **TRFK** | Tea Research Foundation of Kenya |
| **TTP** | Total Polyphenols |
| **UK** | United Kingdom |
| **USD** | United States Dollar |
| **VAT** | Value Added Tax |
| **WCED** | World Commission on Environment and Development |

# ABSTRACT

With the current climatic conditions, purple tea is considered favorable in terms of productivity, health, market and resistance to changing weather patterns (Pradip Baruah, 2013). Although, there are widespread adaptation measures they are not fully being realized due to socio-economic and other constraints. The study aimed at establishing the rate of adoption of purple tea farming, determining the socio-economic factors that hinders adoption and determining the role of purple tea farming for carbon sequestration. Various sampling techniques used involved; purposive, systematic, cluster stratified and random sampling to ensure representation of the whole area. Data was collected by use of $CO_2$ and RGR algorithm, questionnaires, in-depth interviews, literature review, observation and photography. The data was analyzed by use of both descriptive and inferential statistics to answer the research questions. The establishment rate was determined and observed that availability of land was a major setback by farmers adopting the new variety with most famers owning less than 6 acres of land that indicates 82.6% while few famers had acres above 6 that indicates 17.4%. It's evident that, the extension services were rendered highly at 26% to farmers with more than 10 acres of land while with least acres of land (2 acres) the extension services was low 4%. The purple variety had high mean value during wet and dry seasons at 448 kgs and 423 kgs respectively. While the green variety had the least mean value at 337 kgs and 320 kgs respectively. Thus, purple variety was preferred than green variety as adoption mechanism to climate variability and change. The results of negative socio-economic implications indicated that; poor extension services (30.3%), lack of training-farmer field schools (11.1%), poor access to credit (21.1%), and limited market channels (28.2%) and decreased plucking days-change of weather (9.3%) were the major factors hindering establishment of Purple Tea farming. The results of positive socio-economic implications of growing purple variety showed that; little investment (7%), income level (76%), little risk on crop failure (4%) and availability of labour (13%) were major factors that influences the adoption of purple tea variety. This was due to purple tea variety fetching considerable income levels which makes it considered in the market and production capabilities. Results for various chemical and sensory parameters were: Total Polyphenols; TRFK 6/8 26.54%, K-Purple 25.86%, and TRFK 91/1 at 23.87%. Catechins; K-Purple 13.79%, TRFK 91/1 at 11.24% and TRFK 6/8 8.5%. Garlic acid; TRFK 91/1 (1.09%), TRFK K-Purple (0.97%) and TRFK 6/8 (0.88%). Caffein; TRFK 91/1 (2.33%), TRFK K-Purple (1.89%), TRFK 6/8 (1.16%). Theanine; TRFK 6/8 (2.18%), TRFK 91/1 (1.16%), K-Purple (1.1%). The results for purple and green tea variety on drought (90%) and (10%), frost (83%) and (17%), hailstone (71%) and (29%) and pests and diseases (70%) and (30%) resistance respectively showed that purple tea variety was highly rated for impacts of climate variability and change. This was analyzed and noted to be due to the texture and colour that was achieved through advanced hybridization which has led to adaptation to climate change. It was also noted that the purple tea variety mean (%) rate of above ground $CO_2$ sequestration (64.81%) was relatively higher than (35.18%) below ground $CO_2$ sequestration. The difference of the complete sequestration cycle was the time as age and growth rate of tea variety. Thus, increasing the $CO_2$ sequestration ratio in both wet and dry season. This is due to its resistance to the changing climatic conditions. Whereby the rate of survival of purple variety is greater than that of the green variety. The findings of the study are expected to work as a turning point for tea farmers to realize and acknowledge the benefits of purple tea farming as far as economic, environmental, health and other spheres are concerned. It is expected that the findings of this study will enable scientific researchers and policy makers make wise decisions regarding the adoption of available adaptation measures to achieve the sustainable development in Kenya.

# CHAPTER ONE

# INTRODUCTION

## 1.1 General Introduction

Climate change is one of the all-encompassing global environmental changes likely to have deleterious effects on natural and human systems, economies and infrastructure. The risks associated with it call for a broad spectrum of policy responses and strategies at the local, regional, national and global level. While mitigation seeks to limit climate change by reducing the emissions of GHG (greenhouse gases) and by enhancing 'sink' opportunities, adaptation aims to alleviate the adverse impacts through a wide-range of system-specific actions (Fussel and Klein, 2002).

## 1.2 Background

### Origin of Purple Tea

The tea (*Camelia sinensis*) history in Kenya can be traced back to 1903 when G.W.L, Caine, a European settler introduced the first seedlings from India and planted them in Limuru near Nairobi (Tea Board of Kenya, 2010). Tea is defined in the Tea Act 1950, as plant *Camelia sinensis.* The cultivation of Tea for commercial purposes in Kenya commenced in 1924. The early settlers and colonial government restricted tea growing to large scale farmers' and multinational companies because they wanted to maintain high quality. Africans were restricted from growing the crop. On the attainment of independence in 1963, the government passed various land reform bills that had far reaching implications on agriculture in the country. For instance, tea growing was made open to the local farmers. Since then tea growing is wide-spread in Kenya and it is a major economic activity of many small holder farmers. Kenya currently prides itself as one of the world's leading black tea producers (TBK 2010).

Currently, Kenya and Assam (India) is the only country that produces unique Purple Tea and Assam can emerge as the only place in the world after Kenya to become a producer of health-rich Purple Tea (Pradip Baruah, 2013). The special purple tea (TRFK 306/1) was under development for 25 years (TRFK, 2013). Kenya, lies on the equator making farming resourceful, and purple tea trees grow on highland of 1500-2500 meters above sea level. The unique Purple Tea of Kenya is found to be rich in anthocyanins and contains lower catechins and caffeine, and is high in antioxidants that provide anti-cancer benefits and improve vision, lower cholesterol and blood sugar metabolism. Purple tea, claimed to have a host of medicinal properties, has carved out a niche for itself in recent years in Kenya in the domestic market and as an export variety (Pradip Baruah, 2013).

**Climate Variability and Climate Change**

Albeit both mitigation and adaptation measures must be pursued to tackle the climate change problem and to create an effective and inclusive international climate change regime. More attention has been devoted to mitigation in the past, both in scientific research and policy debate. Sensitivity to the issue of adaptation has grown over the last couple of years, particularly after the IPCC (Intergovernmental Panel on Climate Change) (IPCC, 2001). Adaptation has now emerged as an urgent policy priority, prompting action both within and outside the climate change negotiations (Parry *et al.*, 2005).

Unpredictable rainfall patterns are becoming increasingly a common occurrence in many parts of Kenya and the world at large. Farmers, pastoralists and urban dwellers have to adjust to these weather changes. Not only has the rainfall patterns become more unpredictable but the temperatures vary a lot to large extent. Some places are becoming hotter than five decades ago - and others are becoming much colder. Furthermore, the occurrence of extreme weather temperatures and erratic rainfall has increased. The increased hot weather and erratic rainfall is not new but the frequency of the occurrence has increased dramatically in the recent past. Owing to mounting scientific evidence, there is growing consensus that the world has to grapple with increasingly severer climatic events.

Some of the manifestations of climate change are rising average temperatures with the last three decades having got successively warmer (Arndt *et al.,* 2010). Sea levels have been reported to rise at an average 1.8 mm/year between 1961 and 1992 and about 3.1 mm/ year since 1993 (IPCC, 2007) and the thinning snow cover in the Northern Hemisphere.

Climate variability and change will exacerbate impacts such as droughts, floods, extreme weather events and sea level rise, which may contribute to food shortages, infrastructure damage and degradation of natural resources upon which livelihoods are based. This may also jeopardize development gains achieved through development co-operation and make it difficult to reach our development objectives including the Millennium Development Goals. Adapting to the impacts of climate change is therefore critical and not just an environmental issue as also affects the economic and social dimensions of sustainable development (Awuor, 2008; Wandiga *et al.,* 2008)

**The greenhouse effect**

Greenhouse gases do not interfere to any great extent with the incoming solar energy. But once that energy reaches the Earth's surface, it is absorbed, warms the land and ocean surface of the planet, and then is re-emitted. The amount of heat re-emitted and eventually lost to space must equal the amount gained from the Sun if the temperature of the planet is to remain constant.

But the so-called terrestrial energy stream is different in character – it is longer in wavelength than the incoming solar energy as the Earth is cooler than the Sun – and the greenhouse gases interfere with it strongly before it can escape to space. The greenhouse gases absorb the outgoing terrestrial energy, trapping it near the Earth's surface, and causing even more warming. This is the ‘greenhouse effect.’ Without it the planet would be too cold to support life as we know it.

Unfortunately, humanity, through energy generation, changing land use and other processes, has produced a substantial increase in the amount of greenhouse gases in the atmosphere, enhancing the natural greenhouse effect, and it is feared that this continuing change will lead to a major shift in global climate (IPCC, 2007).

**Volcanic pollution**

Explosive volcanic eruptions can inject large quantities of dust and the gas, sulphur dioxide, high into the atmosphere. Whereas volcanic debris in the lower atmosphere falls out or is rained out within days, the veil of pollution in the upper atmosphere is above the weather and may remain for several years, gradually spreading to cover much of the globe. The volcanic pollution results in a substantial reduction in the stream of solar energy as it passes through the upper layers of the atmosphere, reflecting a significant amount back out to space (IPCC, 2007).

**El Niño and La Niña**

The El Niño Southern Oscillation (ENSO) phenomenon is one of the best-defined modes of so - called internal climate variability. It has an oceanic - El Niño and La Niña – and an atmospheric – the Southern Oscillation – component.

The oceanic component consists of a marked warming (or cooling in the opposite, La Niña phase) of the waters of the central and eastern Pacific. The temperature change is strongest in a zone 10 degrees latitude either side of the equator. It affects the regional energy balance, disrupting the atmospheric circulation and climate of much of the low-latitude zone, with effects extending well into middle latitudes during strong 'warm' or 'cold' events (IPCC, 2007).

For several years now, Kenyan tea farmers have incurred losses due to bad weather, low yields, drought, frost, pests and diseases that have conspired to reduce their output and earnings from the cash crop. The farmers have often challenged agricultural research institutes to come up with new varieties of the crop that can withstand frost, pests and diseases. Now, their cries have been heard as the Tea Research Foundation of Kenya (TRFK) has come up with an alternative high quality and high yielding tea variety that is resistant from diseases, pests and changing climatic conditions. The special purple tea (TRFK 306) was under development for 25 years (TRFK, 2014).

### 1.2 Problem Statement

Scientists predict that climate change brought about by global warming and extreme weather will start impacting negatively on tea farming in Kenya in the near future. Already, this is being witnessed in some parts of the Rift Valley and Mt Kenya regions where severe frost, hailstones and drought have been experienced in recent years. Climate variability and change is a reality to the human kind, whereby, tea productivity has reduced and human health is affected too with diseases resulting from climate alteration. Although, there are widespread adaptation measures under different sectors, they are not fully being realized (IPCC, 2007).

Currently, Kenya and Assam (India) is the only country that produces unique Purple Tea and Assam can emerge as the only place in the world after Kenya to become a producer of health-rich Purple Tea (Pradip Baruah, 2013). The special purple tea (TRFK 306/1) has been under development for the past 25 years (TRFK, 2013). Kenya, lies on the equator making farming resourceful, and purple tea variety grow on highland of 1500-2500 meters above sea level. The unique Purple Tea of Kenya is found to be rich in anthocyanins and contains lower catechins and caffeine, and is high in antioxidants that provide anti-cancer benefits and improve vision, lower cholesterol and blood sugar metabolism. Purple tea, claimed to have a host of medicinal properties, has carved out a niche for itself in recent years in Kenya in the domestic market and as an export variety (TRFK, 2013).

With the current climatic conditions, purple tea variety is considered favorable in terms of productivity, health, market and resistance to drought and hailstones as a result of changing weather patterns. The introduction of purple tea in the tea sector is one way of adaption mechanism to climate change that tea farmers need to embrace in order to compete for current fluctuating market, quality, productivity as well as fulfilling sustainable development goals (TRFK, 2013). However, It's not clear the extent to which this mechanism has been adopted by tea farmers in Kenya. This study investigated the extent to which tea farmers have adopted this mechanism, its role as a mitigation measure and identified social and economic challenges they are facing in the process.

## 1.4 Objectives

### 1.3.1 General Objective

To determine the extent of adoption of purple tea farming as a coping mechanism to climate change.

### 1.4.2 Specific Objectives

i. To explore the extent to which farmers have adopted purple tea farming.

ii. To ascertain social and economic factors that affects adoption of purple tea farming.

iii. To determine the role of purple tea variety as a mitigation measure to climate change.

### 1.4.3 Research Questions

i. What is the ratio of purple tea farming to green tea farming?

ii. To what extent could social and economic status of tea farmers be contributing towards the low uptake of purple tea farming?

iii. How could the purple tea variety sequestering $CO_2$ as compared to green tea variety?

## 1.5 Justification

Adaptation measures for climate change are viable in Kenya. With regard to purple tea, the study enhanced the adoption of purple tea farming as an adaptation measure in tea sector that improved tea production and quality. Purple tea was widely developed in order to fetch good market. This is unlike the common Kenyan Green Tea where its market price is three times less of the current Purple Tea price. The adoption of purple tea farming will do well in terms of market and quality as far as climatic conditions are concerned.

Kenyans are becoming health conscious, the presence of anthocyanins in Purple Tea, will serve as health solution to various related diseases like cancer and others. Rich in anthocyanins and with a lower concentration of catechins and caffeine, Purple Tea's high antioxidant effects provide anti-cancer benefits and improves vision, cholesterol and blood sugar metabolism.

## 1.6 Significance of the Study

It is expected that findings of this study shall work as a turning point for tea farmers to realize and acknowledge the benefits of Purple Tea farming as far as economic, environmental, health and other spheres are concerned.

It is expected that the findings of this study will enable scientific researchers and policy makers make informed decisions regarding the adoption of available adaptation measures to achieve the sustainable development in Kenya.

This study will also be relevant to national and international agencies with strong financial and technical background, not leaving out regional and national enterprises interested in pursuit for working adaptation measures for climate variability and change, thus, helping Kenya gain sustainable development agenda.

## 1.7 Study Area

The study was conducted in Kericho County which is located within the highlands west of the Kenyan Rift Valley. It has a population of 752,396 (2009 census) and an area of 2,111 $km^2$. Standing on the edge of the Mau Forest, Kericho has a warm and temperate climate making it an ideal location for agriculture and in particular, the large scale cultivation of tea. Kericho is home to Kenya's biggest water catchment area, the Mau Forest, with a high altitude and virtually daily rains that ranges between 1200mm and 2500mm annually (the rainfall pattern is unimodal), while the temperatures ranges between $12^{\circ c}$ and $28^{\circ c}$ and the soils are well drained and with a pH on range of (4.5-6.5). Kericho is the centre of Kenya's large tea industry, and its town square is even known as Chai square (Chai is Hindi for Tea). Some of the largest tea companies such as Unilever Kenya, James Finlay and Williamson are based here. It is also home to the popular Ketepa brand. Much of the tea is exported, with the UK being the largest market.

The study took a period of four (4) months.

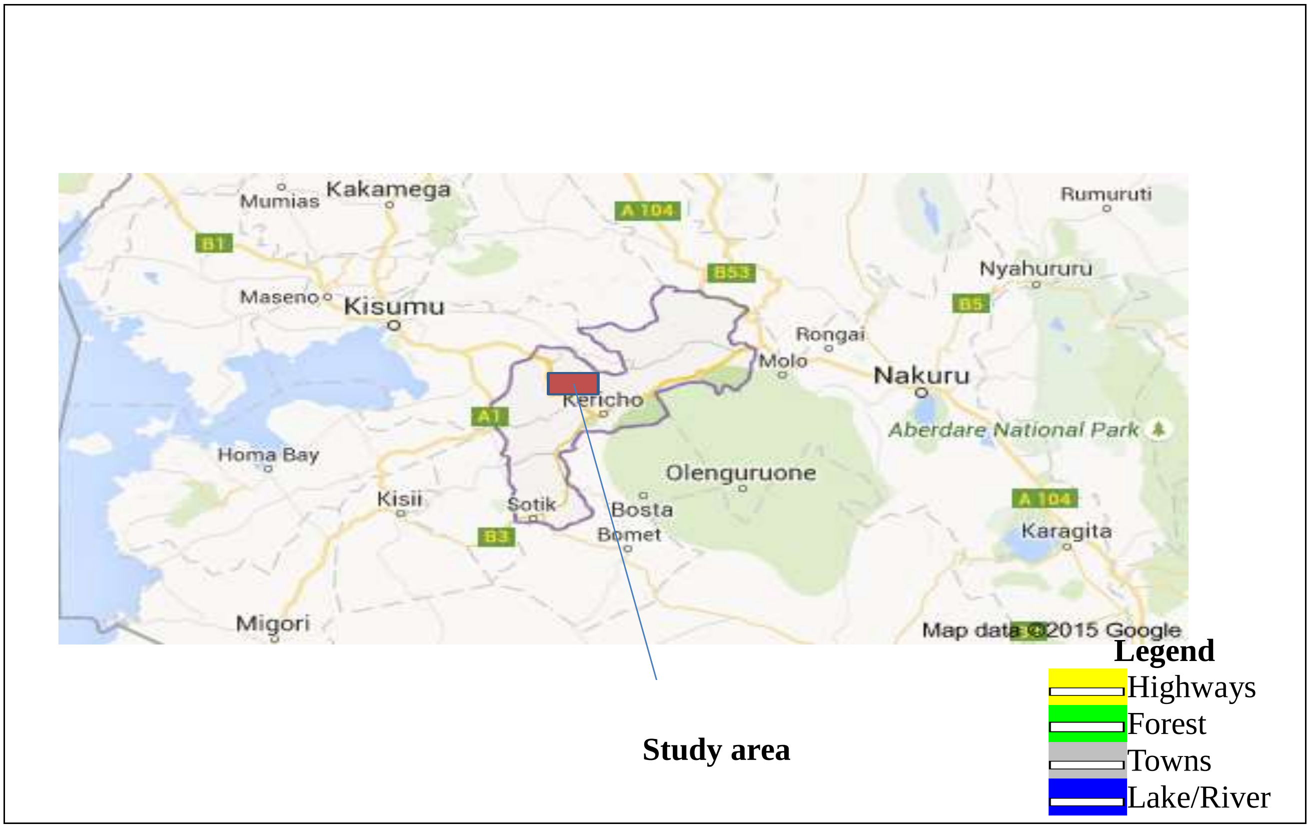



**Plate 1. 1: Map of study location**

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This chapter provides a detailed description of the extent to which purple tea farming has been established, factors that hinders adoption of purple tea farming, and the role of purple tea farming as a mitigation measure to climate change.

## 2.2 To investigate the extent to which farmers have established purple tea farming.

### 2.2.1 Availability of Land

Kenya's economy is heavily dependent on agriculture as 75% of Kenyans make their living from farming, producing both for local consumption and for export (KTDA, 2013). Though its population is high in proportion to its area, Kenya is counted among Africa countries whose food production has kept pace with its population growth.

Small holder farmers in the tea growing zone areas have devoted all their land to mainly tea production with an expectation of making an income from it. A study by Mwaura and Muku (2012) further showed that a large proportion of farmers are living below the poverty line.

They argued that the small holder farmers faced a lot of challenges and there were no returns to their production. Many farmers are skeptical of joining the sector because tea is a mono crop. Once tea is planted, a farmer may not practice mixed agriculture. This implies that growing tea does not only need a stable land tenure system, but it may have major short - run implications on food security and household incomes as a result of the long time lag – 3 years- between tea gestation period and production (Oxfam, 2002).

Lack of land for expansion is another challenge Smallholders face. On average Smallholder tea grower has 0.4 hectares of tea, typically alongside 1-1.5 hectares of maize and other subsistence crops. The land is either personal (60%) or leased by the government (40%). This piece of land yields around 1600 to 2500 kilograms of green leaf equivalent to around US$150 per year minus the cost of production .i.e. fertilizer and labour (Oxfam, 2002).

### 2.2.2 Availability of Purple Tea Seedlings

While purple tea is a first for Kenya, the country is the world's third largest producer of black tea after India and Sri Lanka. But combinations of bad weather, characterized by frequent drought and low prices, have been threatening production. Currently undergoing "stability, adaptability and uniformity" trials in TRFK's field stations and on select farms owned by small-scale growers, the purple tea is awaiting to be awarded plant breeders rights by government authorities before it can be released for commercial cultivation (TBK, 2013). The new clone, TRFK306/1, is drought and frost resistant, high-yielding and will grow in similar weather conditions as the green tea.

The purple tea seedlings are being developed by the extension of self-help groups so as to reduce on the effect of its shortage to the farmers. The groups cut across to the neighbouring Nandi County where the industry is being set. The self-help group sells green tea seedlings at KSh10 each while purple retails at KSh 30. There is demand for the new purple tea because the variety has medicinal value and processing plants buys its leaves at Sh 100 per kg (TBK, 2013).

### 2.2.3 Availability of Extension Services

Creating a sustainable yet profitable agricultural sector in Kenya has been one of the major challenges facing the country for decades. More advanced economies with much less fertile lands than Kenya have managed to feed their vast population and export the surplus. This has been made possible by investing in specialized training and education for their farmers. Since the post-independence years up to the late 90s, providing extension services or training for small-scale tea farmers had been the purview of the Ministry of Agriculture, through the then Kenya Tea Development Authority. The ministry seconded extension staff to the Authority to carry out training of tea farmers on husbandry practices.

In the early 2000s, right after privatization and faced with low farm productivity and green leaf volumes, KTDA realized that its smallholder tea farmers, despite their passion for growing the crop and application of fertilizer to their crop, lacked the requisite scientific knowledge on how to improve yields in terms of quality and quantity. Further, the tea sector was facing challenges such as climate change and reduced landholdings, which informed the need to improve yields on smaller pieces of land, while retaining the quality for which KTDA-produced tea had become renowned globally. These challenges conspired to birth the idea of KTDA's Farmer Field Schools, which is a targeted investment in farmer education (KTDA, 2010)

With support from partners such as Sustainable Trade Initiative (STI), Unilever, Rainforest Alliance and Ethical Tea Partnership (ETP), the idea behind FFS is anchored in the belief that our farmers require the best personalized education service, delivered in an easy-to-understand, yet effective manner. The pedagogy that anchors (Farmer Field Schools) FFS is unique in its bottom-up, needs-based approach, which trains large numbers of farmers at relatively low-cost, who then train others, and the knowledge chain is sustained. (KTDA, 2015)

### 2.2.4 Old Tea Gardens of Green Tea

In Kenya, most tea gardens are over 30 years old and past their most productive age. Some

1950's tea gardens are still intact. Replacements of these old gardens with new varieties could bring about considerable gains. Huque (2007) showed that mature and young bushes are more productive than old bushes and it would be advantageous if farmers were to continuously replace the old bushes. Huque observed that with adoption of young tea bushes production can be increased by 3,818kg/hectare all other things held constant.

Although, the Tea Research Foundation in Kenya has developed 45 tea varieties, farmers have not adopted them because tea as tree crop has a long gestation period (roughly 3-5 years). In addition, the cost of planting tea to maturity is huge, making it difficult for farmers to adopt new varieties. There is also a problem of information dissemination whereby many farmers may not be aware of new varieties of tea. Adoption of new varieties by farmers may be achieved if the supply chain management practices (tea seedlings, extension services etc) are adopted. Tea Research Foundation would also play a great role in encouraging farmers to adopt new varieties that are more productive.

### 2.2.5 Lack of Profitability

In Kenya the majority of agricultural products are sold abroad as raw materials. Investment opportunities for value adding activities through processing and packaging for agricultural commodities have not been exploited to increase farm incomes and off-farm employment (Kimenyi, 2002). Nyangito (2001) has noted that value adding to a crop like tea can fetch up to six times more revenue than unpacked tea. Kenyan tea is sold in semi-processed form to exporters who use it to blend lower quality tea from other countries (TBK, 2009). To ensure sustainability of the sector KTDA managed factories should diversify from production of only black tea and produce a variety of branded tea products. This will help to improve farmers' income and reduce poverty levels in tea growing areas of Kenya.

Kenya Tea Development agency managed factories should aim at being market oriented by producing tea that consumers need. The agency should conduct marketing research in order to understand market requirements. The agency has been producing semi-processed tea instead of adding value to farmers produce resulting in low prices for the farmers. An analysis of the Sri Lanka tea export market, where there is significant value addition, shows that Kenya exported more tea in volume than Sri Lanka in 2009 by 15 percent but the Sri Lanka earned 76 percent more from its exports than Kenya did (EATTA, 2010). Sri Lanka also sells 61 percent of her tea in bulk and 39 percent in value added form (EATTA, 2010). Diversifications in the industry need also to be encouraged so as to induce good prices.

### 2.2.6 Low Local Consumption

Although the inter-governmental group on tea exports consultation on tea market issues (EATT A, 2010) projected that consumption of tea in tea growing countries would grow by 2.1% per year, this may not have been realized in Kenya because generally the promotion of tea especially among the young generation is still low. Aggressive advertising, coupled with conviction messages of health and style of tea consumption is needed to ensure sustainability of small holder tea sector. In addition, production of variety of tea based products will increase total demand of tea in the country. Gesimba et al., (2005) has further noted that elimination of value added tax (VAT) on tea can promote local consumption.

### 2.2.7 Factory Inefficiencies

According to KTDA (2011), the challenges in the management of out-growers business include the ever-escalating labor costs, energy costs and operational overheads. Computerization could make a huge difference in operational efficiency. Therefore, out-grower management and tea value chain should be computerized and automated. Recent implementation of computerization at tea buying centers has started yielding fruits to farmers through greater production brought about by greater accountability and accurate records. This could further lead to reduction of operational costs, enhancing information sharing among all stakeholders (such as factory managers, farmers, regulator, and other value chain partners), and stock reconciliations.

### 2.2.8 Processing Factors

Black and green teas are the two types of tea processed in Kenya. Currently, all Kenya Tea Development Agency factories are only processing black teas. Green tea is different from black tea because fermentation of green leaves is halted in manufacturing green tea (TBK, 2011). Kenyan tea has for many years been sold in its whole form, although in recent times the tea sector has been looking at the likelihood of selling tea extracts (Tea Board of Kenya, 2011). Tea is primarily processed using the Cut, Tear and Curl (CTC) technique to guarantee maximum cuppage per unit weight.

### 2.2.9 Demographic Changes

The size and make-up of the global population is undergoing profound change, with the world's population predicted to reach 9.6 billion by 2050. According to the World Bank (2011), the next several decades will see the 'global middle class' population rise from 440 million to 1.2 billion – a rise from 7.6% of the world's population to 16.1%. And two thirds (66%) of the population in developing countries will live in the urban environment – up from 45% today.

Underlying these figures are specific regional trends. Most of the next billion people to come into the world will be born in Africa and South Asia. The African population alone is set to double reaching two billion by 2050. Most of the growth in the 'global middle class' is expected to come from countries such as India and China.

Growing populations will drive demand for food, which is predicted to increase by 50% by 2030. And this, coupled with urbanization, will put pressure on all available agricultural land. Tea will increasingly have to compete with other food crops to access land for production. Tea estates across the world are also already experiencing the impact of rural depopulation as smallholders and rural workers move to the city to seek better wages and lifestyles (GoK, 2030).

## 2.3 To identify the social and economic factors that undermines adoption of purple tea farming

### 2.3.1 Marginalization of Women in Sharing of Tea Income

One of the unique features of African agriculture is that women customarily specialize in the production of food crops (maize, bananas, beans) while men on commercial crops like tea and coffee. In addition, women do not own land. It's also important to note that in the small holder tea sector in Kenya, majority of tea pluckers are women. However, the income from tea is taken by men who are the owners of land. With the global trend toward empowerment of women it is important that this marginalization of women in sharing of income from the tea sector be reversed. This will be one way of ensuring sustainability of the small holder tea sector in Kenya since women rights are now regarded as criteria for trade in some countries. Violations of women rights might lead to denied entry of Kenyan tea in some export markets (Journal of Management and Sustainability, 2012).

### 2.3.2 Poor Workers-Employee Relationship

Although this may not be a big problem among the micro scale tea farmers since most labor is provided by family members, a number of small scale tea farmers (with more than 10 acres) do experience the challenge. This happens when these farmers cannot get laborers to pick their tea and therefore tea plants overgrow, leading to losses. In addition, tea pickers have been coalescing with the objective of agitating for higher payments. In some places the pickers have managed to force small scale farmers to pay Ksh. 8 ($ 0.1) per kilogram of green leaf plucked. It is also important to note that tea farmers are paid Ksh. 12 ($ 0.15) per kilogram of green leaf for monthly payments. This however excludes annual payments (roughly $ 0.5 per kilogram), commonly referred to as bonus.

Tea pickers' agitations for better payments have led to tea pickers and farmers having poor working relationships. Traditionally, workers agitation for higher payments has been concentrated in plantations and current developments among small holders are surprising (CPDA, 2008).

### 2.3.3 Poor Access to Information

Small holder farmers have lacked information on better tea farming methods since the tea sector was liberalized in 1990s. During the days of government control of the sector, farmers used to get extension services (including information on better tea farming practices) from the Ministry of Agriculture. After liberalization, farmers are required to pay for these services, which most are unable to pay or they are ignorant about their usefulness. As noted earlier, Tea Research Foundation of Kenya has developed 45 varieties of tea but many farmers are yet to adopt them due lack of information about their availability. According to CPDA (2008), the information flow is poor and at times lacking, especially that relating to pricing. Further, farmers at the bottom of the pyramid are the most disadvantaged, as they receive little information and their feedback hardly reaches the top; and when it gets there it is misrepresented.

### 2.3.4 Lack of Training

Small holder farmers lack general farm management practices. Study by Mwaura and Muku (2007) indicated that small scale tea farmers had diverse experience in tea farming, ranging from one year to fifty years, affecting productivity. They further noted that some tea farmers failed to use any fertilizer on their farms, while others used more than the recommended quantity of 150 kg of nitrogen per hectare per year and used 494kg of nitrogen per hectare per year. Poor supervision of tea pluckers and other farm laborers contributes significantly to high operational costs.

### 2.3.5 Safety and Health of Workers

Small holder farmers should provide tea workers with protective clothing like rain coats and gum boots. Similarly, people working in KTDA managed factories should be provided with safety and protective clothing. Their work places should also be safe and healthy. In addition, they should be provided with medical insurance cover and other types of insurance that will guarantee them safety and health security. Small holder farmers can also jointly provide their workers with insurance cover and this can be done through deductions made at KTDA. This is necessary and important as it will ensure that those working in the sector are guaranteed their safety and health. It will also ensure sustainability of the small holder tea sector in Kenya. Workers issues are human right issues which should be considered as standards that must be adhered to in global trade, (CPDA, 2008).

### 2.3.6 Low Quality Tea

Farmers in Kenya have specialized in production of bulk undifferentiated tea with focus on volume rather than quality. The Export Processing Zones Authority has noted that value addition remain the major investment opportunity for the tea sector in the country (EPZA, 2005). On the same vein, Agri-food Consulting International (2004) notes that for tea sector to be a driver of rural growth, interventions in the sector must address the means of raising quality in the value chain. This can be done by adopting improved varieties of tea. However the adoption is hindered by high costs of inputs and long gestation period of tea.

### 2.3.7 Lack of Labor and High Costs of Labor

This is a challenge to small scale farmers with over 10 acres of land whereby they may lack workers to pick their tea. Non-availability of tea pluckers has pushed the tea plucking's average kilogram payment from Ksh. 5 ($ 0.06) in 2008 to Ksh 5.50 ($0.06) in 2009 to Ksh 6.00 ($ 0.07) to Ksh. 7.00 ($0.08) in 2010 and Ksh. 8($0.09) in 2012. It is important to note that at the time of writing this paper, farmers were paid Ksh, 12 ($

0.15) per kilogram monthly by Kenya Tea Development Agency. This implies that the tea pluckers take more than half of what the farmer is paid per month. This trend of labor shortage had however been predicted by the intergovernmental group on tea export consultation on tea market issues in 2002, that despite the projected tea production expansion in Africa and Far East, there was potential labor shortage for Africa due to HIV/AIDs pandemic and Rural-Urban migration (Thomas Jefferson, 2002).

Other reasons contributing to labor shortage in tea growing areas are rural urban migration and young people negative perception towards employment in agricultural sector. To ensure sustainability in availability of labor the government needs to improve the general conditions in rural areas by providing social amenities, improving roads and communications infrastructure, and providing electricity among many others. It is also important to emphasize the importance of agriculture in economic development right from the time the child enters primary school.

### 2.3.8 High Costs of Inputs and other Operational Costs

The cost of fertilizer, the major input, is very high making the cost of production enormous. In 2009, the average price of 50 kilogram bag of fertilizer was Ksh. 1836 (USD 23) compared to Ksh. 1296 (USD 17) in 2007. The other operational costs are the costs of weeding, pruning and plucking. According to CPDA (2008) the cost of tea production in Kenya is USD 1.33 per Kg, and this compares poorly with other countries such as Vietnam (USD 0.81 per Kg) as well as its neighbours in East Africa community; Rwanda (USD 1.32 per Kg, Uganda (USD 1.20per Kg) and Tanzania (USD 1.16 per Kg).

### 2.3.9 Tea Hawking

According to Kegonde (2005), the tea sector in Kenya face challenges of tea hawking practices that are widespread in the West of Rift Valley tea growing region. This happens among the small scale farmers who prefer to sell their green leaves for immediate payment than wait for the monthly payment. This practice may be attributed to high poverty levels. The problem with tea hawking is that the farmer only gets the farm gate payment which is usually very low and misses out on the annual payment commonly called “bonus” that is usually high in price per kilogram. In Kenya, tea hawking is illegal because it leads to exploitation of the small holder farmer by the middlemen who normally buy tea leaves from farmers at very low prices and later resell the produce to large multinational tea firms. To ensure sustainability of small holder tea sector tea hawking should remain illegal and outlawed. Small holder tea should continue selling their tea through KTDA as this helps farmers to achieve enormous economies of scale leading to high farmers’ incomes.

#### 2.3.10 Tea Brokers

Tea brokers facilitate the sale of tea on the behalf of producers. There are 12 registered companies who operate as Tea brokers at Mombasa Tea Auction. To apply to EATTA, they are required to have good financial standing. They are required to provide bank guarantees as security to tea placed for sale. In addition, they are required to be independent and impartial. Their primary functions are: tasting tea for the purpose of quality verification; determining the best price for respective qualities of tea; liaising with warehouses to ensure that tea is received, handled and stored in a professional manner; and addressing concerns from buyers as to quality and quantity of tea purchased (East Africa Tea Trade Association, 2010).

### 2.4 To determine the role of purple tea variety as a mitigation measure to climate change.

#### 2.4.1 Ecological Conditions for Tea Growth

Kenya's tea growing regions endowed with ideal climate; tropical, volcanic red soils; well distributed rainfall ranging between 1200 mm to 1400 mm per annum; long sunny days are some of the climatic features of the Tea growing regions. Vegetative propagation of high-yielding, well-adapted clones are the major factors that new varieties are based on (TRFK, 2013). Chemicals are used rarely and fertilizers are regularly added to replenish soil nutrients.

The main tea growing areas in Kenya are situated in and around the highland areas on both sides of the Great Rift Valley; and astride the Equator within altitudes of between 1500 meters and 2700 meters above the sea level. These regions include the areas around Mt. Kenya, the Aberdares, and the Nyambene hills in the Central Kenya and the Mau escarpment, Kericho Highlands, Nandi and Kisii Highlands and the Cherangani Hills (TBK, 2011).

### 2.4.2 Health Enhancement of Purple Tea

According to (Kamunya, 2015). In terms of value addition, one must come up with something that has multiple benefits to the user and this is what we prioritized on when we carry out research on this purple tea clone. The variety has the best quality tea seed oil, equivalent to the popular olive oil used for cooking and for medicinal purposes.

The purple tea contains anthocyanins which are responsible for the purple colour and which have immense health enhancing properties. Past research on the Anthocyanin pigments, which are also available in some vegetables, fruits, olive oil, some cereals, and even honey, shows that they have the ability to strengthen body cells, decrease capillary impermeability and fragility among other functions (Pradip Baruah, 2014). Rich in anthocyanins and with a lower concentration of catechins and caffeine, Purple tea's high Antioxidant effects "Provide anti-cancer benefits, improves vision, cholesterol levels and blood sugar metabolism." Generally, purple tea is deemed to have lots of medicinal properties (Pradip Baruah, 2014).

Anthocyanin supplements (proanthocyanin) are widely marketed for their health enhancing properties. They are also widely used as preservatives especially in the food industry. The new tea variety which is rich in anthocyanins can be an alternative source of raw material from which these flaronoids can be extracted.

Oryza Oil & Fat Chemical Co., Ltd. (2014), discovered a specific polyphenol compound, Functional compound specifically found in Purple Tea Extract. (1,2-di-Galloyl-4,6-Hexahydroxydiphenoyl-β-D-Glucose) (GHG) which is not found in green tea, oolong tea and black tea. GHG has been shown to demonstrate excellent anti-obesity and anti-ageing effects.

### 2.4.3 Adaptation to Global Warming

Adaptation is a response to global warming that seeks to reduce the vulnerability of social and biological systems to current climate change and thus offset the effects of global warming. Adaptive capacity is closely linked to social and economic development (IPCC, 2007). The economic costs of adaptation to climate change are likely to cost billions of dollars annually for the next several decades, though the amount of money needed is unknown. Donor countries promised an annual $100 billion by 2020 through the Green Climate Fund for developing countries to adapt to climate change. However, while the fund was set up during COP16 in Cancún, concrete pledges by developed countries have not been forthcoming. The adaptation challenge grows with the magnitude and the rate of climate change.

Another policy response to climate change is climate change mitigation (Verbruggen, 2007) is to reduce greenhouse gas (GHG) emissions and/or enhance the removal of these gases from the atmosphere (through carbon sinks). In a literature assessment, Klein *et al.*, (2007) assessed options for adaptation. Klein *et al.*, (2007) reported that in the absence of mitigation efforts, the effects of climate change would reach such a magnitude as to make adaptation impossible for some natural ecosystems. For human systems, the economic and social costs of unmitigated climate change would be very high.

### 2.4.4 Sustainability

Sustainability is a broad concept, sometimes also considered ambiguous because it means different things to different people, at different periods of time. Nevertheless, the sustainability concept was almost ignored until the end of 80's, when the Brundtland Report was published by the World Commission on Environment and Development. This report describes sustainable development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" However, the definition proposed in the Brundtland report does not articulate the concept of "needs" and the mechanisms for achieving a sustainable society. Indeed, after the publication of this report, numerous definitions of sustainability have been suggested, yet none have been universally accepted, contributing to make this concept more misunderstanding (WCED, 1987).

One of the most consolidated concepts in sustainability is the needing of the three pillars of economy, society and environment simultaneously. As a consequence a lot of definitions start with this concept; e.g. the most accepted definition of sustainable agriculture can be summarized as follows: "To be sustainable, a farm must produce adequate yields of high quality, be profitable, protect the environment, conserve resources and be socially responsible in the long term (WCED, 1987).

### 2.4.5 Carbon Sequestration

Atmospheric greenhouse gases released through agricultural processes (e.g., tillage, harvesting, and rotation) are generally accepted to be one of the primary contributors to global warming. An important anthropogenic driver of greenhouse gas emissions takes place during agricultural activity with regards to managerial practices that influence and modify regional carbon storage (West and Marland, 2002). In spite of this fact little interest has been sparked among carbon balance researchers with respect to crop plantation carbon storage while forest systems (Houghton, 2005; Chapin *et al.,* 2009) and timber plantations have been extensively studied due to the belief that they hold considerable influence over the global carbon cycle.

Tea (*Camellia sinensis*) is an intensively managed perennial evergreen broad-leaved cash crop. It is one of three common beverages (coffee, tea, and cocoa) consumed worldwide. As a result, tea plantation area covers approximately three million hectares of the world's arable land (FAO, 2007). Most of these plantations have expropriated large areas originally occupied by forests, and they are continuing to expand. Unlike the intensively studied Carbon dioxide storage dynamics of forest systems, data on tea plantation Carbon dioxide storage is scarce (Kamau *et al*., 2008). Published literature related specifically to research on tea plantation Carbon dioxide is limited solely to soil organic matter (SOM), most of which is only concerned with increasing production or improving tea quality (Dang, 2005; Han *et al*., 2007; Zhang *et al*., 2007). Other studies have been carried out on soil erosion (Othieno, 1975; Hartemink, 2006) and a few studies exist in connection to the Carbon dioxide of tea plants (Kamau *et al*., 2008). Although tea production today is the principal function for the establishment of tea plantations, its relative long rotational life cycle from 40 years to 90 years (Yang, 2005; Han *et al*., 2007) may represent a potential to sequester and store large amounts of Carbon dioxide.

### 2.4.6 Impacts of Climate Variability and Change on Tea

The release of greenhouse gas emissions is causing the Earth to get warmer. Warmer temperatures are causing other major changes around the world because temperature is interrelated to the Earth's global climatic systems. Impacts include a rise in weather related incidents such as floods, droughts, frosts, hailstones and destructive storms; the extinction of countless plant and animal species; the loss of agricultural harvests in vulnerable areas; the changing of growing seasons; the melting of glaciers; the disruption of water supplies; the expansion of infectious tropical diseases; the rising of sea levels and much more. One of the sectors most affected by climate change is the agricultural sector as it is dependent on environmental stability in terms of water supply, atmospheric temperatures, soil fertility and the incidents of pests and disease (Ochola, 2009). Furthermore, the most vulnerable to the expected impacts of climate change are developing countries and their citizens who have a lower resilience to climate change impacts due to limited financial and technical resources to support adaptation. Smallholder tea farmers in rural areas, such as the tea farmers in Kenya, will be especially hard hit unless action is taken now to ensure they are aware of the impacts of climate change and are supported to address these impacts using locally appropriate solutions (IPCC, 2007). Increasing temperatures are also likely to affect the growing of major crops such as tea in the country (Otto, 1999).

### 2.4.7 Effects of Drought on Tea

Drought is a major climatic change effect/factor and a challenge facing tea industry in Kenya. Like most other agricultural crops, small holder tea depends on rain fed agriculture. In times of drought production drops by very huge margins causing a lot of misery especially to small holder farmers. For instance, droughts in the years 1997 and 2000 forced production to slip by about 15 percent (Uniliver, 2000). The drought of the year 2000 was even worse whereby tea farms were badly scorched. In 2006, Unilever Tea Company which controls the largest plantations in Kenya, temporarily closed three of its eight factories and run the others at a reduced capacity because of reduced output as a result of drought (Uniliver, 2000).

### 2.4.8 Tea and Water Resource

Kenya is classified as a chronically water-scarce country and has one of the world's lowest water replenishment rates per capita (World Bank, 2009). The combined effect of rising temperatures, more frequent droughts and decreasing rainfall has led to lowering river, lake and groundwater levels. For instance, the water level in Lake Naivasha has varied by about 12 meters in the last century (Becht, 2007). The country has also witnessed disappearance of some seasonal rivers and falling levels of permanent rivers. Development and implementation of mechanisms that help communities and individuals to mitigate and adapt to climate change vulnerabilities should therefore be intensified (Charles *et al.*, 2010; GoK, 2010). The establishment of Purple Tea farming will increase the vegetation land cover acting like carbon sinks and improving the water replenishment capacity. Hence, increasing the water levels in neighboring streams, rivers and lakes.

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1. Study Design

The study used both qualitative and quantitative research methods (Creswell and Plano-Clark, 2007).

## 3.2 Sampling Techniques

**Table 3.1: Sampling Techniques and Units of the Study**

| Sampling Techniques | Sampling Units |
|---|---|
| Purposive | Tea Research Foundation of Kenya<br>Extension officers<br>Tea Companies |
| Systematic | Tea Zones |
| Stratified | Tea Varieties |
| Random | Tea Farmers |

## 3.3 Target population and response rate of the sample size

The study targeted the relevant personnel's from the Tea factories in Kericho County; TRFK and county ministry of Agriculture. Therefore, the total population was three hundred and sixteen (316) respondents that served with the researcher relevant information on the scope of the study.

### 3.3.1 Sample Size Determination

The required sample size was determined by Cochran's proportionate to size sampling methodology (Cochran, 2006).

$$n = (z)2\,\frac{p(1-p)}{e2}$$

Where; n=sample size; Z=confidence level (α=0.05); p=proportion of the population containing the major interest; q=1-p and e=allowable error. Hence, Z=1.96

$$n = (1.96)2\,\frac{(1-5232/60000)}{(0.05)2}$$

$$n = 1{,}402$$

The sample size ($n_o$) can thus be adjusted using the corrected formulae.

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

Where n is the sample size
N is the population size.
$n_0$ is calculated sample size for infinite population

$$n = 1402/\,1 + (1402 - 1)/5232$$

$n$ = 1,105

From the table above, the Calculated population (n= 1,105) and the Tabulated sample size was 291 at 95% confidence level.

Therefore, the sample size of the farmers randomly drawn from the study area was 291 in total.

Hence, total target population was 316.

**Table 3.2: Target Population of the Study**

| Category | Target Population |
| --- | --- |
| Tea Factories in Kericho County (6) | 18 |
| Tea Research Foundation Of Kenya (TRFK) | 4 |
| Ministry of Agriculture – County Government of Kericho | 2 |
| Tea Farmers | 291 |
| Carbon Sequestration and growth rate | 1 (Zone with same conditions) |
| **Total** | **316** |

### 3.3.2 Response Rate of the Target Population.

Equally, small margins of error are desirable and frequently a precision of $\pm 10\%$ is used to determine reliability of sample size. Hence, 206 respondents participated in the study which represented 65.18% of the target population.

**Table 3.3: Response Rate of the Target Population of the Study**

| Category | Response Rate |
| --- | --- |
| Tea factories (6) | 24 |
| Tea Research Foundation of Kenya | 6 |
| Extension officers | 2 |
| Tea farmers | 174 |
| **Total** | **206** |

### 3.4 Data Collection

The study employed questionnaires, interview schedule, field observation/photography and review of documents. The instruments that were used for data collection are explained below:

#### 3.4.1 Document review

Document review was used to collect data on the background of the socio-economic, ecological and technical aspects that hinders adoption of purple tea farming. This included recording information obtained from existing literature, secondary data obtained from publication and official documents from various relevant sources pertaining the objective of the study.

#### 3.4.2 Questionnaire administration

Questionnaires were used to determine the socio-economic factors that affects the adoption of purple tea variety. The open-ended questionnaires were administered to farmers from the various locations of the study area as per Appendix $A_{20}$.

#### 3.4.3 Interview schedule

The researcher also used an interview schedule which involved use of specific guiding questions to be discussed. This qualitative in-depth technique (semi-structured interview) was used on selected key informant for important information. This group included; TRFK, County government officers from ministry of Agriculture in Kericho County. The technique was ideal for this group of respondents since it provided exhaustive and appropriate information about their own viewpoints. Furthermore, the interview schedule enabled the researcher to verify and guide the kind of information necessary for the study from the respondents (Bernard, 2006).

**3.4.4 Observation and photographic approach**

During observation different photographs were taken to portray and visually represent the current situation in fields that have established Purple and Green Tea Varieties.

**3.4.5 Determining carbon sequestration as a mitigation measure to climate change**

The researcher identified the species of purple and green variety and DBH of all tea within the TRFK plot. The measurements were taken based on the height and age of the sample varieties of each species within the plot. The following equation was used to analyze the collected data and generate the results.

Where (W = Above-ground weight of the tree in pounds, D = Diameter of the trunk in inches, H = Height of the tree in feet)

For trees with D < 11: W = 0.25D2H

For trees with D >= 11: W = 0.15D2H

The total mass of:

C = 12, O = (16)2 = 32

Therefore, the total ratio of C from $CO_2$;

$$C\ ratio = \frac{C+O2}{C}$$

Hence, C sequestered will be;

$$C\ Seq. = \frac{(W=0.25(D)2H)}{C\ ratio}$$

**3.4.6 Determining relative growth rate**

Growth rate algorithm was used to determine the Relative Growth Rate of purple tea as compared to RGR of green tea Poorter and Garnier (2007). And the factors that were studied were rainfall patterns and temperatures of specific period of time for the years 2014 and 2015.

The RGR was also determined under various stages of the tea which was stipulated in number of years.

$$RGR = \frac{L2 - L1}{t2 - t1}$$ Where L*i* is the length of the plant at time (day) t*i*

**3.5 Data Analysis**

This study used the quantitative and qualitative statistical methods to analysis the collected data. The most common analysis of qualitative data is observer impression. That is, expert or bystander observers examine the data, interpret it via forming an impression and report their impression in a structured and sometimes quantitative form. Qualitative data gathered from focused groups and interview guide and open-ended questions was analyzed using qualitative methods which involved establishing the categories and themes, patterns and conclusions in line with the study objectives and using them to answer the study objectives (Gray, 2004). Since the questionnaires used had several closed ended questions with appropriate rating scales then, Microsoft Excel Package and Statistical Package for Social Sciences (SPSS) was used to analyze all the quantitative data collected.

The study also used the *Cochran* variant of the *t-test* to analyze the collected data. It's reliable when the standard deviations of the independent sets (purple & green tea) differ significantly.

$$t_{cal} = \frac{\left|\overline{x_1} - \overline{x_2}\right|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

To determine an alternative critical *t*-value

$$t_{tab} = \frac{t_1 \frac{s_1^2}{n_1} + t_2 \frac{s_2^2}{n_2}}{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

Frequencies, means and percentages were generated for all quantitative data, and results presented using frequency tables, bar graphs, line and pie charts to discuss data and information on various issues addressed by the study objectives. *t-test* was used to test the study.

## CHAPTER FOUR

## RESULTS AND DISCUSSION

### 4.1 Results

This chapter contains detailed analysis of collected data from the small holder farmers for both green and purple tea varieties, TRFK, Factories, Extension and outreach and the measurement parameters. The results are presented in form of tables, graphs and charts where applicable. Critical inferential data analysis and discussions are depicted where appropriate.

### 4.2 Bio Data of Respondents

#### 4.2.1 Age of respondents

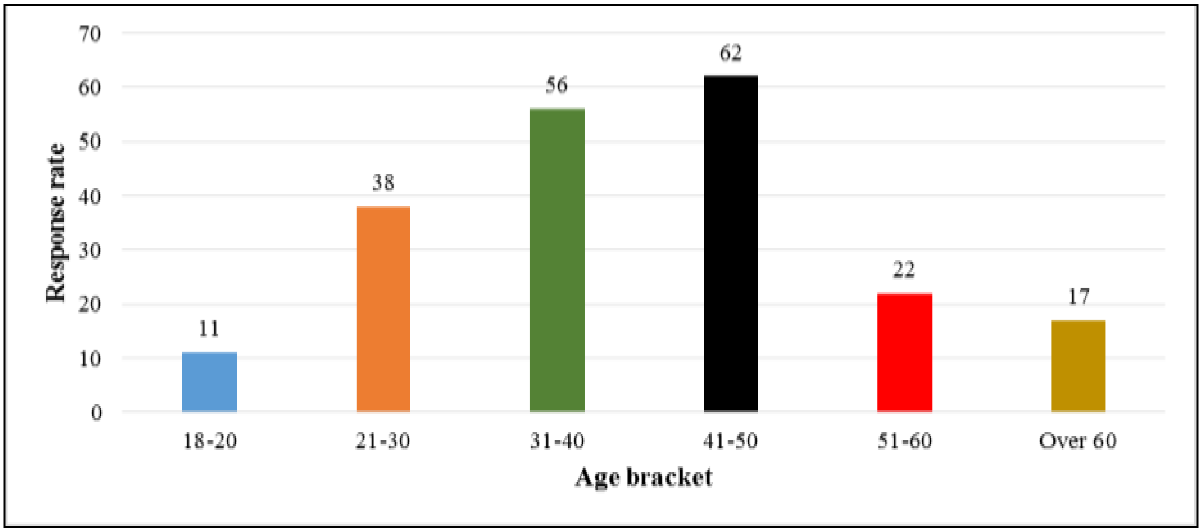



**Figure 4.1: Age of the respondents**

From figure 4.1, the highest number of respondents was from the age bracket (41-50 years) with (62) respondents and followed closely by (31-40 years) with (56) respondents. This was the highest since, they are at the active stage at all levels that include; social, economic and environmental factors that forms the basis of the study. They form the part of the vital labour both at establishment, production, and manufacturing level.

The respondents from the age bracket (21-30 years) and (51-60 years) were slightly low with 38 and 22 respondents respectively. This was due to the insufficient interest to the socio-economic and environmental aspects and the insufficient knowledge on environmental matters respectively for the changing climatic conditions.

The category with the least respondents was (18-20 years) and (Over 60). The respondents among the two categories were basically referred to as non-active in determining the mechanisms that can be able to promote socio-economic and environmental aspects in tea sector.

### 4.2.2 Level of Education

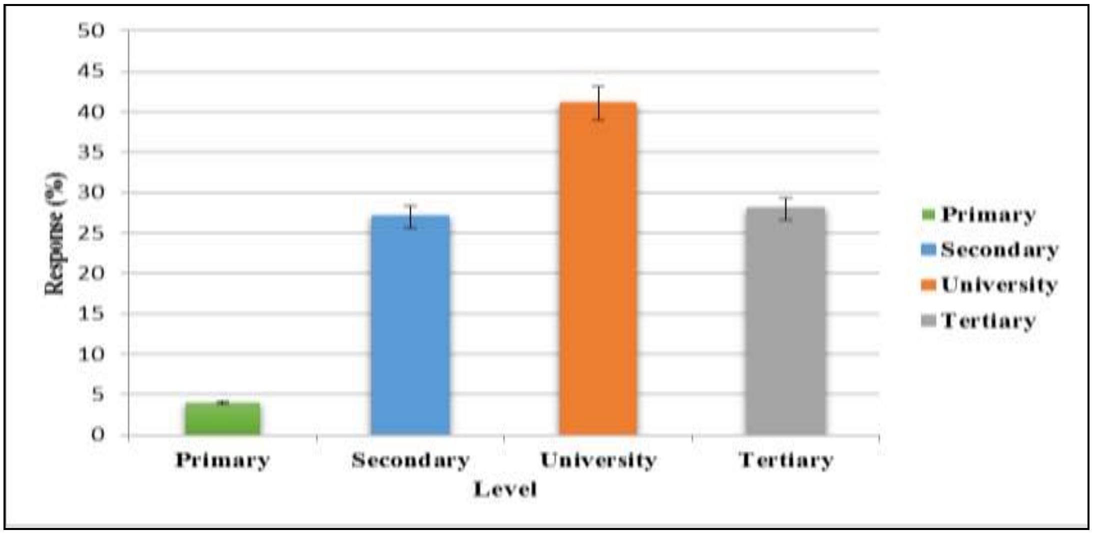



**Figure 4.2: Level of education of respondents**

From the figure 4.2, it was evident that (41%) of the respondents were from university level of education. This group understands both environmental and socio-economic factors that the study intends to identify and make feasible resolutions that will improve the establishment of the purple variety. They are found in all the level of cycles that cuts across the research to the marketing end. (28%) that represent the tertiary was the second highest level in terms of the respondents. In this category, most of the respondents were largely drawn from the high level of management both in the farms/plantations, research, processing, transportation and marketing.

The secondary level of education (27%), respondents from this category were basically forming the labour force at low cadre of management with either permanent forms of contract or temporal. But, they are the ones that ensure that the production cycle is complete and operational at all seasons. Primary level level of education (4%), was the lowest in respondent’s participation, since they possess insufficient basic knowledge and skills of the sector. They form the part of the daily casual labour that is irregular in form.

### 4.2.3 Land Ownership

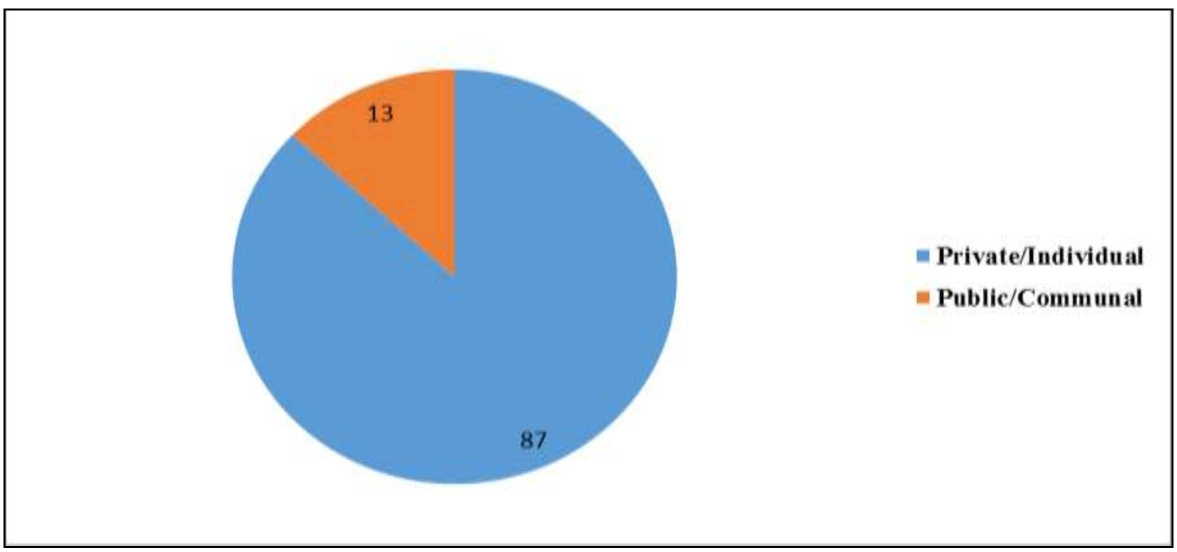



**Figure 4.3: Level of land ownership between private and public**

The study only established two forms of land ownership that includes; private and public land. The highest response on the land ownership was the private 87% since there exist the form of inheritance that is a common form of land ownership in most of the African setting. The least was public 13% whereby ownership is through leasing.

## 4.4 The Extent of Purple Tea Establishment

### 4.4.1 Availability of Land

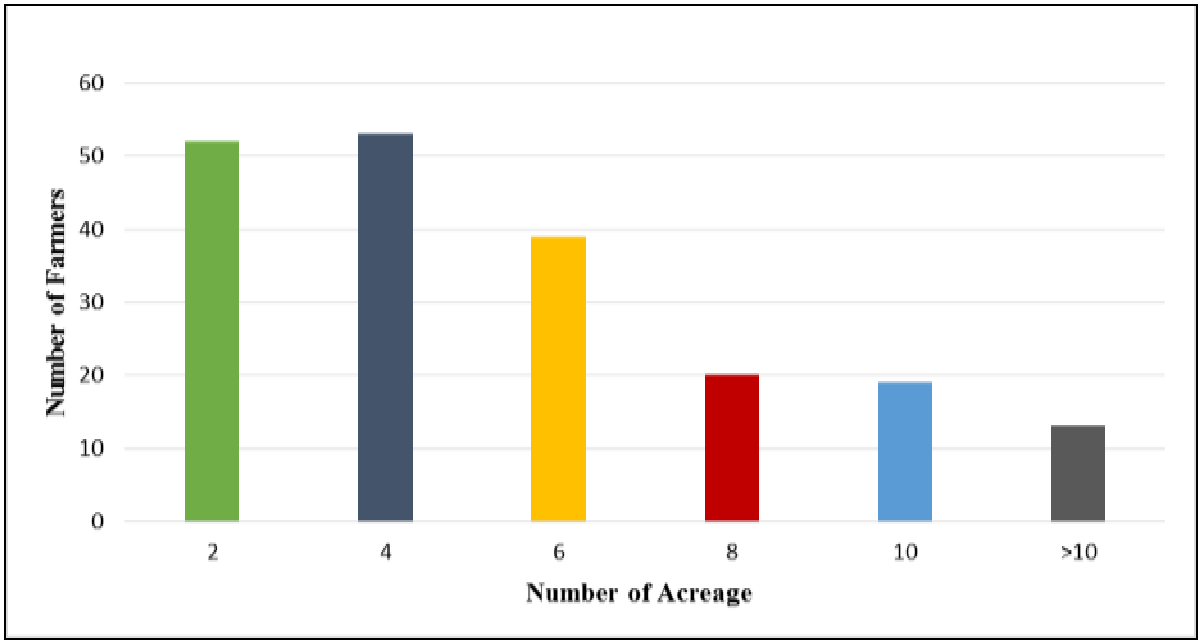



**Figure 4.4: Number of famers per acreage**

The study indicated that, there was a significant difference in all levels of farmers land ownership. The category with the highest number of farmers is 2 acres with 52 farmers followed by 4 with 53 farmers and slightly 6 with 39 farmers. The second category represented lowest number of famers as afar as land ownership is concerned. 8 acres had 20 farmers, 10 had 19 farmers and finally above 10 acres had 13 farmer s of the studied population.

The above indications was determined as a result in determining the possibility of farmers shifting from the old variety to new variety of purple tea. This indicated that availability of land was a major setback by farmers adopting the new variety with most famers owning less than 6 acres of land that indicates 82.6% while few famers had acres above 6 that indicates 17.4%.

### 4.4.2: Replacement analysis in Changoi Area

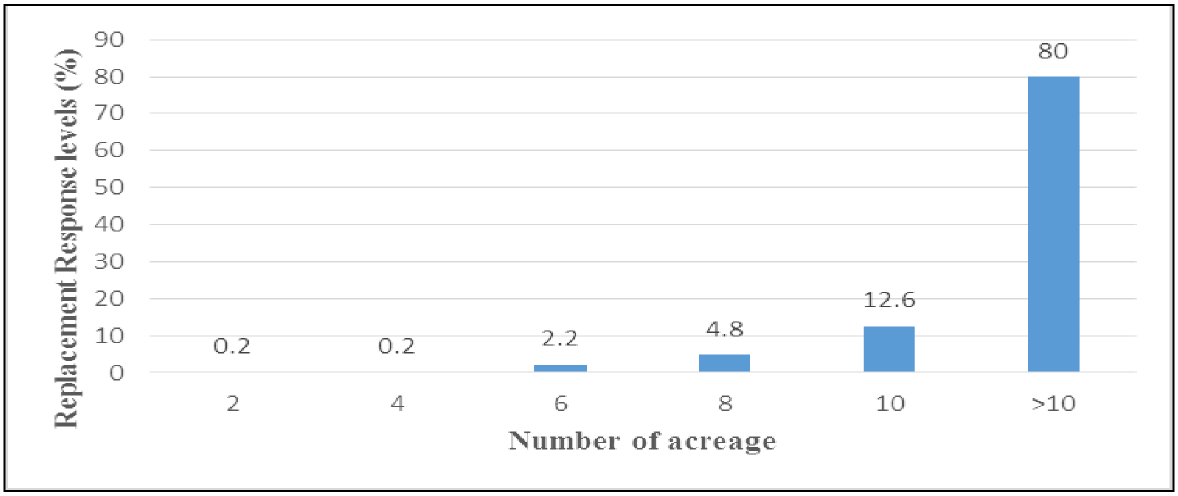



**Figure 4.5: Replacement of old green tea gardens with purple tea variety.**

From the above figure 4.5, replacement of new varieties and clones can only happen in large tracks of land and medium size lands. Thus, smallholder farmers cannot take a risk of replacing the old varieties with new ones or getting some land elsewhere due to their economic constraints. 80% which depicts farmers with more than 10 acres of land are replacing some portions of their land with new variety and clones. This is because they will benefit from the already established variety as they await the maturity of the new ones. Their economic capabilities will not be affected greatly as opposed to farmers with less than 10 acres.

12.6% showed a likely attempt to replace the old gardens with the new varieties since their land can be partitioned to contain both old and new varieties. 4.8% and 2.2% also showed slight attempt to consider replacement of old tea gardens. Farmers with 2 and 4 acres had a response level of 0.2% which showed a minimal attempt to replace old tea varieties with new one due to their small size of the land. They stated that if replacement can happen, they will have to wait for longer gestation period of tea plants without benefiting from the bonuses and daily production rates.

**Plate 4.1: Field of Purple Tea in Tegat factory farm**

The above plate 4.1 shows that purple tea established is spontaneously improving and is targeting to compete with the green tea variety. The improvement was noted to be due to the accessibility of the tea seedlings that cost (Ksh.10) the same as green tea variety; knowledge by the small scale farmers through various channels that includes; farmer field schools (FFS), annual technical reports by the leading research organization (TRFK), and journals on tea sector.

According to TRFK Report, 2013. The widespread establishment was majorly triggered by the national and international market price which was triple the price of green variety ($3.286). The variety also possess the anthocyanin components which has many medicinal properties that particularly known to be beneficial against cardiovascular diseases. It also have high antioxidant effects that provide anticancer benefits, improves vision, reduce cholesterol and blood sugar metabolism, it has low caffeine content, has strong sweet flavor and taste that can be brewed at different temperatures Kamunya (2015).

The purple tea variety was touted to be beneficial to skin care. Its extracts was identified to be beneficial in good digestion and fast metabolism leading to weight loss, anti-ageing, oxygenation of skin due to presence of free radical scavengers and useful as a hair and scalp tonic to aid in hair loss prevention Kamunya (2015).

### 4.4.3 Availability of Extension Services

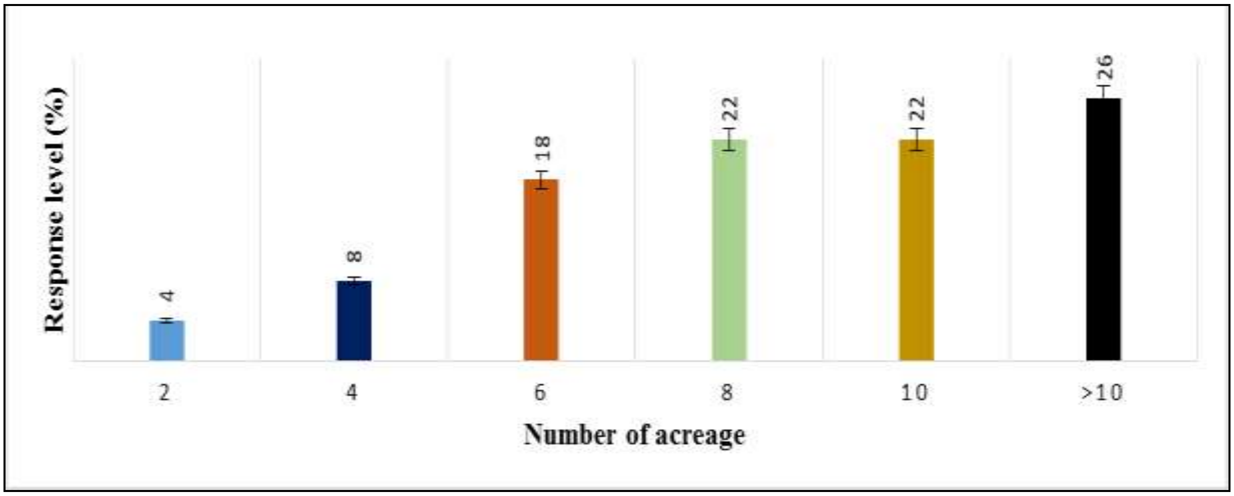



**Figure 4.6: Availability of extension services.**

The availability of extension services was determined by the number of acreage owned by the smallholder farmers. The results depict that, extension officers were concentrating to farmers that own large tracts of land. It's evident that, farmers with more than 10 acres got a huge share of the extension services at 26% followed by 22% for both farmers owning 8 and 10 acres respectively.  Farmers with 6 acres are slightly considered at 18 % since they are close to those with above 8 acres in terms of economic and social perspectives.

The lower cadre comprising of 2 and 4 in terms of acreage respectively are not easily considered since they are perceived usually not to be adhering to the directives given by the extension officers. The response level according to their views was 4% and 8% respectively. This indicates that the economic capabilities favor's the extension services since, farmers holding sizeable tracks of land adhere to their directives which in turn motivates and promotes their services.

### 4.4.4 Production Analysis across the Varieties

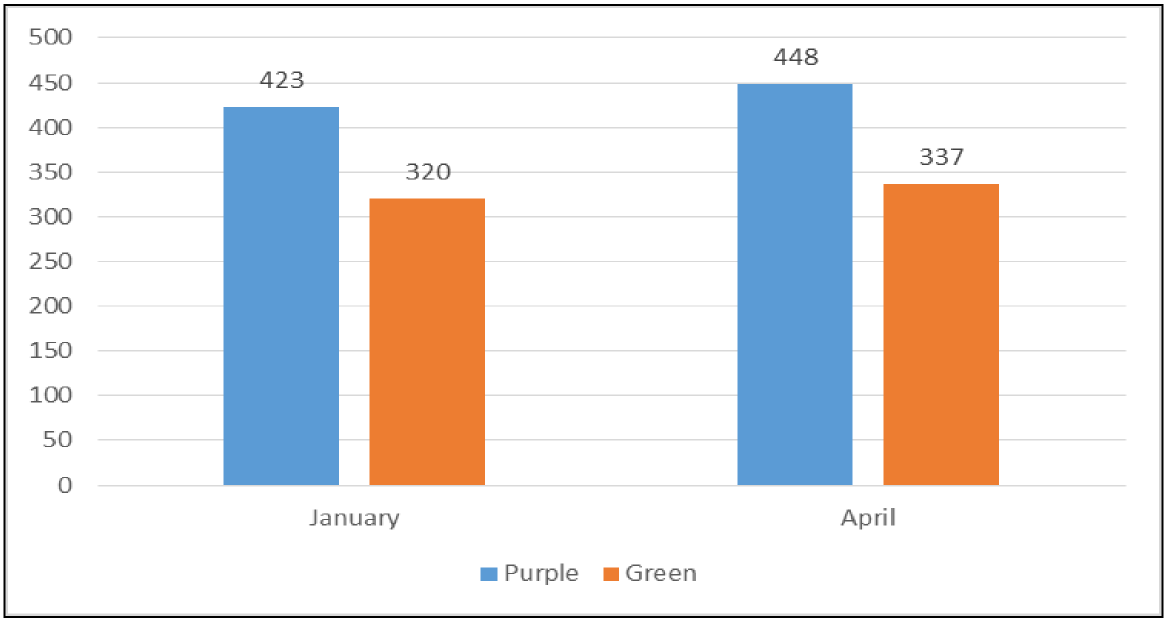



**Figure 4.7: Production analysis across the Varieties.**

There was no significant difference for production of the two varieties between the two months. The t-test shows, $t_{cal}$=0.14 < $t_{tab}$=2.92 at 95% confidence level. The mean calculated for between the varieties was greater 53.5% than the mean calculated for between the seasons which was 10.5%. This clearly shows that, seasons and varieties have a positive impact for productivity. The wet season was considered in April and dry season considered in January. The purple variety had high mean value during wet and dry seasons at 448 kgs and 423 kgs respectively. While the green variety had the least mean value at 337 kgs and 320 kgs respectively. Thus, purple variety was preferred than green variety for any new establishment or replacement.

### 4.4.5 Production Analysis for Selected Clones of Purple Variety

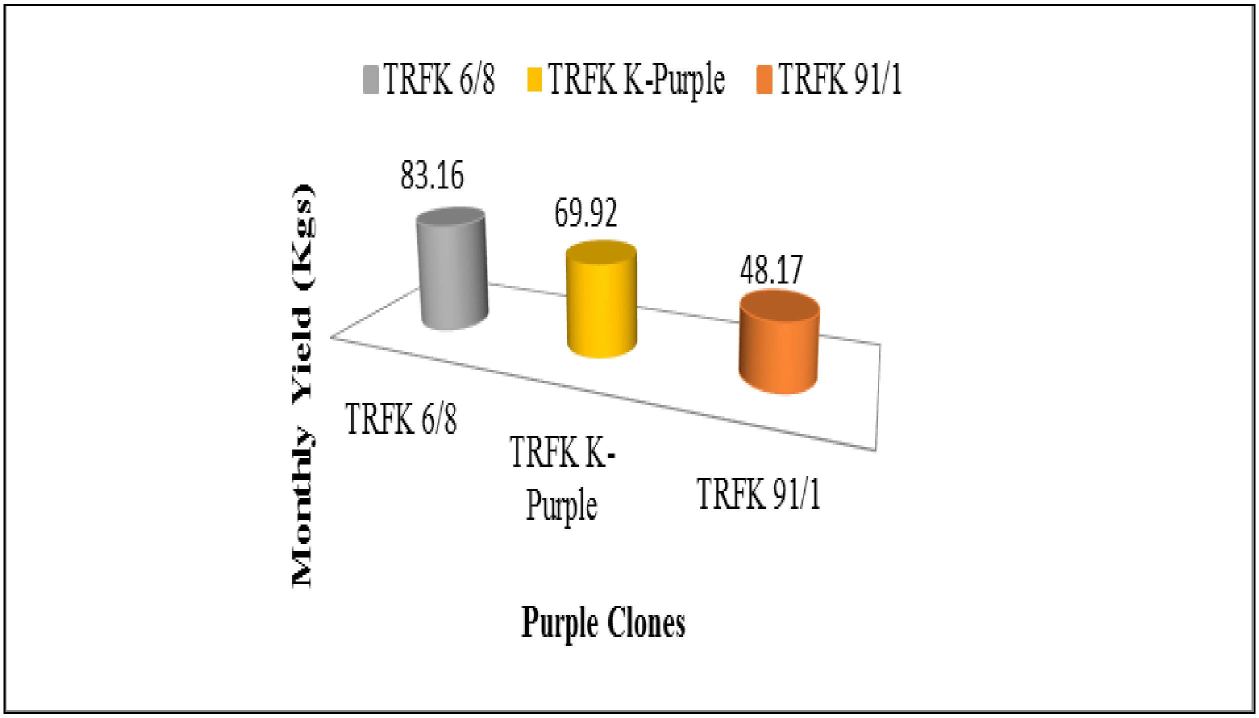



**Figure 4.8: Production analysis for selected clones.**

The *t*-calculated for the selected clones was 17.61 which was greater than the *t* tabulated at 95% confidence level. The results showed that there was a significance difference between the monthly yields of the three clones. Whereby, TRFK 6/8 recorded the highest yield of (83.16 Kgs) followed by TRFK K-Purple (69.92 Kgs) and the least was TRFK 91/1 with (48.17 Kgs).

The results shows that, clonal improvement is needed to determine a complete and more productive clone as far as Purple Tea variety is concerned in order to boost productivity across the seasons.4.5 Socio-economic factors that affects Adoption of Purple Tea Farming.

### 4.5.1 Profitability

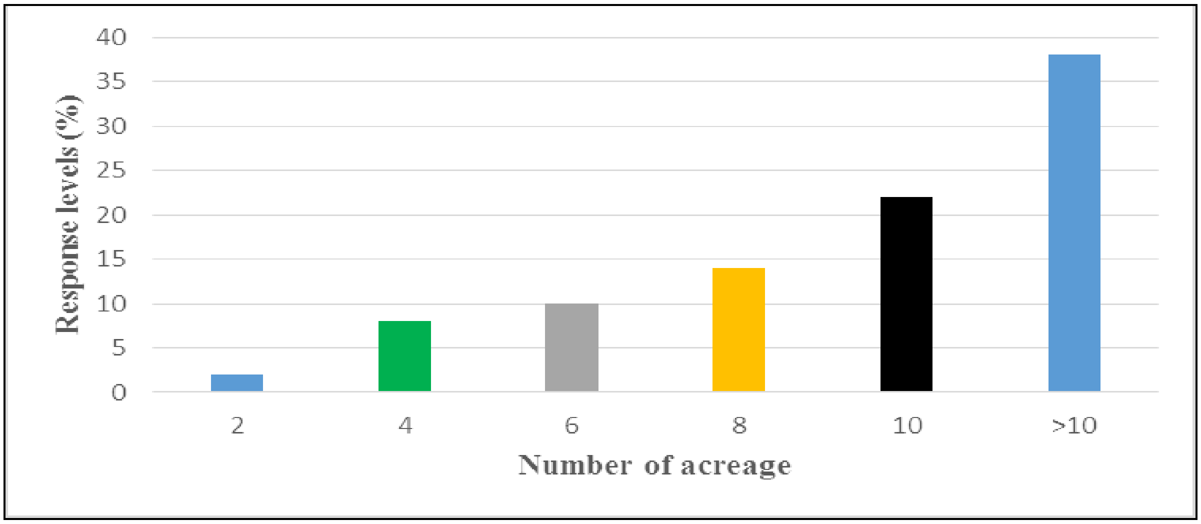



**Figure 4.9 Profitability according to acreage.**

Profitability was determined according to acreage productivity. The response level towards profitability for farmers with 2 acres of land was 2% which indicated that their production is least for profitability determination. There was a slight improved response at 10% for farmers with 4 acres of land which showed that profitability was least felt. Farmers with between 6 and 8 acres responded at 14% each which showed that the value addition was recognized for those farmers with more than 5 acres of land. 10 and more than 10 acres of land depicts 22% and 38% respectively which was more than the rest. The results showed that, profitability is easily identified and determine where there was large ownership of land as opposed to the least ownership of land.

### 4.5.2 Product Diversification Attributes for Purple Tea Variety

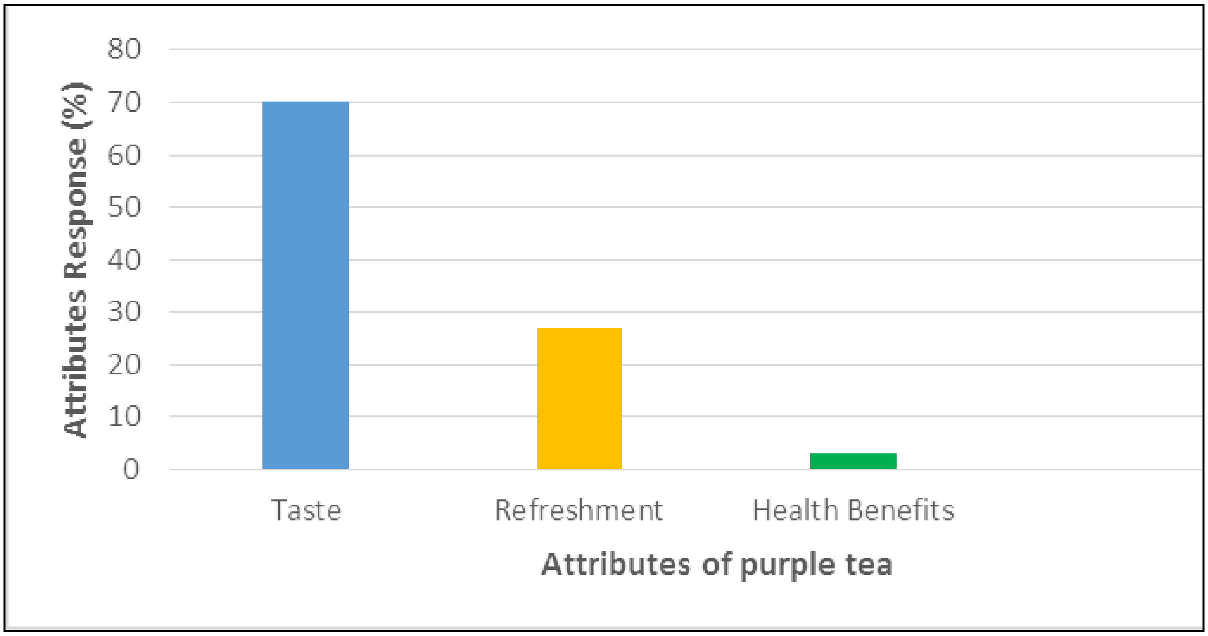



**Figure 4.10: Product diversification attributes for purple tea variety.**

From the above Fig. 4.10, the results showed that there is a significance difference between the three identified attributes that determines the product diversification of Purple tea. Taste in all the attributes was the highest at 70% followed by refreshment at 27% and health benefits at 3%. The attributes were drawn according to the primary use of the tea plants by the locals. It indicates that, the major factors that a market, production and consumers focuses on are the taste, refreshment and health benefits respectively. The tea plant contains a number of essential chemical compounds that includes; polyphenols, catechins, gallic acid, and caffeine that makes it to attain the three attribute that determines its product diversification and local consumption (Kamunya, 2015).

### 4.5.3 Factory Inefficiencies in terms of cost of Processing Tea

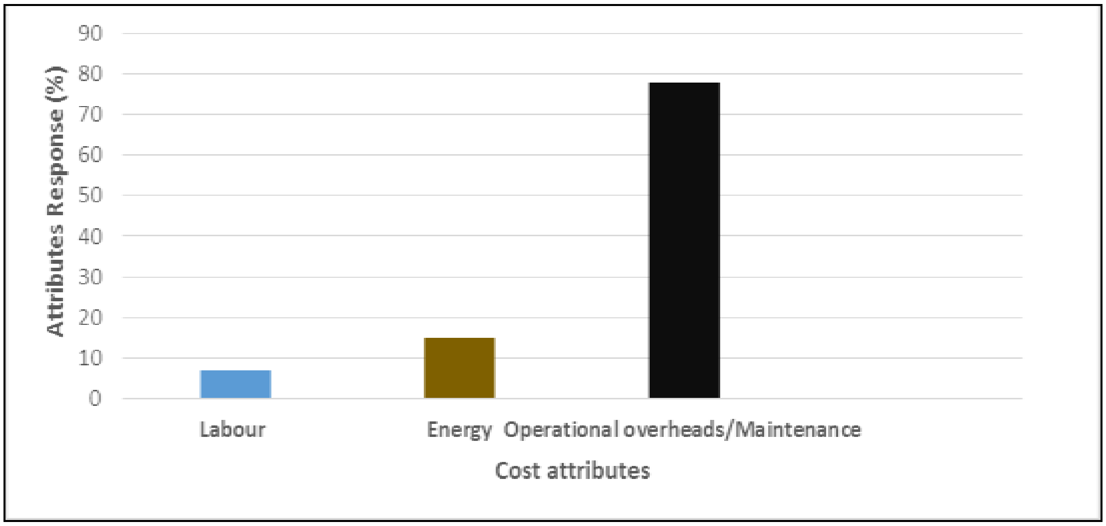



**Figure 4.11: Factory inefficiency in terms of cost.**

The inefficiency attributes response showed that there was a significant difference between the three levels of cost. Cost was determined since it was the fundamental factor that determines the primary components of the production. Operational cost was the highest amongst the evaluated cost parameters at (78%). This was high due to a wide cycle that entails processing of the tea leaves that starts from the time of factory delivery to the time of factory disbursement. The operational cost was more of the machine related activities that involves; transportation, processing, sorting and packaging processes.

Energy cost was determined and the results showed (15%) from the whole process cycle. Energy cost was derived from the drying processes and the lighting in the factories. Labor cost was considered to be the least at (7%) which was culminated by the workforce that delivers in the all cycle processes.

The labor, energy and operational costs were the major components that influenced the prices of the processed tea. The factories will determine the three costs before giving out the calculated cost that will act externally for famers. The mechanization and digitization was determined to be paramount in order to safeguard the interests of the farmers by excluding the unnecessary labor costs.

### 4.5.4 Employee and Labour Relationship in Tea Farming

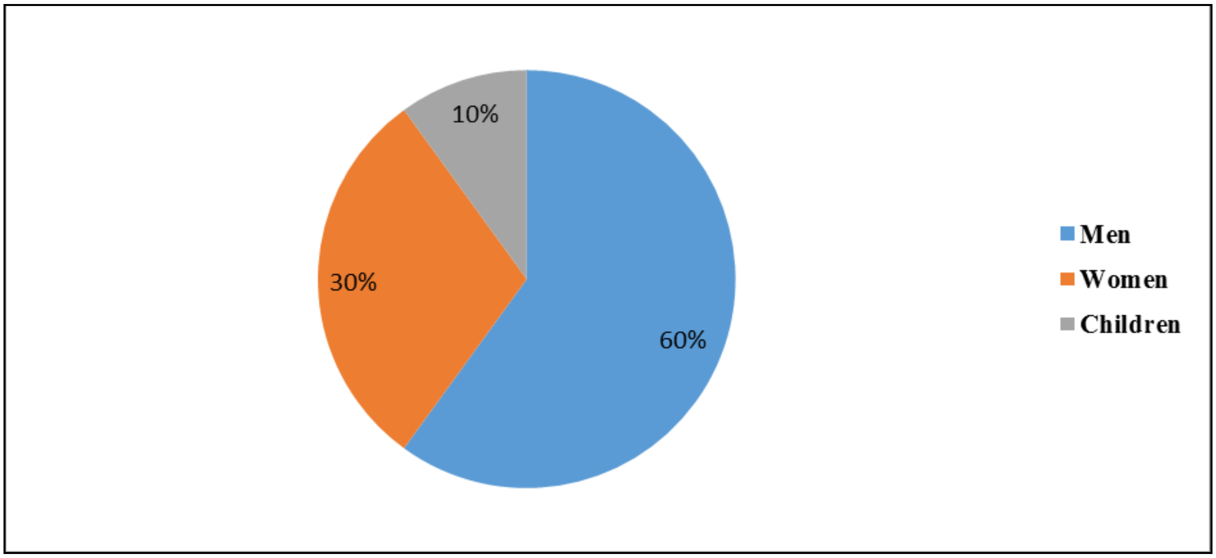



**Figure 4.12: Employee and labour relationship.**

The researcher sought to determine the relationship of the work force and labour relationship. The response level showed that (60%) of the work force employed were men which was a simple of hard work and high daily production during the plucking process. Also, during processing of the plucked tea in the factories, most work forces was more of male respondents where they claim that machines are basically and naturally operated by men.

30% of the respondents were women who were basically categorized as tea pluckers. They argued that they were considered to be handling simple and minor work that includes weeding and plucking which had low pay in return that cannot afford a living. (10%) of the respondents were children which were drawn from different levels that include; the less privileged, school going and partially disabled. The children felt that they were being abused and mistreated but due to the fact that was the only way of earning a living and it was worthy.

### 4.5.5 Access to Information and Training of Tea Farmers

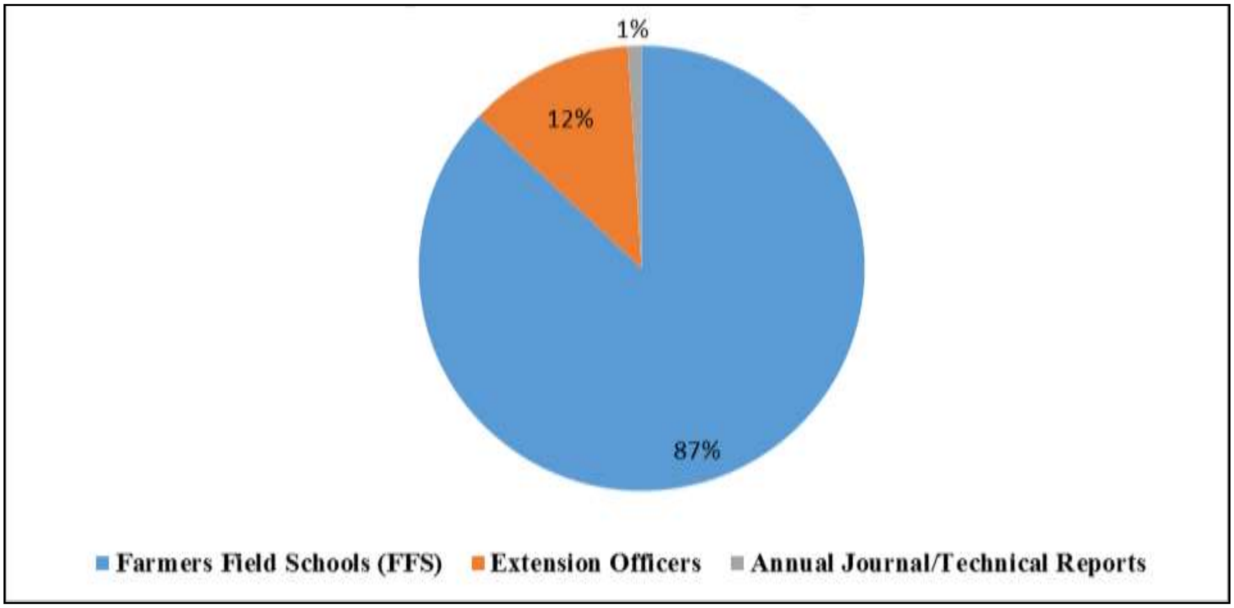



**Figure 4.13: Access to information and training.**

The chart above showed that there were three existing categories of accessing information by the farmers as far as tea growth and production is concerned. (87%) of the respondents acknowledge the fact that participation in the farmer field school (FFS) was of intense benefits whereby farmers across the zones and regions and the qualified tea production experts converge to determine the integrated production mechanism while providing remedy to the challenges facing the growth of the tea plant.

12% of the farmers responded that the improved extension services mechanism has helped them to realize improved daily, monthly and annual production indices. They indicated that it was favoured by the devolution which was easily accessible and close to the needs of the tea farmers. (1%) of the respondents indicated that, some of the fundamental information on integrated and improved tea production mechanisms was derived from the annual journals and technical reports of leading research institution (TRFK) and the processing entities like Finlay's and Williamsons companies.

### 4.5.6 Socio-Economic Implications of Purple Tea Farming

#### 4.5.6.1 Positive Implications of Purple Tea Farming

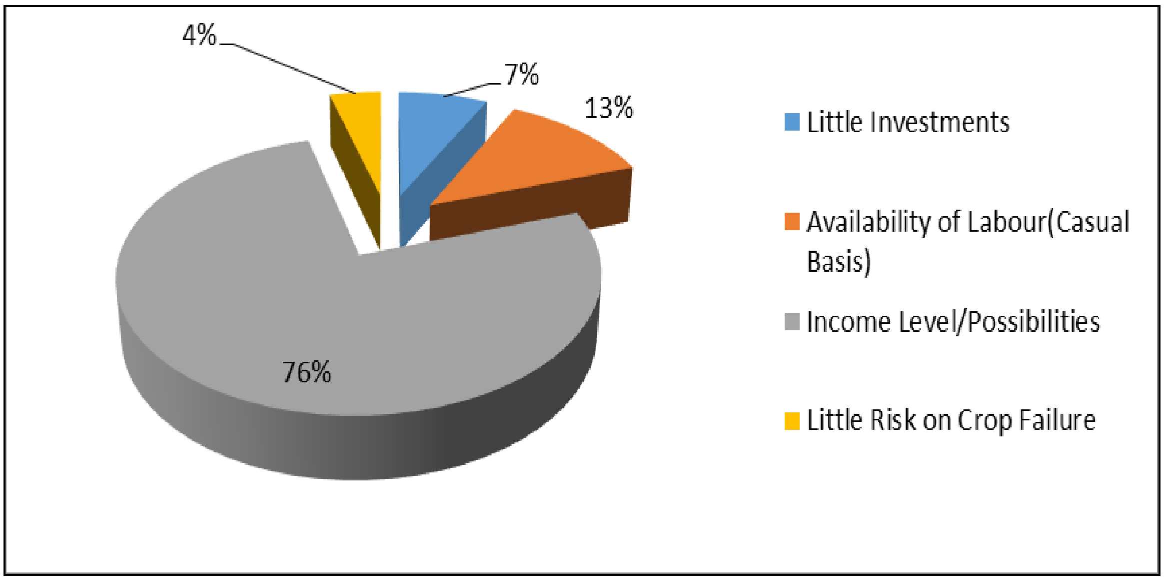



**Figure 4.14: Socio-economic positive implications of purple tea farming.**

The positive socio economic implications of growing purple variety were determined and the results processed as shown on the figure above. The results show that purple tea variety fetches a possible income levels at (76%) which makes it considered in the market and production capabilities. Its production rate is more of the green variety after maturity though maturity rate is relatively low as compared to green variety.

Availability of labour on casual basis at (13%) which is as a result of the tenderness of the plucking buds and the acquaintance of the new variety of purple clones. The results showed that the variety had little investment of (7%) which was a result of the low prices of the seedlings that equals the ones for green variety of Ksh. 10 per seedling. Little risk on crop failure that is depicted at (4%) was another fundamental factor that holds the purple variety un-comparable with the green variety. This is due to its resistance to the changing climatic conditions, whereby the rate of survival of purple variety is greater than that of the green variety.

#### 4.5.6.2 Negative Implications of Purple Tea Farming

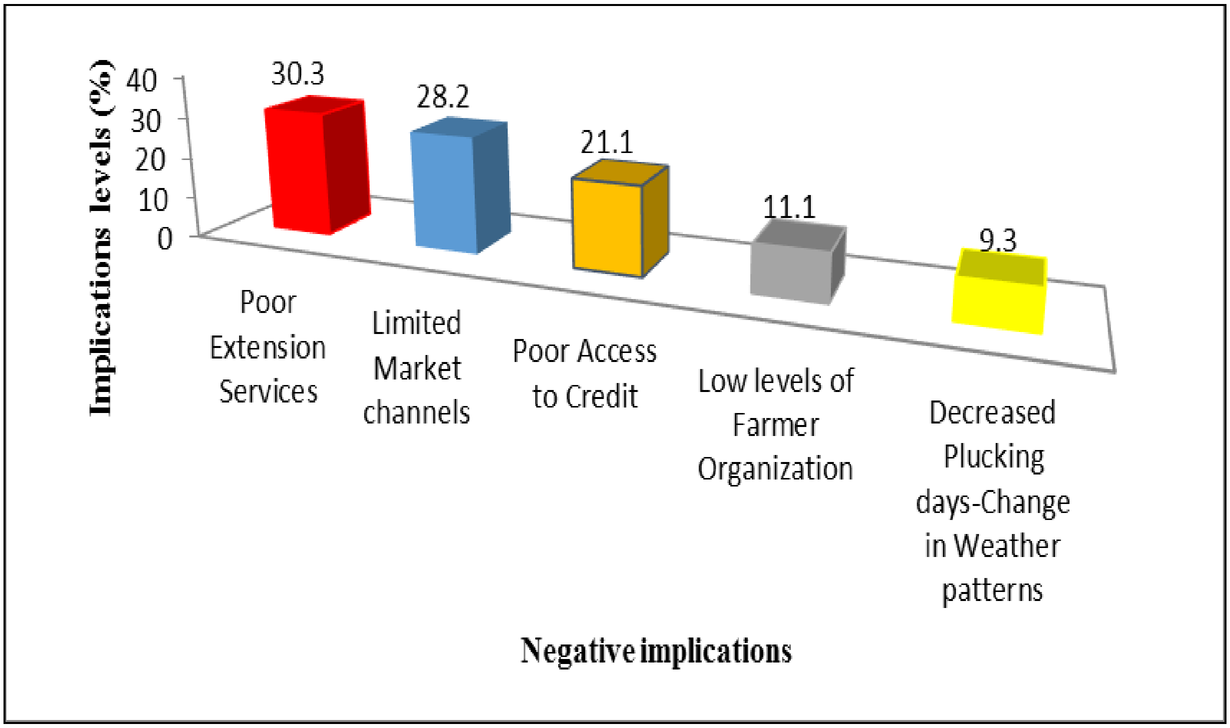



**Figure 4.15: Socio-economic negative implications of purple tea farming.**

The negative implications as far as social economic is concerned was determined and the results indicated as shown above. The purple variety after showing great signs of income level, little investment capabilities, little risk of crop failure and availability of labour on casual basis was facing a number of negative implications. Poor extension services (30.3%) was due to lack of extension officer's motivation and farmers disowning their services. Limited market channels (28.2%) was as a result of it being a new variety that will struggle to gain the market across nationally and internationally. Poor access to credit (21.1%) which emanated from widespread poverty levels as a result of population growth and reduced land size that encourages small farming. Low levels of farmer organization (11.1%) that caused by continued withholding of tea bonuses and low prices that emanate from tea brokers. Decreased plucking days (9.3%) as a result of change in weather patterns that leads to low daily production which in turn affects respective monthly bonuses.

### 4.5.7 Sensory and Chemical Parameters Evaluation of Green and Purple Tea Varieties

The experiment was achieved through use of High Performance/Pressure Liquid Chromatography (HPLC) and results tabulated for all parameters tested. The experiment was achieved through use of sampler, pump and detector. The results for various parameters are shown below:

#### 4.5.7.1 Total Polyphenols

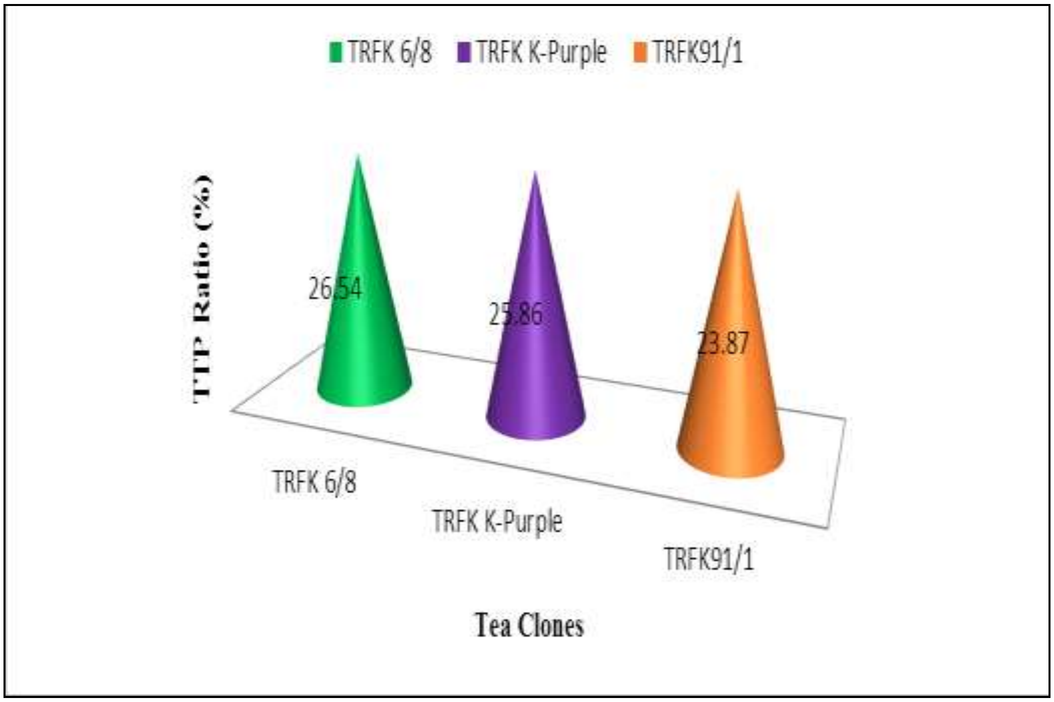



**Figure 4.16: Levels of Total Polyphenols for Tea Clones.**

The results showed that there was significance difference between the three purple tea clones. Since, $t_{cal}=30.4876>t_{tab}=12.924$ at 95% confidence level. It was known that, the TRFK 6/8 had the highest TTP due to both presence of green and purple chlorophyll combined. The TRFK K-Purple showed 25.86 as a result of sizeable purple chlorophyll as compared to green chlorophyll. TRFK 91/1 showed slightly low TTP since green chlorophyll was dominant.

#### 4.5.7.2 Total Catechins

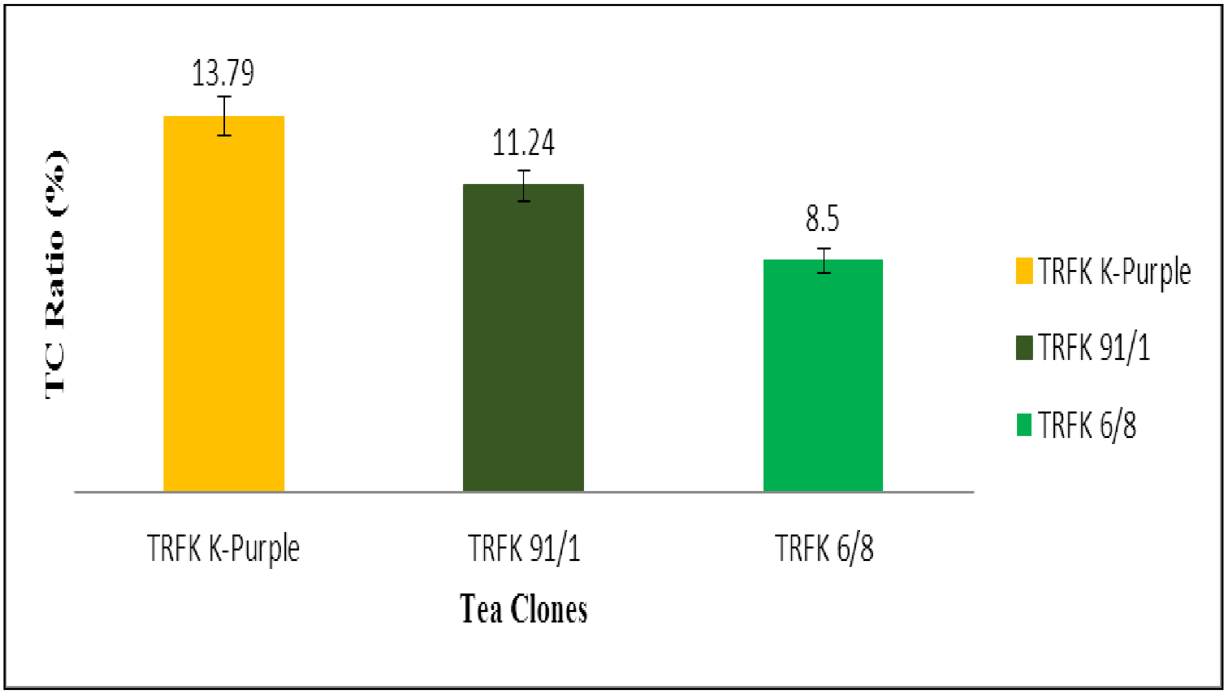



**Figure 4.17: Levels of Total Catechins for Tea Clones.**

From the above fig 4.17, the results depicts that there was no significant difference for the three selected and evaluated clones. Since, $t_{cal}=6.6627<t_{tab}=12.924$ at 95% confidence level. K-Purple showed the highest value ratio of 13.79% followed by TRFK 91/1 at 11.24% and TRFK 6/8 8.5% as the lowest. The ratio was as a result of the dominance of both purple and green amongst the evaluated clones. Catechins can have protective effects to neurons. Also being the antioxidant, it helps in oxidation and reduces metabolism of dough.

#### 4.5.7.2.1 Non-gallated and Gallated Catechins of Tea Clones

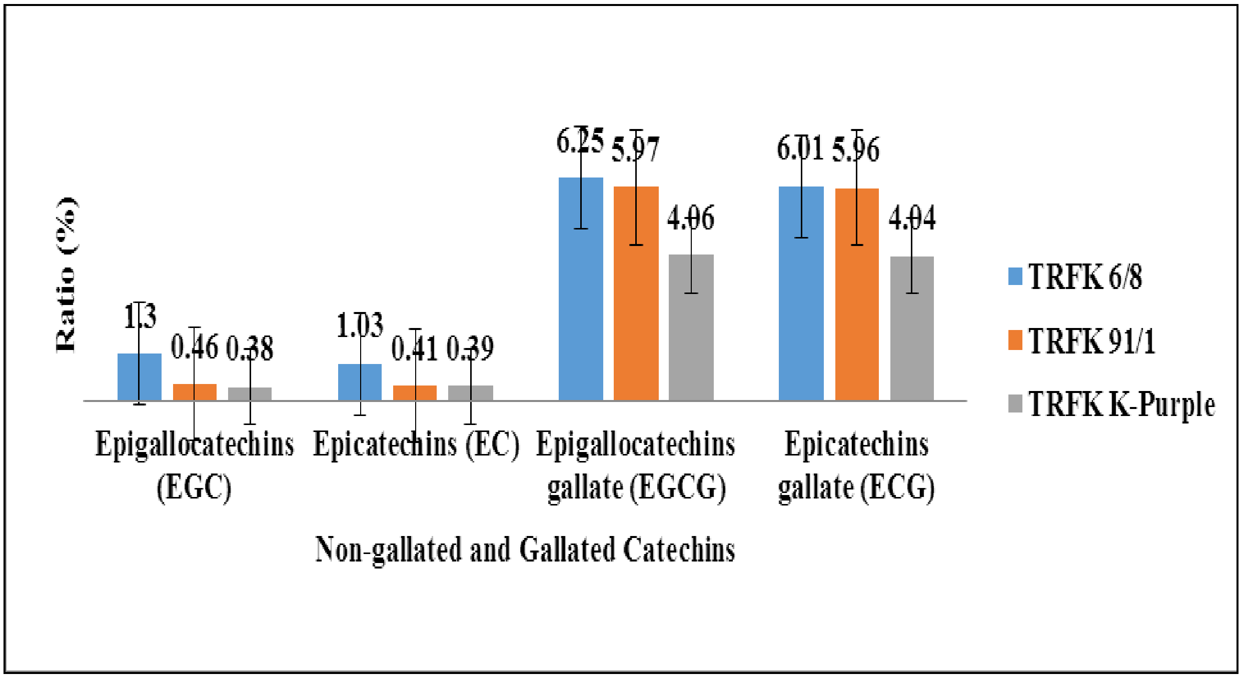



**Figure 4.18: Levels of Non-gallated and Gallated Catechins for Tea Clones.**

TRFK 6/8 showed the highest mean in all, EGC (1.3%), EC (1.03%), EGCG (6.25%) and ECG (6.01%) due to its dominating green chlorophyll. TRFK 91/1 was slightly lower than TRFK 6/8. The results of TRFK in both non-gallated and gallated catechins were; EGC (0.46%), EC (0.41%), EGCG (5.97%) and ECG (5.96%). TRFK K-Purple showed the least results in both categories of catechins evaluated. The results are; EGC (0.385%), EC (0.39%), EGCG (4.06%) and ECG (4.04%). The results from the three clones evaluated, showed that gallated catechins are the most dominant than the non-gallated.

The results show that $t_{cal}$= 0.0289<$t_{tab}$=*2.353* at 95% confidence level. There was no significant difference noted in all the two categories of the non-gallated and gallated catechins. The gallated and non-gallated catechins helps in reducing the glucose and cholesterol absorption in the human bodies which are the major causes of non-communicable diseases that includes; cancer, high blood pressure and arthritis.

#### 4.5.7.3 Gallic Acid

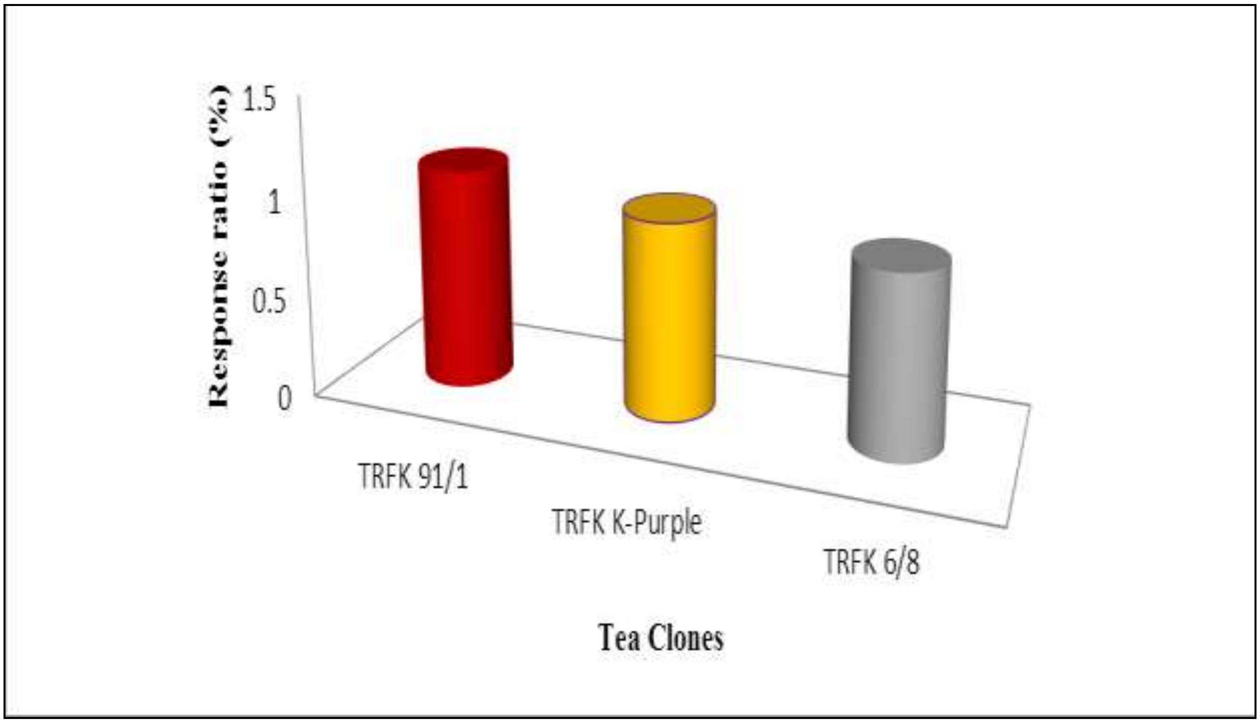



**Figure 4.19: Levels of Total Catechins for Tea Clones.**

Significant difference was not noted in all the three evaluated clones to determine the presence of gallic acid. Since, $t_{cal}=0.3288<t_{tab}=12.924$ at 95% confidence level. The results showed that, only clone TRFK 91/1 had the highest value ratio above 1 while the rest their ratios were below 1. The noted results were; TRFK 91/1 (1.09%), TRFK K-Purple (0.97%) and TRFK 6/8 (0.88%). The subsequent results showed that, gallic acid was common in the clones that have both green and purple chlorophyll in high ratios as compared to the clones that have relatively low distributed chlorophylls.

#### 4.5.7.4 Caffeine

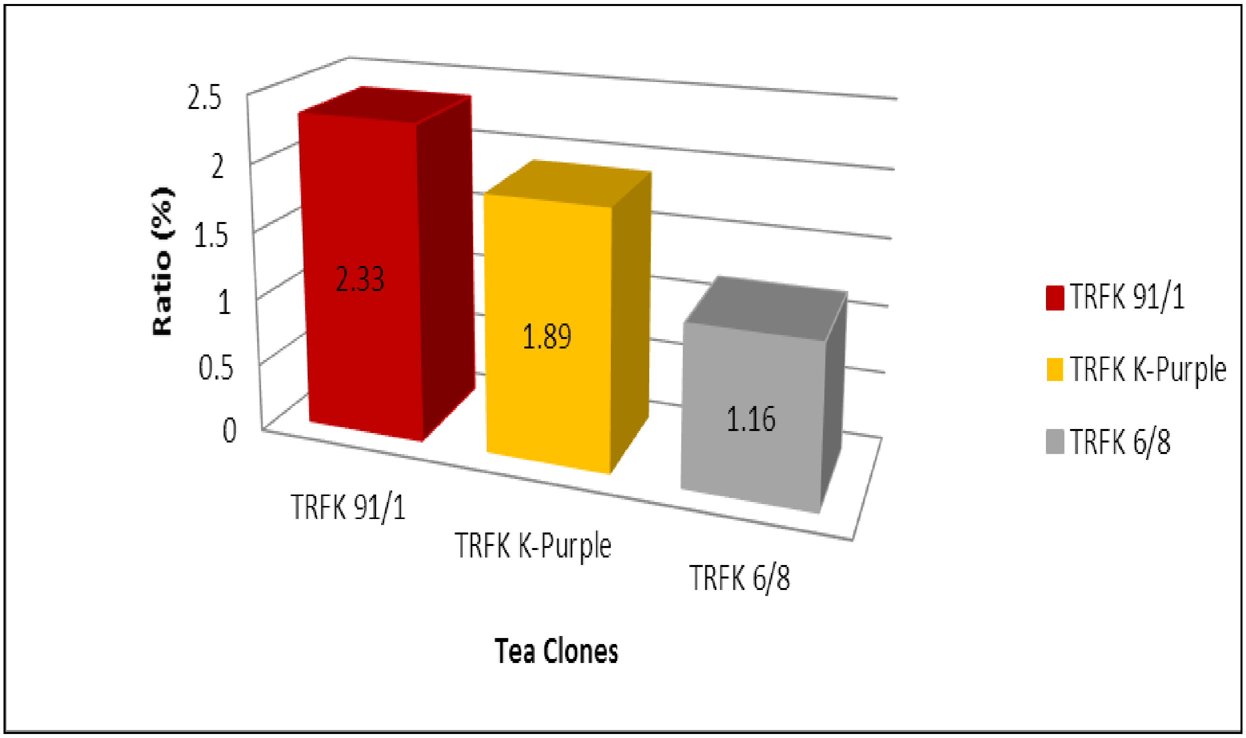



**Figure 4.20: Levels of Caffeine for Tea Clones.**

There was no significant difference as per the results of the three evaluated clones. Since, $t_{cal}=2.3252<t_{tab}=12.924$ at 95% confidence level. The result showed that, among the TRFK 91/1, TRFK K-Purple and TRFK 6/8 the ratio of caffeine was quite little that ranges between 1-3%. The highest recorded value was TRFK 91/1 that indicated (2.33%) followed closely by TRFK K-Purple at (1.89%). While TRFK 6/8 recorded the lowest value at (1.16%). Thus, the results indicate that there could be a reduced ratio of the caffeine components in various clones if research is undertaken through hybridization.

#### 4.5.7.5 Theanine

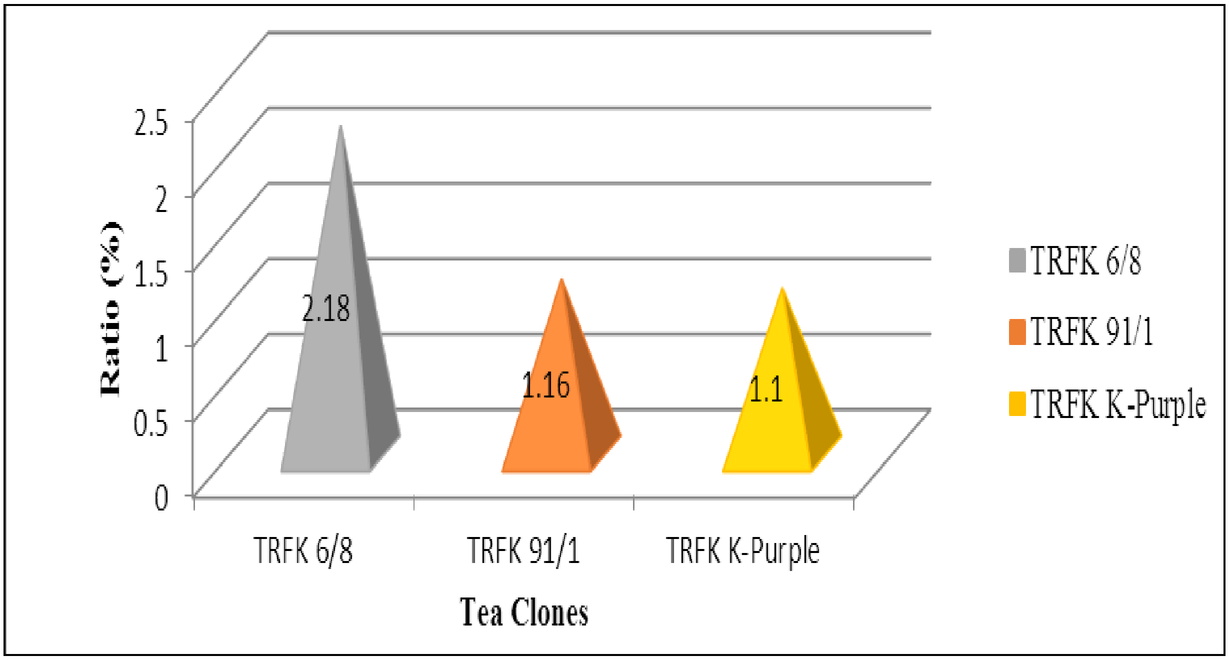



**Figure 4.21: Levels of Theanine for Tea Clones.**

From the graph above, the results showed that there was no significant difference at 95% confidence level according to the evaluated clones to determine the Theanine ratio. Since, $t_{cal}=1.3698<t_{tab}=12.924$. The recorded results showed that clone TRFK 6/8 had the highest levels of Theanine at (2.18%), which was followed by clone TRFK 91/1 at (1.16%). Clone K-Purple recorded the lowest levels of Theanine at (1.1%). This therefore indicated that, Theanine ratio is low on the purple chlorophyll as compared to green dominating chlorophyll clones.

### 4.6 Role of Purple Tea as a Mitigation Measure to Climate Change

#### 4.6.1 Climate Change Scenario Impacts at International Level

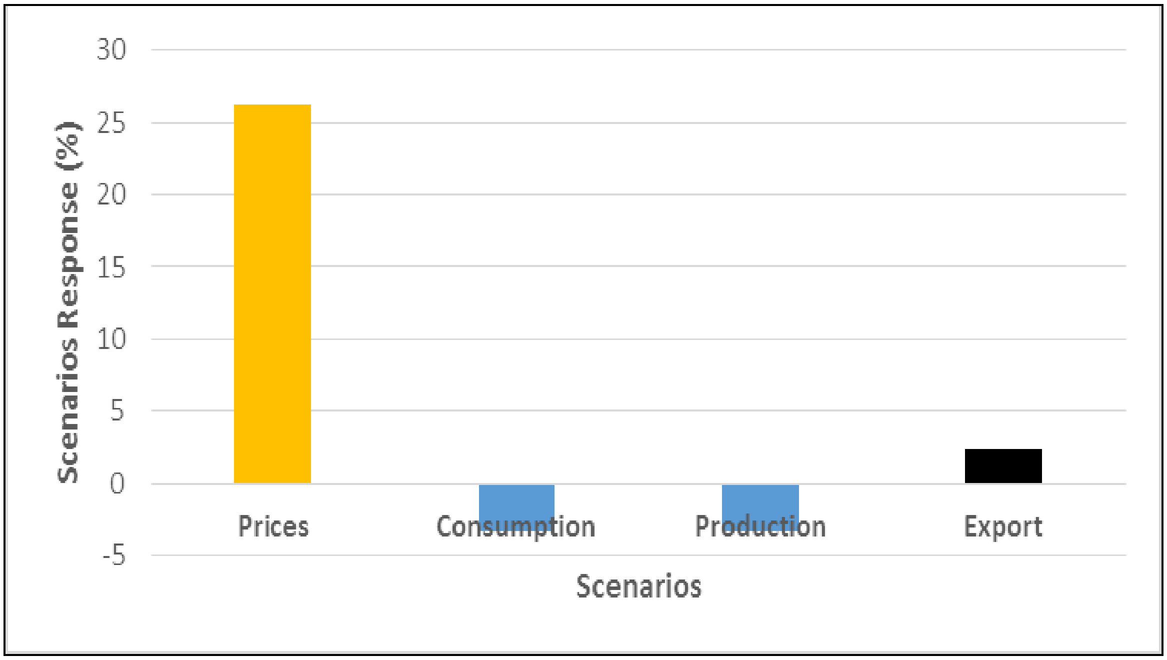



**Figure 4.22: Climate change scenario impacts at international levels.**

The results show how the climate change can cause a shift in various components that determines the outcome of the tea variety. The evaluation according to the prices was (26.3%) that implied the harsh climatic conditions favours the price factor while productivity goes down. This is according to the laws of demand that characterized the shifting of the demand, production and price scales. Export (2.3%) showed a slightly low positive response as a result of low production and consumption rates that will encourage it. Consumption and production (-3.3%) and (-3.4%) respectively scaled out the negative impacts of the changing climatic conditions. The consumption and production depends on each when other factors remain constant.

### 4.6.2 Variety Strength towards Environment

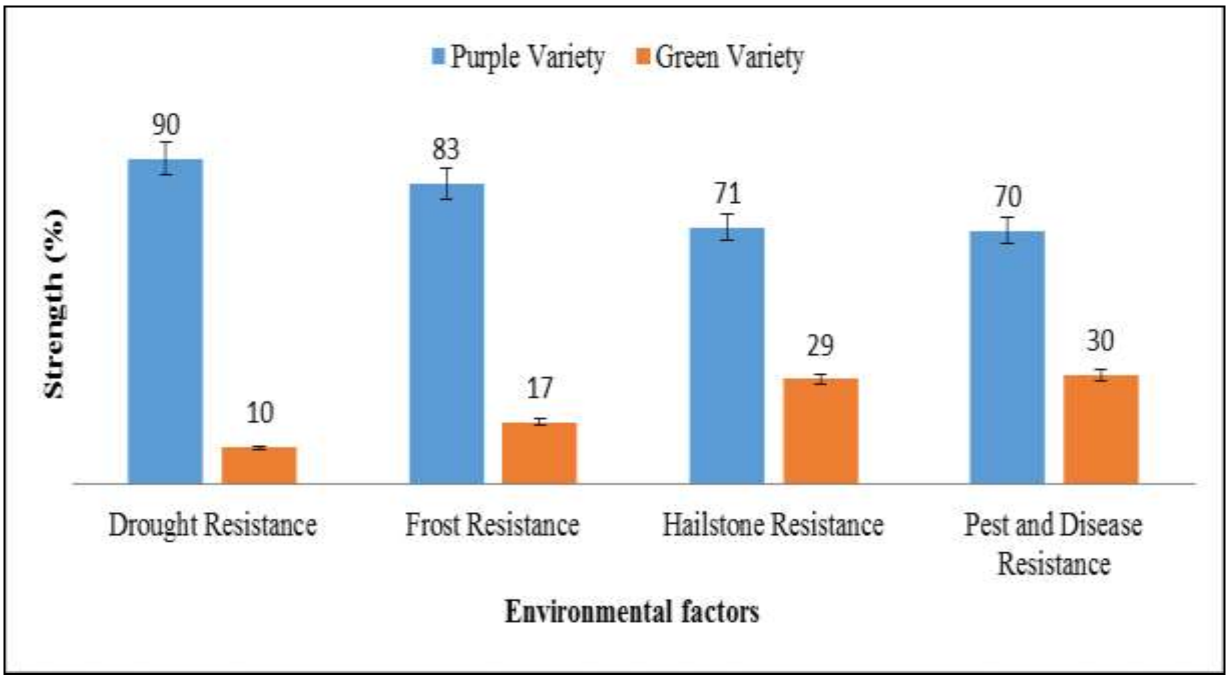



**Figure 4.23: Variety strength towards environment.**

The respondents showed that purple variety was leading in drought resistance (90%) and green variety (10%). This was due to the camouflaging of the variety whereby during the dry conditions, the purple colour tend to camouflage during the wet season, the purple chlorophyll tend to increase earning it the colour purple. The resistance of frost and hailstone, green variety showed an improved resistance as compared to drought resistance due to the leave texture and fibre. (83%) purple and (17%) green for frost resistance and (71%) purple and (29%) green. Purple variety showed a diminished response on disease and pest resistance (70%) while green variety showed improved resistance of (30%).

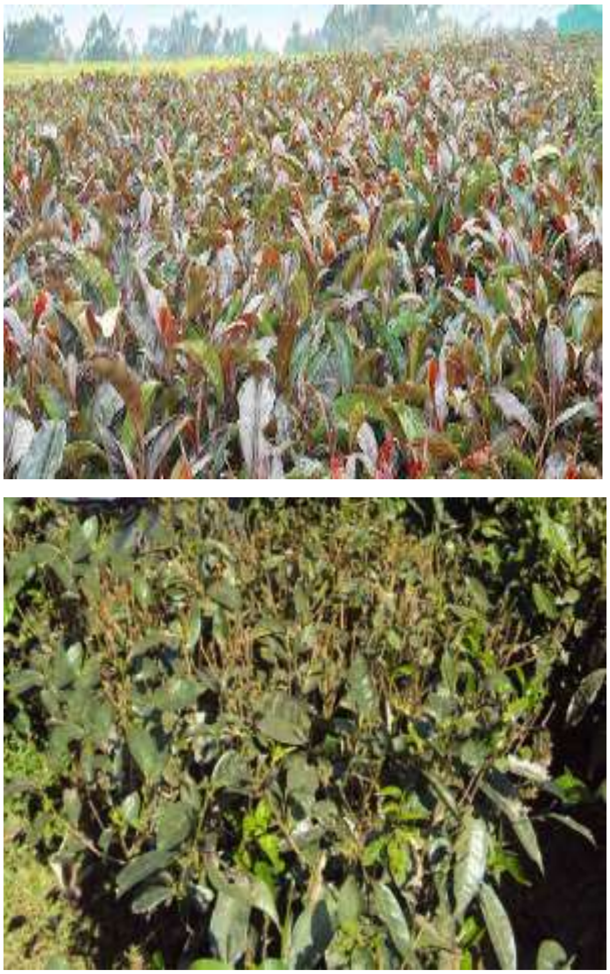
The *t-test* result shows that there was significant difference $t_{cal}=0.557<t_{tab}=2.353$ at 95% confidence level for the two varieties. The highly rated resistance of purple variety was analyzed and noted to be due to the texture and colour that was achieved through advanced hybridization.

a) Purple Variety – Not affected by drought b) Green Variety – Affected by drought

**Plates 4.2: Drought resistatnce of Purple and Green Tea Variety in January 2016**

a) Purple Variety – Not affected by frost b) Green Variety – Affected by frost

**Plates 4.3: Frost resistance of Purple and Green Tea Variety in April 2016**



a) Purple Variety – Not affected by hailstones b) Green Variety – Affected by hailstones

**Plates 4.4: Hailstones resistatnce of Purple and Green Tea Variety in April 2016**

a) Purple Variety-Not affected by diseases & Pests b) Green Variety-Affected by diseases & pests

**Plates 4.5: Diseases and Pests resistance of Purple and Green Tea Variety in January 2016**

### 4.6.3 Rainfall Difference per Year

**Table 4.1: Monthly mean of daily rainfall values.**

| **Month** | **Year (2014) $mm^3$** | **Year (2015) $mm^3$** |
|---|---|---|
| January | 29.7 | 93.9 |
| February | 57.7 | 12.1 |
| March | 76.2 | 292.7 |
| April | 290.7 | 148.7 |
| May | 486.5 | 194.7 |
| June | 57.7 | 231.1 |
| July | 46.5 | 165.5 |
| August | 110.3 | 169.8 |
| September | 150.4 | 261.1 |
| October | 414.7 | 204.8 |
| November | 271.0 | 503.7 |
| December | 101.0 | 103.3 |

**Source: TRFK Report 2016**

The monthly means for the two analyzed years showed a random mean fluctuations from the lowest to the highest. The lowest was 12.1 $mm^3$ which was recorded in February and the highest was 503.7$mm^3$ which was recorded in the month of November all of which was in the same year (2015). This depicts that there was change in rainfall pattern which was culminated by the changing climatic conditions.

### 4.6.4 Temperature Difference per Year

**Table 4.2: Monthly mean of daily temperature values.**

| **Months** | **Year 2014** | **Year 2015** |
|---|---|---|
| | **Mean℃** | **Mean℃** |
| January | 15.3 | 16.6 |
| February | 15.7 | 17.5 |
| March | 17.4 | 17.0 |
| April | 17.9 | 17.1 |
| May | 16.6 | 16.1 |
| June | 15.6 | 16.0 |
| July | 15.3 | 16.0 |
| August | 14.8 | 16.1 |
| September | 15.9 | 16.1 |
| October | 16.4 | 16.8 |
| November | 17.0 | 16.4 |
| December | 13.9 | 17.1 |

**Source: TRFK Report 2016**

The monthly means for the two analyzed years showed a random mean fluctuations from the lowest to the highest. The lowest was 13.9℃ which was recorded in the month of December 2014 and the highest was 17.5℃ which was recorded in the month of February 2015. This depicts that there was change in temperature pattern which was culminated by the changing climatic conditions.

### 4.6.5 $CO_2$ Sequestration Potentials

#### 4.6.5.1 Above Ground Ratio

**Table 4.3: Above ground CO2 sequestration ratios.**

| Age Factor | D(cm) | H(cm) | $CO_2$ Sequestration Potential(kg/cm$^2$) | Cumulative Frequency for $CO_2$ Sequestration |
|---|---|---|---|---|
| 1 | 0.5 | 38 | 4.36 | 18.49 |
| 2 | 0.6 | 44 | 7.27 | 53.29 |
| 3 | 0.8 | 48 | 14.1 | 198.81 |
| 4 | 0.9 | 52 | 19.32 | 372.49 |
| 5 | 1 | 58 | 26.61 | 707.56 |
| 6 | 1.2 | 61 | 40.3 | 1624.09 |
| 7 | 1.4 | 64 | 57.54 | 3306.25 |
| 8 | 1.6 | 66 | 77.51 | 6006.25 |
| 9 | 1.6 | 67 | 78.68 | 6193.69 |
| 10 | 1.8 | 70 | 104.04 | 10081.6 |
| | | | **Mean = 42.97** | **S.D = 34.71** |

The table above shows that there was no significant difference as far as age factor is concerned. Since the t-cal=0.0083<t-tab=1.812 at 95% confidence level. This indicates that the difference was due to the diameter size of the individual tea plants which was ranging from the 0.5 mm being the lowest at age one year and 1.8 mm being the highest at the age of one and ten years. The height was also another factor that led to the significant difference, 38 cm was the lowest height and 70 cm was the highest at one and ten years respectively for above.

#### 4.6.5.2 Below Ground $CO_2$ Sequestration

**Table 4.4: Below ground CO2 sequestration ratios.**

| Age Factor | D(cm) | H(cm) | $CO_2$ Sequestration Potential(kg/cm$^2$) | Cumulative Frequency for $CO_2$ Sequestration |
|---|---|---|---|---|
| 1 | 0.5 | 1.2 | 1.7 | 2.89 |
| 2 | 0.6 | 1.5 | 3.5 | 12.25 |
| 3 | 0.8 | 1.8 | 7.4 | 54.76 |
| 4 | 0.9 | 1.8 | 8.3 | 68.89 |
| 5 | 1 | 2 | 12.2 | 148.84 |
| 6 | 1.2 | 2.2 | 18.8 | 353.44 |
| 7 | 1.4 | 2.5 | 30.8 | 948.64 |
| 8 | 1.6 | 2.7 | 43.4 | 1883.56 |
| 9 | 1.6 | 2.8 | 47.9 | 2294.41 |
| 10 | 1.8 | 2.9 | 59.3 | 3516.49 |
| | | | **Mean= 23.33** | **S.D= 20.66** |

The table above shows that there was no significant difference as far as age factor is concerned. Since the $t_{cal} = 0.00176 < t_{tab} = 1.812$ at 95% confidence level. This was as a result of the $CO_2$ sequestration that was higher on mature clones than the less mature ones.

The difference was due to the volume ratio between the above and below ground part of the tea plant. The height and diameter size of the individual tea plants which was ranging from the (1.2 – 2.9) cm and (0.5 - 1.8) cm at the age of 1-10 years.

### 4.6.5.3 Acreage $CO_2$ Sequestration Potential per Year

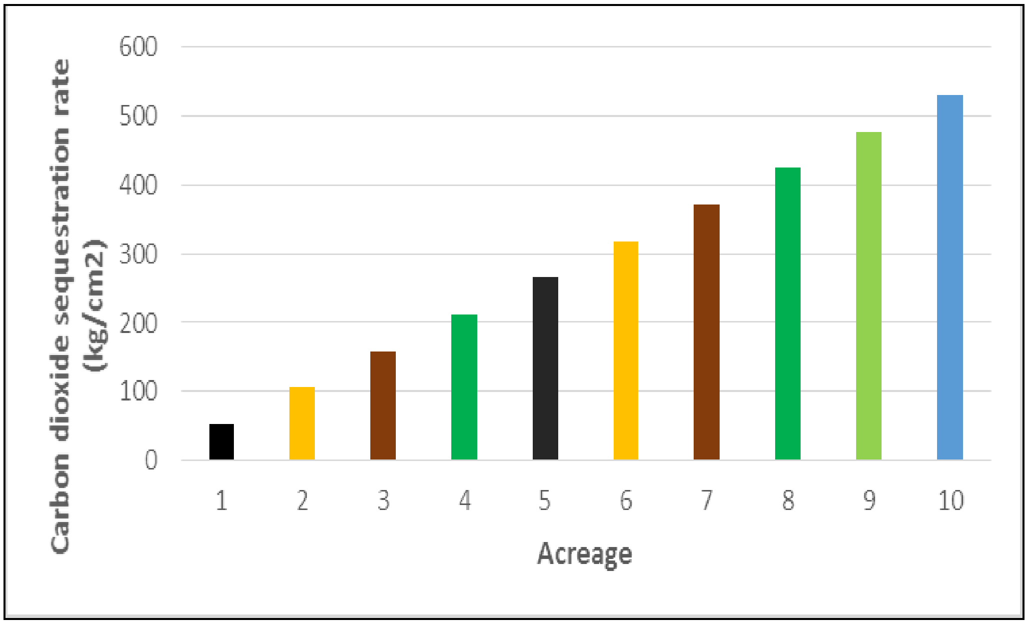



**Figure 4.24: Acreage $CO_2$ Sequestration Potential**

The Fig. 4.24 above shows a significant difference at 95% confidence level according to different acreage levels. Since the mean $_{cal}$= 346.97 > mean $_{tab}$= 240.54. The showed results was due to an increase of the $CO_2$ sequestration potential ratio according to the increased acreage determination. The significant difference was apparent between 1 acre (53.05%) and 10 acres (530.5%). The factors that determine the rate of $CO_2$ sequestration potential include the number of tea bush an acre can accommodate, the size between tea plants from the other, the season and the age of the plant. It was identified that, the young plants were sequestering $CO_2$ in a slower rate than the mature plants at (5.31%) and (53.05%) respectively. The land that was covered wholly by the tea bushes was identified to be sequestering the $CO_2$ in large capacity than the one that the tea bushes were distantly scattered.

### 4.6.6 Relative Growth Rate

#### 4.6.6.1 Precipitation Differentials for Purple Variety growth rate for carbon sequestration during Wet (April) and Dry (January) seasons.

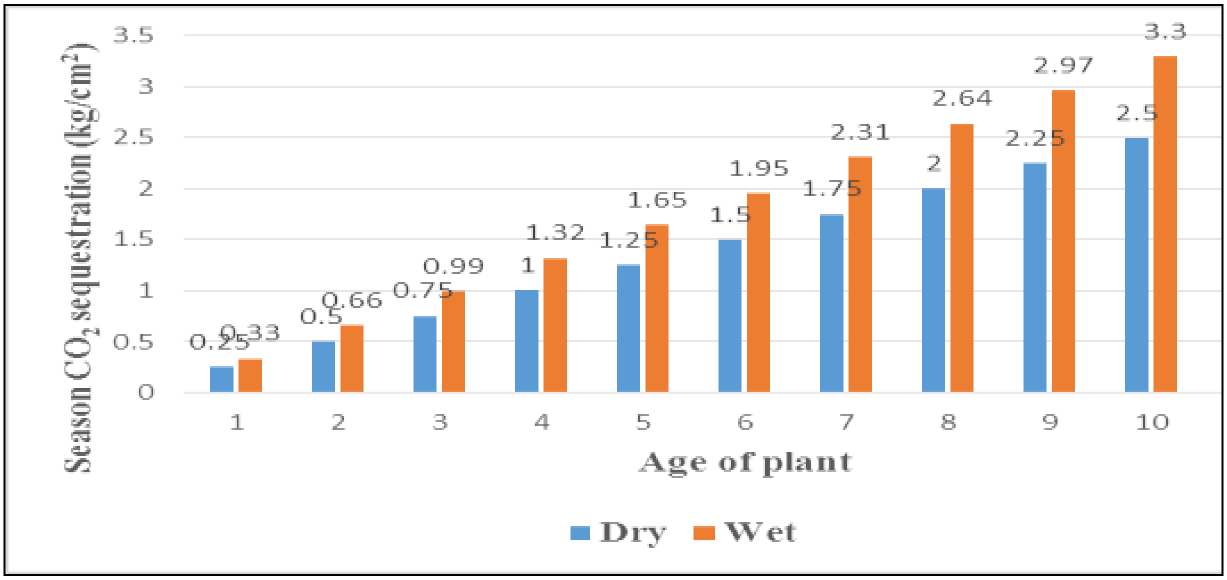



**Figure 4.25: Precipitation differentials for Purple variety growth rate for carbon sequestration for months of January and April.**

The *t-test* results shows that there was no significant difference at 95% confidence level between dry and wet season carbon sequestration potential. Since the $t_{cal}$ =0.131<$t_{tab}$=1.812. Wet season shows high mean figures across the 10 years evaluated plant specimens. It was depicted that, the results under wet season (April) doubled the ones under dry season (January) from the least to the highest number of years. Year 1, wet season showed 0.33 kg/cm$^2$ and dry season showed 0.25 kg/cm$^2$, Year 2, wet was 0.66 kg/cm$^2$ and dry 0.5 kg/cm$^2$, Year 3 and 4, wet 0.99, 0.1.32 kg/cm$^2$ and dry 0.75, 1 kg/cm$^2$ respectively. It showed that, the relative growth rate for the purple and green tea during wet season responded similarly and absolutely different during the dry season which the maturity rate in terms of years was the critical factor of difference.

The highest values across the seasons were 3.3 $kg/cm^2$ and 2.5 for wet and dry seasons respectively at 10 year plant specimen. This indicated that, the growth rate that determines the $CO_2$ sequestration achieved the highest values with the longevity of the years of the plant specimen. The values of $CO_2$ sequestration for purple variety is less compared to the green variety due to continued hybridization of the purple clones to culminate to a hybrids of high productivity.

## 4.7 Discussion

### 4.7.1 Extent of adoption of Purple Tea farming

The acreage indications was determined as a result in determining the possibility of farmers shifting from the old green variety to new variety of purple tea. This indicated that availability of land was a major setback by farmers adopting the new variety with most famers owning less than 6 acres of land that indicates 82.6% while few famers had acres above 6 that indicates 17.4%. According to Kiprono *et al.,* (2016), they indicated that farmers were facing challenges in embracing new tea varieties due to continued subdivision of land.

The availability of extension services was determined by the number of acreage owned by the smallholder farmers. The results depict that, extension officers were concentrating to farmers that own large tracts of land. It's evident that, farmers with more than 10 acres got a huge share of the extension services at 26% followed by 22% for both farmers owning 8 and 10 acres respectively.  Farmers with 6 acres are slightly considered at 18 % since they are close to those with above 8 acres in terms of economic and social perspectives. 12% of the farmers responded that the improved extension services mechanism has helped them to realize improved daily, monthly and annual production indices. They indicated that it was favoured by the devolution which was easily accessible and close to the needs of the tea farmers. (1%) of the respondents indicated that, some of the fundamental information on integrated and improved tea production mechanisms was derived from the annual journals and technical reports of leading research institution (TRFK) and the processing entities like Finlay's and Williamsons companies TRFK Journal (2015).

The purple variety mean values were high during both wet and dry seasons at 448 kgs and 423 kgs respectively. While the green variety had the least mean value at 337 kgs and 320 kgs respectively. TRFK Report (2015) also showed that there was improved productivity mean ratios for purple tea variety during both wet and dry seasons.

### 4.7.2 Socio-economic factors affecting adoption of Purple Tea farming

The negative implications as far as social economic is concerned was determined and the results showed that purple variety after showing great signs of income level, little investment capabilities, little risk of crop failure and availability of labour on casual basis was facing a number of negative implications. Poor extension services (30.3%) was due to lack of extension officer's motivation and farmers disowning their services. Limited market channels (28.2%) was as a result of it being a new variety that will struggle to gain the market across nationally and internationally. Poor access to credit (21.1%) which emanated from widespread poverty levels as a result of population growth and reduced land size that encourages small farming. Low levels of farmer organization (11.1%) that caused by continued withholding of tea bonuses and low prices that emanate from tea brokers. Decreased plucking days (9.3%) as a result of change in weather patterns that leads to low daily production which in turn affects respective monthly bonuses. According to Kiprono *et al., (*2016), they noted that there is need to always subject tea farmers to continuous learning on how to manage the tea farming for better yields and pricing.

Profitability was determined according to acreage productivity. The response level towards profitability for farmers with 2 acres of land was 2% indicated that their profitability levels were low. There was a slight high response at 10% for farmers with 4 acres of land which showed that profitability was least felt. Farmers with between 6 and 8 acres responded at 14% each which showed that the profitability was slightly determined for those farmers with more than 5 acres of land. 10 and more than 10 acres of land depicts 22% and 38% respectively which was more than the rest. The results showed that, profitability was clearly identified and determine where there was large ownership of land as opposed to the least ownership of land. A study by Mwaura and Muku (2012) indicated that although small scale farmers had diverse experience in tea farming. They need to be informed on how to increase the productivity as well as reducing the operational costs.

The factory inefficiency attributes response showed that there was a significant difference between the three levels of cost. Cost was determined since it was the fundamental factor that determines the primary components of the production (KTDA, 2012). Operational cost was the highest amongst the evaluated cost parameters at (78%). This was high due to a wide cycle that entails processing of the tea leaves that starts from the time of factory delivery to the time of factory disbursement. The operational cost was more of the machine related activities that involves; transportation, processing, sorting and packaging processes. Energy cost was determined and the results showed (15%) from the whole process cycle. Energy cost was derived from the drying processes and the lighting in the factories. Labor cost was considered to be the least at (7%) which was culminated by the workforce that delivers in the all cycle processes. The labor, energy and operational costs were the major components that influenced the prices of the processed tea. The factories will determine the three costs before giving out the calculated cost that will act externally for famers. The mechanization and digitization was determined to be paramount in order to safeguard the interests of the farmers by excluding the unnecessary labor costs.

The product diversification results showed that there is a significance difference between the three identified attributes that determines the product diversification of Purple tea.

Taste in all the attributes was the highest at 70% followed by refreshment at 27% and health benefits at 3%. The attributes were drawn according to the primary use of the tea plants by the locals. It indicates that, the major factors that a market, production and consumers focuses on are the taste, refreshment and health benefits respectively. According to Karl Nyabundi (2016), the tea plant contains a number of essential chemical compounds that includes; polyphenols, catechins, gallic acid, and caffeine that makes it to attain the three attribute that determines its product diversification and local consumption.

### 4.7.3 Role of Purple Tea variety in sequestering carbon dioxide and as a mitigation measure to climate change

The precipitation deferential for purple variety with wet season showing high mean figures across the 10 years evaluated plant specimens. It was depicted that, the results under wet season doubled the ones under dry season from the least to the highest number of years. Year 1, wet season showed 0.33 lbs and dry season showed 0.25 lbs, Year 2, wet was 0.66 lbs and dry 0.5 lbs, Year 3 and 4, wet 0.99, 0.1.32 lbs and dry 0.75, 1 lbs respectively. It showed that, the relative growth rate for two plant specimens during wet season responded similarly and absolutely different during the dry season which the maturity rate in terms of years was the critical factor of difference. The difference between the dry and wet seasons of the green variety is absolutely different from the ones for purple tea across the seasons. Year 1 results showed 0.33 lbs wet and 0.25 lbs dry; Year 2, wet 0.66 and dry 0.5; Year 3, wet 0.99 lbs and dry 0.75 and the highest one, Year 10, wet was 3.3 lbs and dry 2.5 lbs. This showed that, wet season and dry of green variety had a relatively low significant difference < 0.5 compared to the ones for purple variety that had absolute high significant difference = or > 0.5 of $CO_2$ sequestration between the respective seasons. A study by Chapin *et al., (*2009), indicated that little interest has been sparked among carbon balance researchers with respect to crop plantation carbon storage while forest systems and timber plantations have been extensively studied due to belief that they hold considerable influence over the global carbon cycle.

The results for above and below ground $CO_2$ sequestration showed that there was significant difference as far as age factor is considered. This was as a result of the fact that, the $CO_2$ sequestration was higher on mature clones than the less mature ones. Since, green variety clones mature fast than purple variety clones and, hence, $CO_2$ sequestration was high in green variety. This also reflects to the above and below ground $CO_2$ sequestration capabilities. The results showed that, the above ground sequestration rate was higher than below ground sequestration rate which was determined in (%) ratio as 64.81% and 35.18% respectively. Published literature related specifically to research on tea plantation Carbon dioxide is limited solely to soil organic matter (SOM), most of which is only concerned with increasing production or improving tea quality (Kamau *et al*., 2008). The difference was also noted to be due to the diameter size of the individual tea plants which was ranging from the 0.5 mm being the lowest at age one year and 1.8 mm being the highest at the age of ten years. The height was another aspect that led to the significant difference, 38 cm was the lowest height and 70 cm was the highest at one and ten years respectively.

Like most other agricultural crops, small holder tea depends on rain fed agriculture. In times of drought production drops by very huge margins causing a lot of misery especially to small holder farmers. For instance, droughts in the years 1997 and 2000 forced production to slip by about 15 percent (Uniliver, 2012). The result showed that purple variety was leading in drought resistance (90%) and green variety (10%). This was due to the camouflaging of the variety whereby during the dry conditions, the purple colour tend to fed while during the wet season, the purple chlorophyll tend to increase earning it the colour purple. The resistance of frost and hailstone, green variety showed an improved resistance as compared to drought resistance. (83%) purple and (17%) green for frost resistance and (71%) purple and (29%) green. Purple variety showed a diminished response on disease and pest resistance (70%) while green variety showed improved resistance of (30%). The highly rated resistance of purple variety was analyzed and noted to be due to the texture and colour that was achieved through advanced hybridization.

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

The establishment rate was determined and observed that availability of land was a major setback by farmers adopting the new variety with most famers owning less than 6 acres of land that indicates 82.6% while few famers had acres above 6 that indicates 17.4%. It's evident that, the extension services were rendered highly at 26% to farmers with more than 10 acres of land while with least acres of land (2 acres) the extension services was low 4%. The purple variety had high mean value during wet and dry seasons at 448 kgs and 423 kgs respectively. While the green variety had the least mean value at 337 kgs and 320 kgs respectively. Thus, purple variety was preferred than green variety as adoption mechanism to climate variability and change.

The results of negative socio-economic implications indicated that; poor extension services (30.3%), lack of training-farmer field schools (11.1%), poor access to credit (21.1%), and limited market channels (28.2%) and decreased plucking days-change of weather (9.3%) were the major factors hindering establishment of Purple Tea farming. The results of positive socio-economic implications of growing purple variety showed that; little investment (7%), income level (76%), little risk on crop failure (4%) and availability of labour (13%) were major factors that influences the adoption of purple tea variety. This was due to purple tea variety fetching considerable income levels which makes it considered in the market and production capabilities.

The results for purple and green tea variety on drought (90%) and (10%), frost (83%) and (17%), hailstone (71%) and (29%) and pests and diseases (70%) and (30%) resistance respectively showed that purple tea variety was highly rated for impacts of climate variability and change. This was analyzed and noted to be due to the texture and colour that was achieved through advanced hybridization which has led to adaptation to climate change. It was also noted that the purple tea variety mean (%) rate of above ground $CO_2$ sequestration (64.81%) was relatively higher than (35.18%) below ground $CO_2$ sequestration. The difference of the complete sequestration cycle was the time as age and growth rate of tea variety. Thus, increasing the $CO_2$ sequestration ratio in both wet and dry season. This is due to its resistance to the changing climatic conditions. Whereby the rate of survival of purple variety is greater than that of the green variety.

## 5.2 Recommendations

Farmers need to be highly sensitized on how to manage the population growth which has a greater impact on subdivision of land that affects replacement or new establishment of purple tea variety. Also, extension outreach should be improved and be rendered without discrimination to all tea farmers. This will increase the establishment rates of the Purple variety.

There is a need for the KTDA, TBK and other relevant custodian agencies of tea marketing to provide clear marketing structure for the green and purple tea varieties which will determine the rate of adoption of the purple tea variety.

There is need for collaboration between TRFK and extension officers to enlighten the farmers on why they should embrace better clones of the new purple tea variety. This is due to its high resistance to drought, hailstone, frost, pests and diseases. Hence, enhancing adoption mechanism to climate variability and change.

# REFERENCES


Arndt, D. S, Baringer M. O, and Johnson M. R. (2010). The state of climate in 2009. *Bulletin of the American Meteorological Society, 91*, (6).

Awuor, C. B. (2008). Report of an adaptation project at Sakai Village, Kisau Division, Mbooni East District. *LEISA Magazine 24, 4 December 2008*.

Becht. R. (2007). Environmental effects of the floricultural industry on the Lake Naivasha basin, unpublished paper, *ITC Naivasha Database, Enschede, The Netherlands*.

Bernard, H. R. (2017). *Research methods in anthropology: Qualitative and quantitative approaches*. London: Rowman & Littlefield.

Brewer, J., & Hunter, A. (1989). *Multimethod research: A synthesis of styles*. Newbury Park, NJ: Sage.

Canadian Center of Science and Education (2012). Environment and Pollution. *Journal of Management and Sustainability, 2*, (2).

Chapin F.S. III, A. D. McGuire, R. W. Ruess, T. N. Hollingsworth, M. C. Mack, J. F. Johnstone, E. S. Kasischke, E. S. Euskirchen, J. B. Jones, M. T. Jorgenson, K. Kielland, G.P. Kofinas, M. R. Turetsky, J. Yarie, A. H. Lloyd, and D. L. Taylor (2009). *Arctic and boreal ecosystems of western North America as components of the climate system*. Global Change Biol. 6 (1 Suppl): 1–13.

Charles H. J. Godfray, John R. Beddington, Ian R. Crute, Lawrence Haddad, David Lawrence, James F. Muir, Jules Pretty, Sherman Robinson, Sandy M. Thomas, Camilla Toulmin (2010). *Managing Agricultural Greenhouse Gases***:** Coordinated Agricultural Research.

Christian Partners Development Agency (CPDA), (2008). *Report on Small-Scale Tea sector in Kenya*.

Creswell, J. W. & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Dang M. V. (2005). *Physical properties of the soils under long-term Tea growing*. Vietnam Soil Science Journal 23: 11-15. (In Vietnamese).

East Africa Tea Trade Association (EATTA), (2010). *Increasing Tea Productivity through Improved Nutrition.*

Export Processing Zones Authority (EPZA), (2005). *Tea and Coffee Industry in Kenya*.

FAO (2006). *Conservation Agriculture for Sustainable Agriculture and Rural Development*. Food and Agriculture Organization of the United Nations (FAO), Rome.

Frederick Verbruggen, Ian P. L. McLaren and Christopher D. Chambers (2007). Climate change & Mitigation. *Contribution of Working Group III to the Fourth Assesment Report of the Intergovernmental Panel on Climate Change.*

Füssel H. M and Klein R. J. T. (2002). *Climate Change Vulnerability Assessments*: An Evolution of Conceptual Thinking. Climatic Change, 75:301–329, 2006.

Gesimba R. M, Langat M. C, Liu G, & Wolukau J. N. (2005). The Tea Industry in Kenya: *Challenges and Positive Developments*. Journal of Applied Sciences, *5*(2), 334-336.

GoK (2010). *National Climate change Response Strategy*: Executive Brief. Ministry of Environment and Mineral Resources, Government of Kenya (GoK), Nairobi.

Gray D. E, (2004): *Doing Research in the Real World*. SAGE Publications. London. 422 str.

Hartemink A. E, (2006). Nutrient stocks, nutrient cycling, and soil changes in cocoa ecosystems—a review. *Adv. Agronomy, 86*, (227–253).

Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai X., Maskell, K., and Johnson C. A. (2001). *Climate Change*: The Scientific Basis.

Huque. R. (2007). Strategic Cost Management of tea Industry: *Adoption of Japanese Tea Model in Developing Country Based on Value Chain Analysis*.

IPCC (2007). *Climate Change Impacts, Adaptation, and Vulnerability*. Cambridge University Press, Cambridge, 2007.

Kamau D. M., Wanyoko J. K., Owuor P. O. and Ng'etich W. K. (2008). Experimental Design and Initial Soil Chemical Properties. *NPK(S) Fertilizer Use in Commercially Cultivated Clone BBK 35 in Different Tea Growing Regions of Kenya*, 29(1): 31-36.

Kamunya, (2015). *New purple tea variety promises greater returns*, 2015 Magazine.

Kegonde P. (2005). *Economic Governance of the Tea Sector,* A paper presented to CGD.

Kimenyi M. S, (2002). *Agriculture, Economic Growth and Poverty Reduction*. *KIPPRA* Occasional Paper No.3, *KIPPRA*, Nairobi.

Klein R. J .T, Erickson S. E. H, Naess L. O, Hammill A., Tanner T.M., Robledo C., O'Brien K. L. (2007). *Portfolio screening to support the mainstreaming of adaptation to climatic change into development assistance*: Tyndall Centre Working Paper 102.

Mugenda O. M, and Mugenda, A. G. (2003). *Research Methods*. *Quantitative and Qualitative Approaches.* Nairobi: Acts Press.

Mwaura F., & Muku O. (2007). *Tea farming enterprise contribution to small holders' well-being in Kenya*. (pp. 307-313). Nairobi: Tea Research Foundation of Kenya.

Nyangito H. O, (2001). *Policy and legal framework for the tea sub sector and the impact on the liberalization in Kenya*. KIPPRA Policy Paper No.1, KIPPRA, Nairobi.

Ochola S. O, (2009). *Integrated Flood Hazard, Vulnerability and Risk Assessment in Nyando River Catchment*, Kenya: Options for Land-Use Planning. Sierke Verlag, Göttingen.

Oso W. Y. and Onen D. (2005). *A General Guide to Writing Research Proposal and Report*: A Handbook for Beginning Researchers. Kisumu, Kenya: Option Press and Publishers.

Othieno C. O. (2013). Surface run-off and soil erosion on fields of young tea. *Tropical Agriculture, 52*, 299–308.

Otto S, (1999). *Potential Impacts of Global Warming, Geneva, Case Studies on Climate Change.* Geneva, 1999.

Oxfam International. 2002. Adapting to Climate Change*: What's Needed in Poor Countries, and Who Should Pa*y. Oxfam Briefing Paper 104. Oxford, UK.

Parry M, Cynthia R., and Matthew L. (2005). *Climate change, global food supply and risk of hunger*. Philosophical Transactions of the Royal Society of London. Series B, 360:2125–2138, 2005.

Pradip Baruah. (2013). Purple Tea potential in Assam: *Origin and Development*. *77*, (9–10)

Rui Li, Cheng X., Min Y., Hui F., Xing Z., and De-An G. *(*2007). *Qualitative and quantitative analysis of four species of Curcuma rhizomes using twice development thin layer chromatography*.

Wandiga, S. O., Opondo, M., Olago, D., Githeko, A., Githui, F., Marshall, M., ... & Yanda, P. Z. (2010). Vulnerability to epidemic malaria in the highlands of Lake Victoria basin: the role of climate change/variability, hydrology and socio-economic factors. *Climatic Change*, *99*(3-4), 473-497..

Taylor S. J, & Bogdan, R. (1998): Introduction to qualitative research methods*: a guidebook and resource.* 3`d ed. New York.

Tea News Briefs. (2015). *The Monthly On-Line Newsletter of the Tea Board of Kenya*- Nairobi, May 2015.

Tea News Magazine. (2010). *A quarterly publication of the Tea Board of Kenya*. Nairobi, May 2010.

Thomas Jefferson Auditorium. (2002). *Intergovernmental group on tea expert consultation on tea market issues.* United States Department of Agriculture. 25 September, 2002.

Unilever (2000). *Technical report on Sustainable Agriculture Programme.* Nairbi, Kenya

West T. O. and Marland G. (2002). Net carbon flux from agricultural ecosystems: *Methodology for full carbon cycle analyses*. *Environmental Pollution Journal 116*:437-442.

World Bank (2009). World Bank Water Resources Sector Strategy*: Strategic Directions for World Bank Engagement*, World Bank, Washington, DC, USA.

Yang C. S, Lambert J. D (2005). *Mechanisms of cancer prevention by tea constituents*. Coordinated Tea Farming

# APPENDICES

## Appendix I: Table of determining minimum Returned Sample Size of a given Population Size

| Population size | Confidence = **95%** Margin of Error | | | | Confidence level = **99%** Margin of Error | | | |
|---|---|---|---|---|---|---|---|---|
| | **5.0%** | **3.5%** | **2.5%** | **1.0%** | **5.0% 1.0%** | | **3.5%** | **2.5%** |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 20 | 19 | 20 | 20 | 20 | 19 | 20 | 20 | 20 |
| 30 | 28 | 29 | 29 | 30 | 29 | 29 | 29 | 30 |
| 50 | 44 | 47 | 48 | 50 | 47 | 47 | 48 | 50 |
| 75 | 63 | 69 | 72 | 74 | 67 | 71 | 73 | 75 |
| 100 | 80 | 89 | 94 | 99 | 87 | 93 | 96 | 99 |
| 150 | 108 | 126 | 137 | 148 | 122 | 135 | 142 | 149 |
| 200 | 132 | 160 | 177 | 196 | 154 | 174 | 186 | 198 |
| 250 | 152 | 190 | 215 | 244 | 182 | 211 | 229 | 246 |
| 300 | 169 | 217 | 251 | 291 | 207 | 246 | 270 | 295 |
| 400 | 196 | 265 | 318 | 384 | 250 | 309 | 348 | 391 |
| 500 | 217 | 306 | 377 | 475 | 285 | 365 | 421 | 485 |
| 600 | 234 | 340 | 432 | 565 | 315 | 416 | 490 | 579 |
| 700 | 248 | 370 | 481 | 653 | 341 | 462 | 554 | 672 |
| 800 | 260 | 396 | 526 | 739 | 363 | 503 | 615 | 763 |
| 1000 | 278 | 440 | 606 | 906 | 399 | 575 | 727 | 943 |
| 1200 | 291 | 474 | 674 | 1067 | 427 | 636 | 827 | 1119 |
| 1500 | 306 | 515 | 759 | 1297 | 460 | 712 | 959 | 1276 |
| 2000 | 322 | 563 | 869 | 1655 | 498 | 808 | 1141 | 1785 |
| 2500 | 333 | 597 | 952 | 1984 | 524 | 879 | 1288 | 2173 |

**Source: Cochran Statistical Table (2006)**

**Note:** Equally, small margins of error are desirable and frequently a precision of $\pm 10\%$ is used to determine reliability of sample size. The required sample size was determined by Cochran's proportionate to size sampling methodology (Cochran, 2006).

**Appendix II: Questionnaire**

Kimtai K. Ronald is a student at Jomo Kenyatta University of Agriculture and Technology (JKUAT) pursuing a Master's degree in Environmental Legislation Management and with permission from Tea Research Foundation of Kenya is undertaking a researching on the adoption of purple tea farming as a coping mechanism to climate change. This questionnaire is meant to gather relevant information that will help in achieving set objectives in this research.

The information provided will be accorded the confidentiality it deserves, as the research is strictly educational.

Section A: General information of the respondents

1. Age: Below18 years [ ]  19 – 25 years [ ]  26– 30 years [ ]  31 – 40 years [ ]

41-45 years [ ]  46 - 50 Years [ ]  51 - 55 Years [ ] 56 - 60 Years [ ]  above 60 Years [ ]

2. Marital status:  Married [ ]  Single [ ] Divorced [ ]

3. Level of education:  Primary education [ ]  Secondary education [ ]

College [ ]  University [ ]  Informal Education [ ]

4. What is your relationship with the tea sector i.e tea farmer, farmer's sibling or employee?

…………………………………………………………………………………………………
……

5. For how long have you been in the tea sector as a farmer or employee?

…………………………………………………………………………………………………
…….

7. Which tea variety do you grow and when did you establish it?

i. Green [ ]...…….

ii. Purple [ ]………

iii. Both [ ]………

a. If purple, how? /why did you consider it over green tea?

......................................................................................................................................
......................................................................................................................................
................

b. If both, why did you not maintain the green variety only?

......................................................................................................................................
......................................................................................................................................
................

8. Which tea variety seedlings are readily available in the locality?

…………………………………………………………………………………………………
……

9. What is the cost of both varieties? ............................................................................................................................
.

10. What type of ownership is your land?

( ) Communal/Public ( ) Private/Individual

Others Specify………………………………………………………………………………..

11. How many tea bushes did you establish for?

a) Green tea ( )

b) Purple tea ( )

**Section B: The extent to which farmers have established Purple Tea farming**

1. How have the following factors influenced purple tea variety establishment/growth?

i. Availability of Land …………………………………………..…………………

ii. Availability of extension services...…………………………………………………

iii. Old tea gardens …………………………………………………………………..

iv. Population growth…………………………………………………………………

2. When did you plant either of the variety and which year did you start harvesting?

Purple………………………………………………………………………………..

Green…………………………………………………………………………………

3. Does the same factory which collects green tea also collect the purple variety?

Yes [ ] No [ ]

If not who collects? ...........................................................................................

Is it collected regularly? ..........................................................................................

How are the prices per kg before they are processed? ...................................................

4. How can you compare the withstanding rate of purple tea variety to green tea variety to?

i. Drought resistance……………………………………………………………….

ii. Frost resistance…………………………………………………………..

iii. Hailstone resistance………………………………………………………………

iv. Pests and diseases………………………………………………………………

**Section C: Socio-economic factors undermining the adoption of Purple Tea farming**

1. a. What are the roles of women, men and children in tea farming?

………………………………………………………………………………………………
…………………………………………………………………………………………

b. Are women and children overlooked in the sharing of tea income?

…………………………………………………………………………………………

2. What are the available channels of information concerning purple tea farming?

………………………………………………………………………………………………
………………………………………………………………………………………………
……

3. How can worker-employee relationships affect tea productivity?

………………………………………………………………………………………………
…………………………………………………………………………………………

4. How do the following safety and health hazards influence tea productivity?

i. Cuts to hands, legs and feet from the sharp edges of tea leaves……………………

ii. Injuries from cutting tools……………………………………………………….

iii. Exposure to harsh climatic conditions………………...........................................

iv. Snake and insect bites……………………………………………………………

v. Poisoning and long term health problems from pesticide use or exposure………

vi. Long hours of work………………………………………………………………

vii. Stress and harassment by supervisors…………………………………………..

5. Are the purple and green tea processed together? How are the prices determined of processed green and purple tea variety?

………………………………………………………………………………………………

……………………………………………………………………………………………

6. How the following labour related constraints are affects tea productivity?

i. Pruning …………………………………………………………………………

ii. Plucking…………………………………………………………………………

iii. Weeding ………………………………………………………………………..

iv. Fertilize and chemical application……………………………………………...

v. Sundry/miscellaneous activities………………………………………………..

**Section D: The role of Purple Tea variety as a mitigation measure to climate change**

1. Have you witnessed climate change indicators in the recent past?

Yes [ ] No [ ]

If yes, give your view of mitigation measures to be employed to contain it.

………………………………………………………………………………………………

………………………………………………………………………………………………

……

2. What do you think is the cause of climate change?

……………………………………………………………………………………………

………………………………………………………………………………………

3. State the impacts of climate change on:

a. Green tea variety;

i.

ii.

iii.

b. Purple tea variety;

i.

ii.

iii.

4. Is the establishment of tea farming likely to raise the water table and curb drought occurrence?

Yes [ ] No [ ]

If yes, state how

……………………………………………………………………………………………

…

## Appendix III: Interview Schedule

The oral questions were based on the following topics and sub-topics between the researcher and the respondent whereby the researcher captured the responses accordingly.

1. Tea Research Foundation of Kenya (TRFK)

**a. Ecological aspects**

i. Temperature
ii. Precipitation
iii. Soil components
iv. Time (growth rate)
v. Maturity time(before fist pluck)
vi. Longevity of tea picking

**b. Health aspects**

i. Pests and diseases
ii. Tropical diseases
iii. Lifestyle related diseases
iv. Health benefits of drinking purple tea and if there are statistics to support this

**c. Environmental aspects**

i. $CO_2$ Sequestration
ii. Soil erosion

2. Tea Factories

**a). Productivity and marketing**

i. Harvest during wet season (Kg/bush)

ii. Harvest during dry season (Kg/bush)

iii. Total annual harvest during dry and wet season (kg/bush)

iv. Comparative analysis of market dynamics of purple versus green tea

3. County Agricultural Extension Officers

**a). Extension services**

i. Growth rate

ii. Establishment rate

iii. Problems that hinder adoption of purple tea farming

iv. Support from government in their extension effort

v. Pest and diseases of purple tea

vi. Control measures both cultural and use of agrochemicals

## Appendix IV: $CO_2$ Sequestration Measurement

**$CO_2$ sequestration measurement components for purple and green tea variety**

1. **Season**

i. The $CO_2$ seq. will be determined during dry and wet seasons separately and the results quantified respectively according to number of years.

The results will be attained by use of the *algorithm* equation

$$\text{i.e C Seq.} = \frac{\{W = 0.25(D)2H\}}{50\%} * \text{C ratio}/ CO_2\text{-e}$$

2. **Above and underground CO2 seq. ratio**

i. The $CO_2$ seq. ratio will also be determined between the above ground biomass and underground biomass (20% of the above ground biomass)

The above ground $CO_2$ seq. ratio results will be attained by use of the *algorithm* equation

$$\text{i.e C Seq.} = \frac{\{W = 0.25(D)2H\}}{50\%} * \text{C ratio}/ CO_2\text{-e}$$

The following *allometric* equations will be used to determine underground $CO_2$ seq. ratio

$\log W = a + b \log DBH$ or $DBH^2 + h + DBH^2h$

Whereby, *a* and *b* are regression coefficients and *h* height of the tree

3. **Acreage $CO_2$ seq. potential**

i. The acreage $CO_2$ seq. potential will be determined according to number of acres cumulatively (Kg/ha or t/ha).

The results will be attained by use of the *algorithm* equation i.e C Seq. = {W = 0.25(D)2H} * C ratio/ $CO_2$-e

50%

4. **Number of years**

i. The $CO_2$ sequestration ratio will be quantified according to number of years to determine the rate of sequestration per year (Kg/year or t/year)

The results will be attained by use of the *algorithm* equation

i.e C Seq. = {W = 0.25(D)2H} * C ratio/ $CO_2$-e

50%

## Appendix V: Growth Rate Measurements

The researcher will employ Growth rate algorithm to determine the Relative Growth Rate of purple tea as compared to RGR of green tea.

The following equation will be used throughout the specific and quantifiable conditions.

$RGR = \frac{L2-L1}{t2-t1}$ Where L*i* is the length of the plant at time t*i*

The conditions will include;

i. Prevailing temperatures
ii. Relative humidity
iii. Precipitation/rainfall
iv. Soil pH
v. Soil structure/aeration
vi. Supply of mineral nutrients