UNIVERSITY OF NAIROBI

CROP DIVERSIFICATION USING IMPROVED SWEET POTATO [*Ipomoea batatas* (L.) Lam.] VARIETIES AS AN ADAPTATION STRATEGY TO CLIMATE VARIBILITY BY SUBSISTENCE FARMERS IN TAITA HILLS, KENYA

BY

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DECLARATION

I declare that this thesis is my original work and has not been submitted for examination in any other University. Where other people's work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

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DEDICATION

This thesis is dedicated to my family; my late dad, mum, brothers and sisters, husband and sons Adrian and Joel Jeremy.

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ABSTRACT

A study on mechanisms used by subsistence farmers to cope with climate variability and change was conducted in the Taita Hills, Kenya from January 2014 to March 2015. Household surveys together with key informant interviews were used to collect data to assess farmers' use of crop diversification as a strategy to cope with climate variability and change. Further there was an assessment of past crop records in relation to weather and climate data in the area. The study then assessed the potential of improved sweet potato varieties to shield farmers from crop failures. One hundred and ninety one (191/393) respondents cited drought as the event that has affected them in the past. Various forms of crop diversification have been employed by farmers; however, improved sweet potato variety did not feature much as vines are obtained locally. The most preferred being drought resistant crops (52%), the other diversification forms adopted by the community included crop variety (18%), fodder (17%), horticulture (9%), cash crops (1%). Demographic factors strongly influenced choice of crop for crop diversification as a strategy. They include age, gender, marital status, and occupation, duration of residence and source of income of the respondents. Analysis of past crop performance in relation to past weather data revealed a significant positive correlation between rainfall amount and maize performance $P \leq 0.01$. There was no significant correlation between yields of other crops and rainfall and temperature. This study has shown that the impacts of climate variability are felt by the farmers and that their adaptation strategies are guided by their perception of the same. An assessment of improved sweet potato varieties revealed varied performance among the five varieties as well as in three selected sites. Bungoma variety outperformed the other varieties with a total and marketable yield of 1313.2Kg/ha and 895.0 Kg/ha respectively. The Ejumla variety recorded the highest attack on yield by insect pests which affected significantly its total yield and marketable yield. The site in Josa recorded the highest total yield and marketable yield despite it recording the highest pest attacked yield (0.16 g/ha) whereas Mwatate site recorded the least total yield and marketable yield. Crop diversification was encouraged and use of improved sweet potato varieties recommended.

Keywords: Climate variability and change, subsistence farmers, crop diversification, Sweet potato varieties, Taita Hills, Kenya.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ACRONYMS

ANOVA	-	Analysis of Variance
CHIESA	-	Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa project
CV	-	Coefficient of Variation
DFID	-	Department for International Development
EMCA	-	Environmental Management and Coordination Act
HIV/AIDS	-	Human Immunodeficiency Virus/ Acquired Immune Deficiency Syndrome
IPCC	-	Intergovernmental Panel on Climate Change
KALRO	-	Kenya Agricultural and Livestock Research Organization
KARI	-	Kenya Agricultural Research Institute
KII	-	Key Informant Interviews
LSD	-	Least Significant Difference
MAM	-	March April May
MASL	-	Meters above sea level
NEMA	-	National Environment and Management Authority
SAS	-	Statistical Analysis System
SSA	-	Sub Saharan Africa

CHAPTER ONE

1.1 INTRODUCTION

Many people in Sub-Saharan Africa (SSA) and particularly in Kenya depend on rain-fed agriculture for their food and source of livelihood. Food production uncertainties associated with seasonal rainfall variability will continue being a major constraint to agricultural food production in the tropics for quite a long time (Cooper *et al.*, 2008).

80 % of the population in Kenya live in rural areas and practice smallholder farming for their subsistence. This accounts for the largest country's agricultural food production source (Mohajan, 2014). Despite this, smallholder agricultural production is influenced and affected by environmental factors such as land degradation, soil erosion, declining soil fertility and poor water management. Agriculture is the main user of environmental resources like water, forests, pastures and nutrients (DFID, 2002). Climate variability and change, demographic pressures, insecure land tenure systems and inadequate institutions to advice farmers also threaten agricultural production. Extreme climatic events are likely to result in more severe impacts on the African continent as they directly affect households as a result of high dependency on agriculture (Collier *et al.,* 2008). This study was conducted in the Taita Hills, a mountainous ecosystem in Southeast Kenya where rainfall seasonality is complex and can change within tens of kilometers with changes in topography.

Farmers in Kenya engage in intensive agriculture, with emphasis placed on one or two crops at any given time. Intensification of agriculture in most parts of the world, has resulted in high yields, however, climate variability and change pose a challenge to crop yields from rain-fed agriculture since weather conditions directly influence the performance of most plants (IPCC, 2007; Parry, 2007). Agricultural intensification also affects the distribution of organisms through conversion of land to increase the area under tillage hence affect the ecological processes that are dependent on the interaction of these organisms (Matson *et al*, 1997, Benton *et al*, 2003). In stable climatic conditions, there is a strong interdependence between the climate, soils and the biotic components in a given space (Turner, 1989). In order to sustain and maintain productivity, interaction between various organisms in a particular ecosystem should be maintained.

Like most areas in Africa, farmers in the Taita Hills of Kenya practice intensive agriculture on small sized farms. The income of many families is solely dependent on rain-fed agricultural production. As a result, the area has experienced land use changes and arable land for farming has decreased due to land degradation caused by poor agricultural practices and loss of top soils (Pellikka *et al*, 2004). The small size of the farms coupled with indigenous management practices, has made it difficult for the farmers to manage risks associated with crop failures (Fleuret, 1988). Current trends indicate that agriculture will occupy up to 60% of the area by 2030 (Maeda, 2012). This will in turn result in reduction of vegetation cover leaving soil more exposed to direct impacts of rainfall and wind. In the lower altitudes, the soils are cracked due to compaction and less water infiltration. The lower zone experiences hydrologic droughts during the dry season (Pellikka *et al,* 2013) and soil erosion during the wet season (Sirviö *et al*, 2004). Expansion will also result in an increase in the annual demand for irrigation water by approximately 40 %. Use of fertilizers also leads to increased concentrations of nitrous oxide in the atmosphere which also contributes to climate change (Rosenzweig and Hillel, 1998).

To cope with climate variability and change, farmers need to adopt sound agricultural practices. Planting the right seed materials combined with the right inputs can ensure farmers get high yields from various crops. Increasing crop diversity also referred to as crop diversification, can also help cushion farmers against total crop failure as different crop species respond differently to shocks associated with climate variability (Paavola, 2008; Lin, 2011).

Crop diversification refers to the deliberate effort by farmers to increase the number of species of crops, varieties or hybrids of one specific crop in order to reduce susceptibility to climate variability and change as well as other attributes like pest attacks that might result in reduced yields (Wandel and Smit, 2000). It provides a buffer to farmers against environmental and economic risks associated with changes in land use and climatic patterns. In addition it helps increase income from farm holdings, improves fodder availability for livestock, conserves natural resources as well as increase community food security. Crop diversification is however influenced by many attributes such as the perception of farmers to climate change, seed availability, poverty levels, income distribution, farm output, gender relations as well as perceptions to farming systems (Ellis, 1998). Crop diversification is an old practice among many rural communities, however, most farmers use indigenous methods of farming and in most cases, do not use improved seed varieties. Crop diversification has the potential to reduce vulnerability to climate variability and change at the farm level but its uptake by farmers for this reason has not been well documented (Bradshaw *et al*, 2004). Research has been a bit limited and more needs to be done to understand the benefits arising from on farm plant interactions. When coupled with improved seed varieties, crop diversification has potential to improve farm yields, build resilience and also stabilize the yields from farms (Mugendi, 2013).

This study therefore sought to assess the farming practices in the Taita Hills, Kenya by reviewing the various forms of crop diversification conducted in the area. In order to help improve on crop diversification, there was also a review of the performance of various crops in the study area in relation to past climate patterns. Emphasis was placed on sweet potato farming as an alternative crop that can help cushion farmers against climate variability. Farming practices with regard to sweet potato growing were evaluated and new varieties tested through farmer mobilization in the study area.

Sweet potatoes [*Ipomoea batatas* (L.) Lam.] are grown as an alternative crop to maize to help cushion farmers during extreme climatic events (Ebregt *et al*., 2007). However, sweet potato yields are hampered by traditional farming practices like piece meal harvesting (Nicole, 1997) and recycling of sweet potato vines. The recycled vines are locally obtained and take a longer time to mature; they are susceptible to attacks by pests and diseases leading to increased vulnerability. Crop rotation is rarely practiced with sweet potatoes as most farmers practice piece meal harvesting. This in turn leads to increased damage by the sweet potato weevils (Ebregt *et al*., 2007; Nicole, 1997) and thus reducing the quality further. In the Taita Hills, farmers plant sweet potatoes on a flat surface, leading to increase in sweet potato weevil attack. This is so because sweet potato weevils rely on cracks in the soil to get to the storage roots. Flat surface planting brings the storage roots closer to the surface and hence increased cracks as the tubers expand (Hue & Low 2015). This in turn leads to reduced yields and thus hampering food security. With climate change, extreme climatic events are likely to be more frequent and severe thus reducing the yields further.

1.2 Problem Statement

Most farmers in the Taita Hills engage in intensive agriculture with emphasis placed on one or two crops to help them meet their daily food and other livelihood needs. However, increased temperatures and erratic rainfall due to increased frequencies of extreme climatic events has led to increased rates of crop failures. Climate variability coupled with soil degradation and the high cost of farm inputs (Soini, 2005), has led to poor yields from farms leading to threatened livelihoods and increased vulnerability among many members of the community as they are unable to meet their daily needs.

76% of the Taita people live in rural areas. 90% of this population depend on small-scale agriculture for their livelihoods (Taita Taveta County Integrated Development Plan, 2013-2017). Maize being the main crop grown by farmers in Kenya and in the Taita Hills has been severely affected by the rainfall and temperature changes thus leading to up to 60% loss in its yields (Omoyo *et al.,* 2015). In addition, maize requires high inputs such as fertilizer and manure application (KARI, 1995). This is a hindrance to many farmers since they are not able to afford the inputs therefore increasing their vulnerability to crop losses. There is hence an urgent need to understand the performance of other crops that are high yielding even with low input in order to reduce the cost of production while ensuring optimum yields even in the face of increased vulnerability. Improving seed varieties is also essential since seeds for planting crops other than maize are normally obtained locally by recycling, buying from the market, or borrowing from neighbours resulting in reduced yields further increasing vulnerability.

1.3 Research questions

The research was guided by the questions:

i) What forms of diversification have been employed by farmers in the Taita Hills?
ii) How has the weather pattern of the area been for the period between 1989-2014, how has this impacted on sweet potato production in the Taita Hills in the past?
iii) Where do farmers in the Taita Hills get their sweet potato seeds?
iv) What improved sweet potatoes varieties are available in the market and how can they perform under field conditions in the Taita Hills?
v) Can the new varieties and farming practices help improve sweet potato production and reduce vulnerability to climate variability?

1.4 General Hypothesis

There were two hypotheses for this study. First, farmers in the Taita Hills use different mechanisms to cope with climate variability. Second, responding to these impacts, farmers still use indigenous methods that are not able to sustain their sources of livelihood.

1.5 Objectives of the study

The overall objective of the study was to assess the various forms of crop diversification that have been used by farmers in the Taita Hills and how this can be linked with improved sweet potato varieties to reduce vulnerability to impacts arising from climate variability and change.

The specific objectives were:

i) To assess the various forms of crop diversification that have been employed by subsistence farmers in the Taita Hills as a response to past climate variability.
ii) To assess sweet potato production in relation to past weather in the Taita Hills.
iii) To assess the production potential of improved sweet potato varieties in the Taita Hills in order to enhance production from sweet potatoes.

1.6 Justification and Significance

Climate change poses a threat to production as agriculture is highly dependent on specific climatic parameters like rainfall and temperature. There is hence an urgent need to protect the sector from the vagaries of climate variability and change and ensure its sustainability and in turn the livelihood of many poor farmers (Chambers and Conway, 1992).

As a coping mechanism, there is need for an affordable and efficient way of producing crops because most people in rural areas practice subsistence farming and in most cases cannot afford extra inputs to enhance their yields. Crop diversification as a strategy has the potential to improve farm output in a cost effective way if employed strategically. Therefore, in combination with improved crop varieties, crop diversification can help farmers get better yields. This is due to the fact that it can reduce pathogen transmission, suppress pest attacks and also cushion against total crop failure in case of extreme events (Krupinsky *et al*, 2002; Dalin *et al*, 2009; Lin, 2011; Mugendi, 2013). The research therefore aimed at exploring forms of crop diversification that have been used by farmers in the Taita Hills to cope with crop failures as a result of extreme climatic events. Furthermore, promotion of improved sweet potato varieties to boost sweet potato production as a strategy to cope with weather extremes in the Taita Hills was encouraged.

The information obtained will help inform policies for agricultural production as this is the main occupation for the people of the Taita Hills and the East African region in general. It shall also help improve farming practices as far as sweet potato production is concerned and thus improving production and also encouraging business enterprises if there is surplus.

CHAPTER TWO

2.1 Literature Review

All farmers are at the core of and therefore major stakeholders in the climate change debate. This is because their perception, appraisal and subsequent understanding of the gradual change in global climate have a direct impact on future food production and projected farm yields. According to Maddison (2007), a number of surveys conducted in Africa point to and acknowledge farmers belief in elevating temperatures and declining precipitation rates. It is worth noting that their ability to detect and ascertain climate change, influences their adaptation and integration into the agricultural activities. There exist major differences in the inclination of farmers living in different and distinct geospatial regions in as far as adaptation to climate change is concerned. Adaptation strategies were also found to be influenced by economic means of the household. Farmers failed to attach reduction in agricultural yields to climate changes and instead sited lack of capital to enhance adaptation (Antwi-Agyei *et al,* 2014). In such cases, they attributed declining production to lack of appropriate seeds and market accessibility problems while others cited security of tenure as the underlying issue.

Agriculture has seen several changes over the years. In sub-Saharan Africa, the change is characterized with clearing of land to create space for agriculture (Pellikka *et al*, 2013). Farmers also engage mostly in intensive agriculture with emphasis placed on a few crops, in order to improve farm yields. This has led to conversion of large areas into fields of monocultures. Agricultural intensification, which refers to the use of a greater amount of non-land resources such as labour and farm inputs for a given piece of land to produce higher output aims at solely increasing productivity from farms. It can also refer to an increase in financial and physical investment to boost existing patterns of production leading to an increase in yields from food and cash crops as well as livestock production. The aim of agricultural intensification is to increase yields from existing production by altering the amount and type of inputs used. (Dixon *et al*, 2001).

Intensive agriculture uses high yielding varieties and aims at solely increasing productivity of a given area. This has however, resulted in a decrease in the natural resources available resulting in a decrease in plant and animal diversity and also a decrease in the provision of essential ecosystem services (Krebs *et al,* 1999). Chemical use is also a common characteristic of intensive agriculture. This has hence contributed to depletion of plants and insects that otherwise play important roles such as pollination and also provision of habitat for important insects (Holzschuh *et al*, 2007).

In East Africa, maize is the main crop in a mixed system of farming. However, the system is threatened by high prices of fertilizers relative to the maize prices hence resulting in low yields and soil fertility decline. Drought due to climate variability is said to be the main cause of poor yields. The system is also affected by changes in market process (Dixon *et al,* 2001).

Water resources influence agricultural production in the study area. In the high zones (1500-2100 m.a.s.l. S 03^{0}22’54.98’’ E 038^{0}20’42.32’’to S 03^{0}24’14.83’’ E 038^{0}17’3.44’’) where water is readily available, crops such as maize, beans, bananas and fruits are grown on farms lands. The scenario changed in the mid zone (1000 to 1700 m.a.s.l. S 03^{0}26’38’’ E 038^{0}21’48.13’’ to S 03^{0}22’54.98’’ E 038^{0}20’42.32’’) as crops such as bananas and sugarcane are grown in moist water valleys. In the lower zones (700- 1250 m.a.s.l. S 03^{0}29’35.41’’E 038^{0}22’43.72’’ to S 03^{0}26’38’’ E 038^{0}21’48.13’’) it is normally too dry to support maize growing and agricultural scope changes to early maturing sorghum and millet varieties as well as livestock production (Soini, 2005).

Water shortages during the crucial phenological stage between flowering and grain filling are also found to affect maize yields due to maize sensitivity to low soil moisture content. Consequently, unreliable rainfall will thus lead to increased vulnerability of farmers due to increased crop failures (Omoyo *et al*, 2015).

Intensification can result in reduced biodiversity on the farm as indigenous plant, insect and animal diversity are replaced with new high yielding varieties (Krebs *et al,* 1999). Biodiversity includes plants, animals and insects and is influenced by the structure of the landscape and management practices. It plays an important role in the production of an agricultural system in that besides production of food, it helps in exchange of nutrients, regulation of the microclimate of the area, suppression of undesirable organisms and cleaning of poisonous chemicals (Altieri, 1999).

Most conventional fields have low plant diversity as most virgin lands are cleared for agricultural production; this in turn affects the flower density in the fields. The flower density in any given farm affects the diversity of insects. Insect diversity is an important aspect of agricultural production. A study conducted on pollinator bees found that proximity to natural habitats improved the rate at which pollination occurred in plants, it also found that even in crops that had heavy pollination requirements, full pollination occurred as the distance between crop and natural habitat reduced (Kremen *et al*, 2002).

The concentration of one species of plants in one place also increases the number of pests in the field as most pests get attracted by concentrations of their food stuff (Davari *et al*, 2010). Species concentration can be reduced by either incorporating other crops in between rows of the target crop- crop diversification or by routinely changing the crop that is planted at a particular spot- crop rotation. This in turn helps to reduce the damage caused by pests.

Herbicides and other chemicals that are a characteristic of many farms that practice intensive agriculture affect both plant and insect diversity on the farm. Farm productivity is in turn affected as services obtained from the habitat are destroyed (Holzschuh *et al,* 2007). In order to maintain production, there is need for alternative, more effective and more sustainable practices (Mugendi, 2013).

Climate change is likely to exert pressure on water resources, agricultural production, natural resource productivity, health, and infrastructure and also influences desertification. The economic development of the African continent is dependent on agricultural resources and any changes in water availability will significantly affect development. Poverty remains a huge burden in the African continent despite the over reliance on the natural environment resources. Coupled with climate change, these problems are likely to intensify and create new combinations of challenges for the continent (Boko *et al.*, 2007).

Habitats that are well managed have the potential to reduce the rate of losses arising from pests, diseases and weather extremes (Lin, 2011). It can also reduce the cost incurred due to agricultural intensification (Mugendi, 2013) as less fertilizer will be required on the fields. This in turn has a direct impact on mitigation of climate change as most of the Nitrous oxide emissions are from fertilizer use on farms. Diverse habitats can be created by incorporating other plants into the farm thus reducing the impacts from intensification (Holzschuh *et al,* 2007).

Diversification entails altering of the farm production system in order to increase yields and income from the enterprise. It may involve the complete change of the crops grown or incorporate high yielding varieties or even changing to incorporate value addition to crops produced to help generate income (Dixon *et al*, 2001). A diversified farming system can also be defined as a system that incorporates several practices to increase production over different spaces as well as different times (Kremen *et al*, 2012). Crop diversification helps in maintaining a balance of nutrients by ensuring recycling of nutrients and ecosystem services hence resulting in good quality soils as well as provision of pollination services and pest and disease control.

Two levels of diversification can be identified: geographic diversification and crop diversification. Geographic diversification entails increasing the number of areas under crops being produced whereas crop diversification on the other hand, entails increasing the number of crops produced. It can involve increasing the varieties or hybrids of a particular crop that is being produced. This helps to reduce the effects of micro climatic events and other impacts that lead to low yields (Wandel and Smit 2000). This increases the spatial as well as the temporal diversity on the farm and thus resilience is increased.

Different crops respond differently to changes in the weather conditions. A study carried out in Morogoro, Tanzania found that in dry years, there was a decrease of up to 75% and 50% for maize and rice respectively, no much variation was recorded for sorghum and cassava yields while the yields of sweet potatoes increased in those years (Paavola, 2008). Crops such as sweet potatoes take a shorter time to mature and thus can cushion farmers from crop failures in case of low rainfall amounts. Sweet potatoes can withstand low rainfall amounts of 500 mm but require a maximum of between 750 mm to 1,000 mm. Maize on the other hand is extremely sensitive to temperature rise therefore any changes in temperatures affect its yields. When compared with rainfall, temperatures have been found to more impact on the total yields. In one study by Omoyo *et al.,* (2015) it was found that increase in temperature had led to over 60% variation in maize yields.

Sweet potato production on the other hand, is hampered by changes in soil moisture content. Soil moisture content needs to be maintained between 25 % and 50 %. Soil moisture deficits result in reduction of total plant mass where as any increases in soil moisture support shoot formation as opposed to tuber formation (Saraswati, 2007). Thus sweet potatoes will perform better in a season with relatively less rainfall amounts (about 500 mm). It equally affects the planting dates as there needs to be an adjustment for planting when the rains have subsided and soil moisture has decreased as moisture saturation affects the size and quality of tubers.

In order to ensure yields and cushion farmers from total crop failures, farming households have been encouraged to adopt drought resistant crops. This can be carried out independently as a strategy or in combination with other strategies like adjusment of the dates of planting and use of plant varieties that mature fast (Shiferaw *et al*, 2014, Antwi-Agyei *et al* 2014). The choice of adaptation strategy is influenced by the socioeconomic characteristics of the households.

Besides yields, crop diversification enhances pollination services and can also help suppress pest infestations as it helps reduce the concentration of food for pests (Mugendi, 2013, Davari *et al*, 2010, Dalin *et al*, 2009). Increasing the distance between sweet potato crops by using a barrier crop and crop rotation was found to be effective in the management of sweet potato weevil, *Cylas spp* as it makes the penetration of pests' impossible (Ames *et al*, 1996).

Crop mixtures also help increase the number of natural enemies for insect pests, as well as making the penetration of insect pests impossible. It can also help suppress disease attacks by making disease pathogen penetration impossible and also breaking disease cycles (Krupinsky *et al*, 2002). It also increases production (Smith *et al*, 2008) by improving soil fertility (Mugendi, 2013). Crop diversification can also help farmers buffer their farms against climate change as it ensures that farmers don't suffer total crop losses.

Smith *et al.* (2008) found that agricultural production linked with good ecosystem management resulted in increased yields and also reduced chemical inputs in these systems did not result in reduced yields. Increased crop or species diversity on a farm resulted in improved ecosystem services that enhance food production.

In order to suppress pest and disease attacks, crop diversification helps in provision of host plants and serves as habitats for the natural enemies of pest insects. The natural enemies help to reduce the abundance as well as the damage by the insect pests. The mixture of crops also reduces resource concentrations and thus preventing weeds and pests. In addition, the crop mixtures modify the farm environment making the dispersion of pest and disease causing pathogens difficult (Mugendi, 2013). In another study, Krupinsky *et al.*, (2002) found that by growing several species of crops in a rotation also helped in preventing disease attacks. A rotation between cereal crops and non-cereal crops minimizes attacks from soil borne and plant residue diseases. Furthermore, crop diversification can enable rural families create several activities that help them improve their standards of living (Ellis, 1998).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in the Taita Hills along the 2 kilometer wide CHIESA project transect that runs from Mwatate in Mwatate sub-county to Mwanda in Wundanyi sub-county, Taita-Taveta County in Southeast Kenya. The research transect runs along an altitudinal gradient as one progresses from Mwatate to Mwanda, this results in three zones that are agro-ecologically different. Land use patterns also change along the gradient leading to different challenges to the members inhabiting the different zones.

Map of the study area

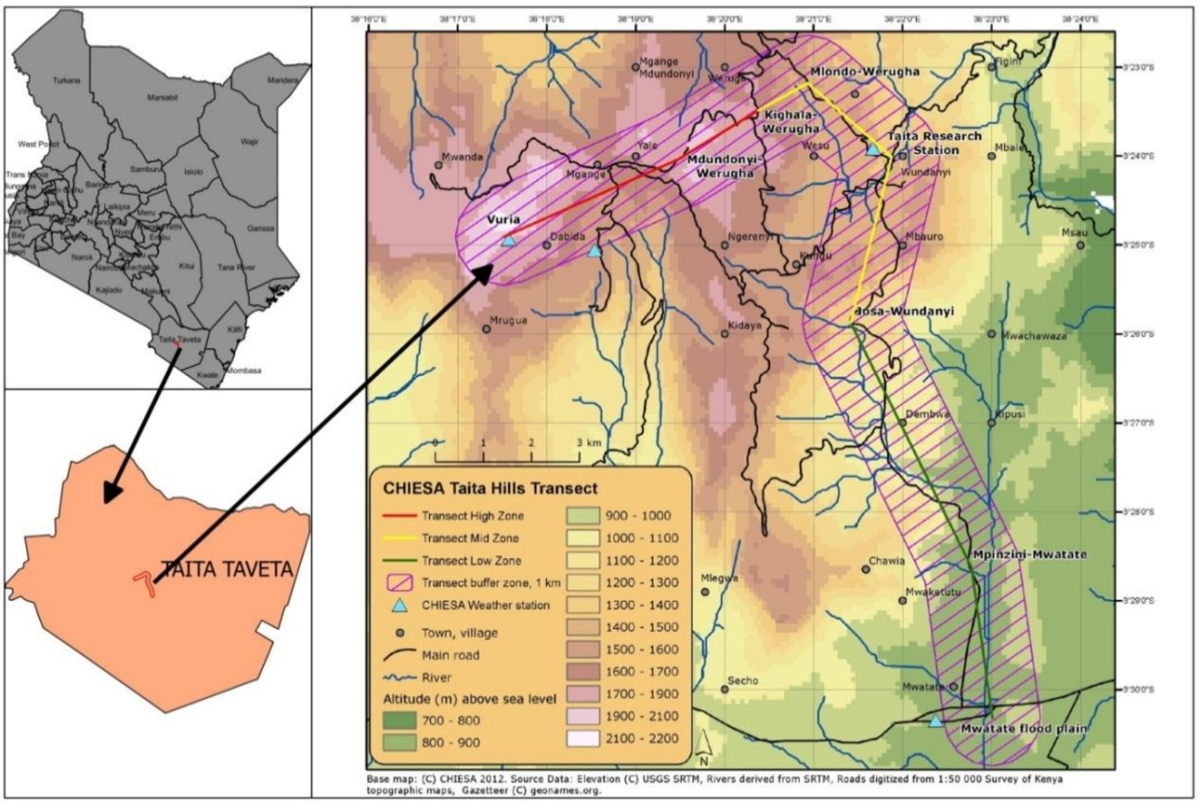

Figure 1: A map of Taita Hills region showing the research transect

(Source: Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa)

The study area was subdivided into three altitudinal zones: High zone which lies between 1500-2100 m.a.s.l. (S $03^0$22’54.98’’ E $038^0$20’42.32’’to S $03^0$24’14.83’’ E $038^0$17’3.44’’), mid zone which lies between 1000 to 1700 m.a.s.l. (S $03^0$26’38’’ E $038^0$21’48.13’’ to S $03^0$22’54.98’’ E $038^0$20’42.32’’) and the transect lower zone which lies between 700- 1250 m.a.s.l. (S $03^0$29’35.41’’ E $038^0$22’43.72’’ to S $03^0$26’38’’ E $038^0$21’48.13’’). Taita Hills are a biodiversity hotspot and form part of the Eastern Arc Mountains (Maeda *et al.*, 2010).

3.2 Sampling Design:

The study employed a multi-stage stratified random sampling procedure that combined purposive and random sampling to select the households from the three strata that were established.

The first stage entailed division of the study area according to temperature and rainfall characteristics. Based on these criteria, the area was divided into Lower Zone, Mid Zone and High Zone.

The sample size was estimated based on the formula by Mahajan, (1997):

$n = Z^2pq\ L^2$,

Where:

n = required sample size

Z= confidence level at 95% (standard value of 1.96)

p = estimated population that is engaged in mixed farming 0.34 (34 %) (Ouma *et al.*, 2013)

q=1-p

L = precision of estimate (allowable error)

With an L of 0.05(5%), the sample size will be:

$n = 1.96^2 \times 0.34 \times 0.66/ (0.05)^2 = 346$

To gather for drop outs 10% was added as advocated by Mugenda (2008) making the sample size of 381 respondents as the minimum. This sample was evenly distributed across the three sites. A household survey was then conducted with the aim of understanding the vulnerability of the households, forms of crop diversification strategies employed so far as well as factors that have influenced the choice of a crop diversification strategy.

3.3 Research tools

3.3.1 Semi structured questionnaire

For quantitative study a semi structured questionnaire that contained both open ended and closed ended questions (Appendix 2) was used. The questionnaire survey was conducted in the study area during the period January to April 2014. The questions covered the background information, a brief description of the extreme events that affected their households in the recent past (10 years), how they responded to the extreme climatic event overtime as explained by Tarleton and Ramsey, (2008). The questions were to help capture the farmers who, in responding to the effects of climate variability and change, had used crop diversification as a strategy to better cope with climate variability.

3.3.2 Key informant interviews

Key informant interviews (KII) were used to enrich the quantitative aspects of the study (Appendix 1). A total of six agricultural officers and three community focal persons were interviewed. The script covered issues underlying farming practices, farmers' choice of crops, and any crops that have been promoted in the area and the up take by farmers, any changes in farm produce. The questions also gave an indication of factors that influence farmers' choice of crops. The informants were agricultural officers and community focal persons.

3.3.3 On farm demonstration

Farmer demonstration farms were established on the upper, mid and lower zones (Werugha, Josa and Kipusi valley villages) to assess farmer's willingness to accept new adaptation strategies. This involved the use of five varieties of sweet potatoes; white backed, white fleshed Bungoma, red backed yellow fleshed Kipenda Roho, white backed yellow fleshed Mtwapa 8, red backed white fleshed Riziki and orange fleshed Ejumla. Sweet potato vines were sourced from KARLO Mtwapa. The study ran through the period May 2013 to March 2014.

Plate 1: Farm Preparation in the Taita Hills.
Photo by B. Monchari, 2014

In the background is Vuria forest fragment. Middle ground shows normal farming practice in the area while the foreground shows farmers demarcating the area for planting sweet potatoes during the demonstration.

Willing farmers were trained on use of ridges to grow sweet potatoes as a new adaptation strategy rather than the flat farming that is normally practiced in the area. The farmers were also trained on cultural practices (planting, weeding, pest control, harvesting and post harvesting approaches). A demonstration farm and 10 on farm trials was established on each site. The farmers were supported technically during planting, growth period (weeding, pest attack, watering) and during harvesting. Yields from the demonstration plots were weighed and recorded for analysis.

3.4 Statistical Analysis

Data was entered, coded and cleaned in the excel software (Microsoft Office 2010) and analyzed using standard statistical packages, namely the Statistical Package for Social Science (SPSS version 20) and Statistical Analysis System (SAS version 9.1.). For objective one and two descriptive and inferential statistics were applied. Chi square was used to test relationship between variables at bivariate level. For objective one, crop diversification was the dependent variable while individual and social economic factors were the independent variables. For objective two, historical rainfall, temperature data from meteorological department were obtained together with crop performance data from the Ministry of Agriculture were obtained and used. For objective three data from field evaluation was subjected to the General Linear Model procedure in SAS version 9.1 to determine analysis of variance (ANOVA) on yields obtained from the five varieties. Parameters used to evaluate the yields were total yield, Marketable yield and pest attack on yield. The means, standard errors and least significant differences, coefficients of variation were computed. The varieties were set as the fixed effects and locations and replications set as random effects (Osiru *et al.,* 2009).

3.5 Logistical and Ethical Considerations

This thesis work was part of the CHIESA project and was duly cleared by officials in Taita Taveta County. Clearance and cooperation was obtained from the administrative levels in the county. Participation was voluntary. The participants were informed of their right to decline to participate and to terminate the interview at any point during the interview session. No payments were given to the respondents for participating in this study and there were no anticipated participation costs on the part of the participants. Participants were assured of confidentiality and informed on the purpose of the survey and how survey results were to be used. Confidentiality of participants was maintained throughout the survey and presentations by limiting access to questionnaires and personal information of the respondents.

3.6 Conceptual Framework

Many factors affect farming practices in any given area. The conceptual framework used here portrays some of these factors and how this in turn affects production trends. The conceptual framework (figure 2 below) is constructed based on assumptions that the various factors that influence farming practices can influence choice of crops planted by farmers. This in turn influences crop diversification which can help farmers to better adapt to climate variability and change.

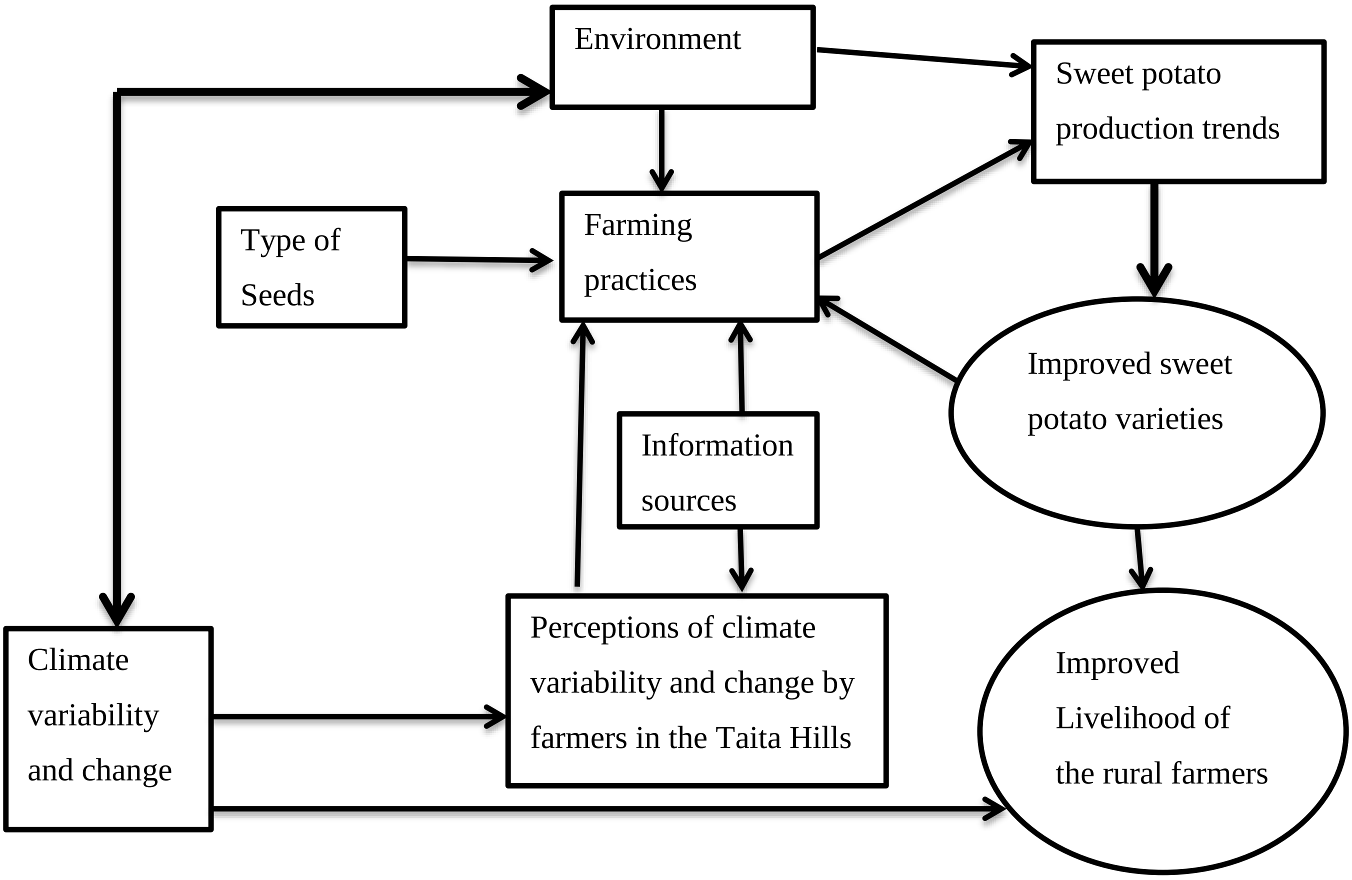

Figure 2: Conceptual framework

Adopted and modified from Legesse *et al.*, 2013

CHAPTER FOUR

4.0 RESULTS FOR THE VARIOUS FORMS OF CROP DIVERSIFICATION IN TAITA HILLS

4.1 General characteristics of the respondents

A total of 393 people took part in the questionnaire survey, of which 140 (35.6 %) were men and 253 (64.4 %) were women (Table 1 below). Based on altitude, 129 (32.8 %) were from the high zone, 117 (29.8%) from the mid zone and 147 (37.4%) were from the low zone. In addition, 59.5 % of the people sampled are married and living with their spouses and the widowed at 20.6%. From the sample population, 380 (96.7%) were Taita and 13 (3.3%) are from other ethnic groups. The main occupation and the source of livelihood 333(84.7%) in this region is subsistence farming. In regard to the level of education, 205 respondents had attained primary school education (52.2%), 102 (26.0%) secondary education, 8(2.0%) Diploma level, 4(1.0 %) University degree, 24(6.1%) Technical, 3(0.8%) other specialties, 47(12.0 %) had no formal education. Most of the households averagely have 4 to 6 (52.9%) members which were followed by those with 1 to 3 (29.0%) members.

Table 1: Demographic characteristics of the respondents

General Characteristics	Proportion of the respondents n=393 (%)
Age	
• <24 years	• 19(4.8)
• 25-34 years	• 60(15.3)
• 35-44 years	• 96(24.4)
• 45-54 years	• 78(19.8)
• 55-64 years	• 73(18.6)
• >65 years	• 67(17.0)
Gender	
• Male	• 140(35.6)
• Female	• 253(64.4)
Marital Status	
• Single	• 39(9.9)
• Married and living together	• 234(59.5)
• Married but not living together	• 24(6.1)
• Married to more than one spouse	• 2(0.5)
• Widowed	• 81(20.6)
• Divorced	• 13(3.3)

Table 1 Continued…

Occupation • Subsistence Farming • Dairy farming • Casual labour • Permanent employment • Business	 • 333(84.7) • 2(0.5) • 8(2.0) • 14(3.6) • 36(9.2)
Level of education • Primary • Secondary/High school • Tertiary/College(Diploma) • University • Technical • Other specialities • No formal education	 • 205(52.2) • 102(26.0) • 8(2.0) • 4(1.0) • 24(6.1) • 3(0.8) • 47(12.0)
Duration of residence • <1 year • 1 year-5 years • 5.1 years – 10 years • 10.1 years- 15 years • 15.1 years- 20 years • 20.1 years-25 years • 25.1 years-30 years • >30 years	 • 5(1.3) • 10(2.5) • 15(3.8) • 18(4.6) • 23(5.9) • 32(8.1) • 33(8.4) • 257(65.4)
Source of income • Subsistence farming • Livestock rearing • Cash crops • Short term labour • Permanent employment • Business • Pension and remittances	 • 300(76.3) • 19(4.8) • 3(0.8) • 22(5.6) • 12(3.1) • 29(7.4) • 8(2.0)

4.2 Perception of farmers on climate variability and change

Most of the respondents are aware of climate variability as they have been impacted directly or indirectly. 191 respondents (68 in the high altitude zone, 50 in the mid altitude zone and 73 in the lower altitude zone) cited drought as the main climatic event that has affected them in the past. Below average rainfall (68 respondents) and erratic rainfall patterns (63 respondents) has also affected them in the past as shown in the table in Appendix 3.

Key informant interviews reported that the rainfall pattern has been unpredictable and this has led to total crop failures and hence most people in the area depend on food aid especially in Mwatate area. In Werugha, rainfall is unreliable, not well distributed and erratic leading to a sharp drop in yields. Maize yields have dropped sharply from 15 bags per ha to two bags per ha.

4.3 Crop farming

Farming (388 respondents) was the major occupation for most people in the area because only 5 respondents said farming is not the primary occupation. This comprised of 321 (81.7%) who practice rain-fed agriculture, seven (1.8 %) irrigate their farms, 60 (15.3 %) practice both rain-fed and irrigated agriculture. In the last one year, a total of 348 farmers planted crops on their farms, 321 (81.7%) planted in the long rains and 289 (73.5%) in the short rains. Maize was planted by most farmers in both seasons with 286 planting in the long rains season and 245 in the short rains. Beans were second with 232 farmers planting during the long rains and 162 in the short rains. Other crops that were panted by many farmers are Cow peas (28, long rains, 24 short rains), Cassava (52 long rains, 25 short rains), sweet potatoes (40 long rains, 14 short rains) and vegetables (49 long rains, 14 short rains) as shown in the (Table 2 below).

The production of alternative crops like sweet potatoes that help cushion farmers during extreme climatic events is quite low. This leaves farmers more exposed to food insecurities in cases of extreme climatic events that affect the production of the main crops like maize and beans. There is need therefore for more farmers to plant these crops and also to increase the area under cultivation in order to boost yields.

Table 2: Farming practices and crops grown during the 2013-2014 growing season

Crop farming undertaken normally	**Proportion of the respondents**
• Yes rain fed • Yes irrigated • Yes, rain-fed and irrigated • No	• 321(81.7) • 7(1.8) • 60(15.3) • 5(1.3)
Crop farming in the last 12 months • Yes • No	 • 348(81.7) • 45(11.5)

Table 2: Continued…

Long rains • Yes • No Total	• 321(81.7) • 22(5.6) 343	
Short rains • Yes • No Total	• 289(73.5) • 29(7.4) 318	
	Long rains	**Short Rains**
Maize	**286**	**245**
Sorghum	1	3
Millet	2	2
Cow peas	28	24
Pigeon peas	6	5
Beans	**232**	**162**
Green grams	24	18
Fodder	1	0
Cassava	52	25
Avocado	4	0
Sweet potatoes	40	14
Arrow roots	5	2
Bananas	2	1
Vegetables	49	14
Other crops	6	4

Key informant interviews showed that most farmers are affected by crop failures largely due to their over reliance on maize farming. Poor farming practices have also contributed to total crop failures. Most farmers don't prepare their farms and this contributes to crop failures since many farmers don't prepare their farms adequately and on time. These failures have led to them seeking other sources for their livelihood thus negatively impacting on their farming activities since less time is spent on their farms. Crop failures are also occasioned by low investment in terms of the quality of planting seeds used since farmers don't use certified seeds thus leading to low yields. The fluctuating rainfall patterns are also a contributing factor.

4.4 Forms of crop diversification

50.3% (198) of the respondents have embraced crop diversification as a strategy to minimize impacts of climate variability. The most preferred being drought resistant crops (52%), the other diversification forms adopted by the community included crop variety (18%), fodder

(17%), horticulture (9%), trees for firewood (2%), trees for timber (1%) and cash crops (1%) as shown in figure 3 below.

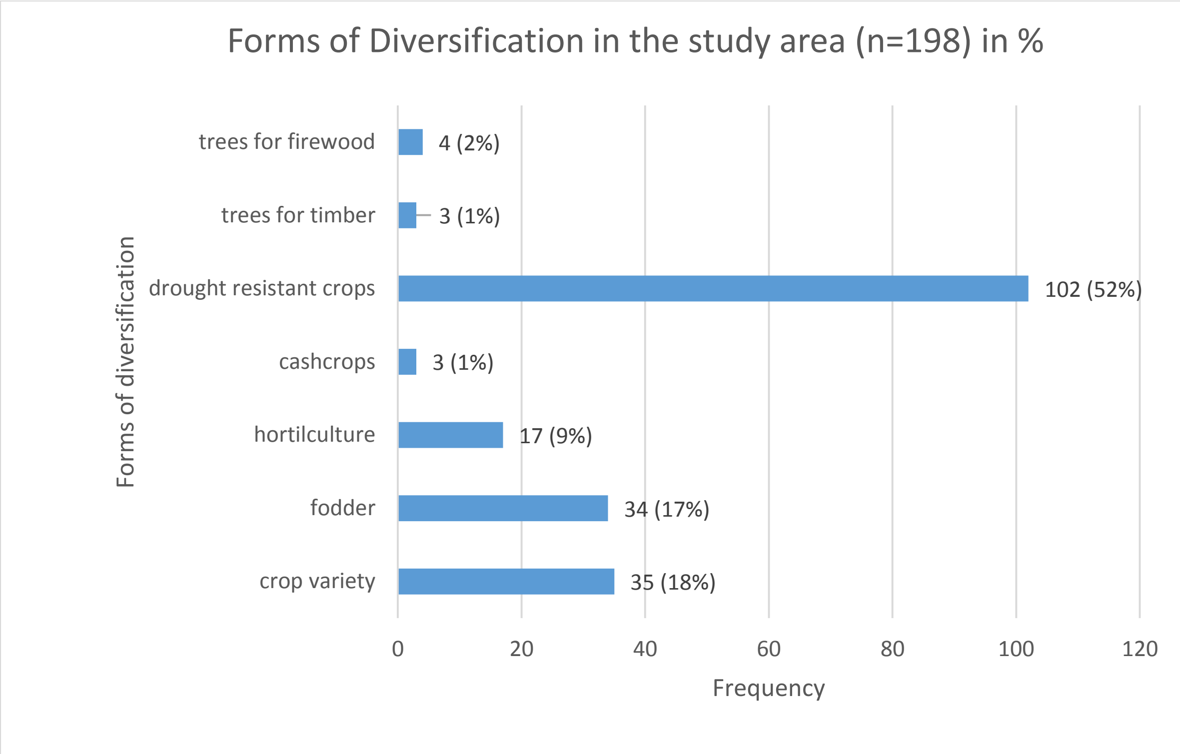

Figure 3: Farmer preferences with regard to crop diversification.

4.5 Demographic factors influencing crop diversification

A number of factors influenced the choices made by farmers in the region in adopting the various forms of crop diversification. This included age, gender, marital status, and occupation, level of education, duration of residence and source of income of the respondents. These are general indicators of vulnerability and were used in the study to assess how they influence farmers' decisions when it comes to crop diversification. Choice of a farmer to diversify crops grown on his farm is influenced age and duration of residence as these bring with them experience. Education provides exposure to information while marital status influences the choices as married couples need to provide for their families.

Table 3: Demographic factors that influence change in crop variety as an adaptation strategy

Factors	**Crop variety**		**χ 2**	**df**	**p value**
	Yes	No			
Age categories • <24 years • 25-34 years • 35-44 years • 45- 54 years • 55-64 years • >65 years	• 0 • 1(1.7%) • 14(14.6%) • 5 (6.4%) • 6 (8.2%) • 9(13.4%)	• 19 (100%) • 59 (98.3%) • 82 (85.4%) • 73 (93.6%) • 67 (91.8%) • 58 (86.6%)	**11.881**	**5**	**0.036**
Gender • Male • Female	• 15(10.7%) • 20 (7.9%) •	• 125 (89.3%) • 233 (92.1%)	0.877	1	0.349
Marital status • Single • Married living together • Married not living together • Married to more than one spouse • Widowed • Divorced	• 2(5.1%) • 25(10.7%) • 2(8.3%) • 0 • 5(6.2%) • 1(7.7%)	• 37 (94.9%) • 209 (89.3%) • 22(91.7%) • 2 (100%) • 76(93.8%) • 12(92.3%)	2.572	5	0.766
Occupation • Subsistence farming • Dairy farming • Casual Labour • Permanent employment • Business	• 33(9.9%) • 1(50.0%) • 0 • 0 • 1(2.8%)	• 300(90.1%) • 1(50.0%) • 8 (100%) • 14(100 %) • 35(97.2%)	8.394	4	0.078
Level of education • Primary • Secondary • Tertiary • University • No formal education	• 20(9.8%) • 9(8.8%) • 0 • 0 • 6 (12.0%)	• 185(90.2%) • 93 (91.2%) • 32(100%) • 4(100%) • 44 (88%)	4.293	4	0.368
Duration • 1 year-5years • 5.1-10 years • 10.1-15years • 15.1-20 years • 20.1-25years • 25.1-30 years • >30 years	• 1(6.7%) • 0 • 1(5.6%) • 4(17.4%) • 5 (15.6%) • 1 (3%) • 23(8.9%)	• 14 (93.3%) • 15 (100%) • 17 (94.4%) • 19 (82.6%) • 27 (84.4%) • 32 (97.0%) • 234(91.1%)	7.035	6	0.318

Table 3: Continued…

Source of income			6.001	6	0.423
• Subsistence farming	• 32(10.7%)	• 268 (89.3%)			
• Livestock rearing	• 1(5.3%)	• 18(94.7%)			
• Cash crops	• 0	• 3 (100%)			
• Short term labour	• 0	• 22 (100%)			
• Permanent employment	• 0	• 12 (100%)			
• Business	• 2 (6.9%)	• 27 (93.1%)			
• Pension and remittances	• 0	• 8 (100%)			

There was a significant difference between age and choice of crop variety as a form of diversification (χ2 =11.881, df=5, p=0.036). Respondents in the age brackets 35-44years (14.6%) had the highest preference for this method compared to the other ages as shown in **Table 3**, above. Majority of the respondents in this age bracket are in their productive age and are mainly living with their families therefore, in order to have sustainable food supply they have to try different crop varieties to ensure food security. However, there was no significant difference in relation to the other factors such as gender, marital status, occupation, level of education, duration and source of income.

Table 4: Demographic that influence farmers change to horticulture as an adaptation strategy

Factors	**Horticulture**		**χ 2 value**	**df**	**p**
	Yes	No			
Age categories			2.479 0.78	5	
• <24 years	• 1(5.3%)	• 18 (94.7%)			
• 25-34 years	• 3(5.0%)	• 57(95.0%)			
• 35-44 years	• 5(5.2%)	• 91(94.8%)			
• 45- 54 years	• 1 (1.3%)	• 77 (98.7%)			
• 55-64 years	• 3(4.1%)	• 70 (95.9%)			
• >65 years	• 4(6.0%)	• 63 (94.0%)			
Gender			0.001 0.977	1	
• Male	• 6 (4.3%)	• 134 (95.7%)			
• Female	• 11 (4.3%)	• 242 (95.7%)			
Marital status			**12.174 0.032**	**5**	
• Single	• 2(5.1%)	• 37 (94.9%)			
• Married living together	• 7(3.0%)	• 227 97.0%)			
• Married not living together	• 1(4.2%)	• 23(95.8%)			
• Married to more than one spouse	• 1(50%)	• 1(50%)			
• Widowed	• 5(6.2%)	• 76(93.8%)			
• Divorced	• 1(7.7%)	• 12(92.3%)			

Table 4: Continued…

Occupation			1.478 4 0.833
• Subsitence farming	• 16(4.8%)	• 317(95.2%)	
• Dairy farming	• 0	• 2(100%)	
• Casual Labour	• 0	• 8 (100%)	
• Permanent employment	• 0	• 14(100 %)	
• business	• 1(2.8%)	• 35(97.2%)	
Level of education			1.299 4 0.862
• Primary	• 7(3.4%)	• 198(96.6%)	
• Secondary	• 5(4.9%)	• 97 (95.1%)	
• Tertiary	• 2 (6.3%)	• 30(93.8%)	
• University	• 0	• 4(100%)	
• No formal education	• 3 (6.0%)	• 47 (94.0%)	
Duration			7.497 6 0.277
• 1 year-5years	• 2(13.3%)	• 13 (86.7%)	
• 5.1-10 years	• 1(6.7%)	• 14(93.3%)	
• 10.1-15years	• 0	• 18 (100%)	
• 15.1-20 years	• 5(21.7%)	• 18(78.3%)	
• 20.1-25years	• 2(6.2%)	• 30(93.8%)	
• 25.1-30 years	• 3(9.1%)	• 30 (90.9%)	
• >30 years	• 21(8.2%)	• 236(91.8%)	
Source of income			2.970 6 0.813
• Subsistence farming	• 14 (4.7%)	• 286 (95.3%)	
• Livestock rearing	• 0	• 19(100%)	
• Cash crops	• 0	• 3 (100%)	
• Short term labor	• 1(4.5%)	• 21 (95.5%)	
• Permanent employment	• 0	• 12 (100%)	
• Business	• 1(3.4%)	• 28(96.6%)	
• Pension and remittances	• 1(12.5%)	• 7 (87.5%)	

Marital status was statistically significant in relation to horticulture as a form of crop diversification ($\chi2$=12.174, df=5, p=0.032). Married and living together respondents were actually the least in embracing this form of crop diversification as an adaption strategy (3%). Horticulture is a high investment form of farming and lack of alternative sources of income to couples living together could be attributed to inability to invest in horticulture. It also could be attributed to the fact that the need to provide daily subsistence to their families made them shy away from investing in horticulture. However, there was no significant difference (**Table 4**, above) amongst the other factors.

Table 5: Demographic factors that influence adoption of cash crops as an adaptation strategy

Factors	Cash crop		χ2 df p value
	Yes	No	
Age categories			5.585 5 0.349
• <24 years	• 0	• 19 (100%)	
• 25-34 years	• 0	• 60 (100%)	
• 35-44 years	• 1(1.0%)	• 95 (99.0%)	
• 45- 54 years	• 0	• 78(100%)	
• 55-64 years	• 2(2.7%)	• 71 (97.3%)	
• >65 years	• 0	• 67(100%)	
Gender			1.270 1 0.260
• Male	• 2(1.4%)	• 138 (98.6%)	
• Female	• 1 (0.4%)	• 252 (99.6%)	
Marital status			2.618 5 0.759
• Single	• 1(2.6%)	• 38 (97.4%)	
• Married living together	• 2(0.9%)	• 232 (99.1%)	
• Married not living together	• 0	• 24 (100%)	
• Married to more than one spouse	• 0	• 2 (100%)	
• Widowed	• 0	• 81 (100%)	
• Divorced	• 0	• 13 (100%)	
Occupation			7.992 4 0.092
• Subsistence farming	• 2(0.6%)	• 331(99.4%)	
• Dairy farming	• 0	• 2(100%)	
• Casual Labour	• 0	• 8 (100%)	
• Permanent employment	• 1(7.1%)	• 13(92.9 %)	
• Business	• 0	• 36(100%)	
Level of education			**31.917 4 0.000**
• Primary	• 1(0.5%)	• 204(99.5%)	
• Secondary	• 1(1.0%)	• 101 (99.0%)	
• Tertiary	• 0	• 32(100%)	
• University	• 1(25.0%)	• 3(75.0%)	
• No formal education	• 0	• 50 (100%)	
	•		

Table 5: Continued…

Duration • 1 year-5years • 5.1-10 years • 10.1-15years • 15.1-20 years • 20.1-25years • 25.1-30 years • >30 years	 • 0 • 1(6.7%) • 0 • 0 • 1 (3.1%) • 1 (3%) • 0	 • 15 (100%) • 14 (93.3%) • 18 (100%) • 23 (100%) • 31(96.9%) • 32 (97.0%) • 257(100%)	**13.903 6 0.031**
Source of income • Subsistence farming • Livestock rearing • Cash crops • Short term labour • Permanent employment • Business • Pension and remittances	 • 3 (1.0%) • 0 • 0 • 0 • 0 • 0 • 0	 • 297 (99.0%) • 19(100%) • 3 (100%) • 22 (100%) • 12 (100%) • 29(100%) • 8 (100%)	0.937 6 0.988

The level of education and duration of residence had a role to play in adopting cash crop as a form of diversification, hence there was significant difference between these two factors in relation to this method ($\chi2$=31.917, df=4, p=0.000) and ($\chi2$=13.903 df=6, p= 0.031) respectively (**Table 5**, above). In as much as the level of education showed significant results, the number that sited this form of adaptation was so small to have any major impact on the community. It was notable that residents who had stayed for a short period (1-5years, 0) and longest (>30years, 0) did not embrace cash crop farming as an adaptation strategy. This could be mainly due to the fact that shorter period respondent did not understand the climatic conditions of the region hence reluctant to do cash crop farming while those that had stayed for longest period understood the climatic conditions of the region did not prefer this type of farming. It could also be attributed to the fact that they have understood crop performance over time and thus have embraced crops that cushion them from crop failures. The age, gender, marital status, occupation and sources of income were not statistically significant in relation to this form of diversification.

Table 6: Demographic factors that influence adoption of trees for firewood as an adaptation strategy

Factors	Trees for firewood		χ^2 value	df	p
	Yes	No			
Age categories • <24 years • 25-34 years • 35-44 years • 45- 54 years • 55-64 years • >65 years	• 0 • 0 • 0 • 1 (1.3%) • 5 (6.8%) • 1 (1.5%)	• 19 (100%) • 60 (100% • 96 (100% • 77 (98.7%) • 68 (93.2%) • 66 (98.5%)	**14.035**	**5**	**0.015**
Gender • Male • Female	• 3 (2.1%) • 4 (1.6%)	• 137 (97.9%) • 249 (98.4%)	0.163	1	0.687
Marital status • Single • Married living together • Married not living together • Married to more than one spouse • Widowed • Divorced	• 0 • 3(1.3%) • 0 • 0 • 4(4.9%) • 0	• 39 (100%) • 231 (98.7%) • 24 (100%) • 2 (100%) • 77(95.1%) • 13 (100%)	6.363	5	0.273
Occupation • Subsistence farming • Dairy farming • Casual Labour • Permanent employment • Business	• 4(1.2%) • 0 • 0 • 1 (7.1%) • 2(5.6%)	• 329(98.8%) • 2(100%) • 8 (100%) • 13 (92.9 %) • 34(94.4%)	6.054	4	0.195
Level of education • Primary • Secondary • Tertiary • University • No formal education	• 4 (2.0%) • 0 • 0 • 1 (25.0%) • 2 (4.0%)	• 201(98.0%) • 102 (100%) • 32(100%) • 3(75%) • 48 (96%)	**16.198**	**4**	**0.003**

Table 6: Continued…

Duration			1.952 6 0.924
• 1 year-5years	• 0	• 15 (100%)	
• 5.1-10 years	• 0	• 15 (100%)	
• 10.1-15years	• 0	• 18 (100%)	
• 15.1-20 years	• 0	• 23 (100%)	
• 20.1-25years	• 1 (3.1%)	• 31 (96.9%)	
• 25.1-30 years	• 1 (3%)	• 32 (97.0%)	
• >30 years	• 5(1.9%)	• 252 (98.1%)	
Source of income			4.371 6 0.627
• Subsistence farming	• 5 (1.7%)	• 295 (98.3%)	
• Livestock rearing	• 0	• 19(100%)	
• Cash crops	• 0	• 3 (100%)	
• Short term labour	• 0	• 22 (100%)	
• Permanent employment	• 1 (8.3%)	• 11 (91.7%)	
• Business	• 1 (3.4%)	• 28 (96.6%)	
• Pension and remittances	• 0	• 8 (100%)	

There was a significant statistical difference between the age ($\chi2$=14.035, df= 5, P= 0.015) and the level of education ($\chi2$=16.198, df= 4, P=0.003) of respondents in relation to adopting trees for firewood (**Table 6**, above) as a method to counter the impacts of climate variability. However, none of the respondents in the age brackets <24 years, 25-34 years and 35-44 years embraced this form of diversification. This is a clear indication that being a younger generation they prefer to use other forms of energy which are easier and readily available. In addition, none of the respondents with secondary and tertiary education adopted this form of diversification. The other factors; gender, marital status, occupation, duration of residence and source of income had no significance difference in relation to this form of crop diversification.

4.6 Fodder, Drought resistant crops and trees for timber

None of the demographic factors showed any significant difference in adoption of fodder, drought resistant and trees for timber as forms of crop diversification adopted to enable farmers better cope with the effects of climate variability. However, in adopting crop diversification as a strategy, drought resistant crops were found to rank highest among the respondents. This is due to the fact that, most farmers perceive drought as the major climatic event that has affected them in the recent past. Farmers thus, found changing to drought resistant crops more appropriate and thus adopted this irrespective of their economic or social factors.

When the factors were analyzed against trees for timber, there was no significant. This can be attributed to the fact that food security is the most immediate need amongst many households and thus adoption of long term strategies such as planting trees for timber does not feature prominently.

4.7 DISCUSSION

4.7.1 Forms of crop diversification employed by farmers in the Taita Hills as a response to past climate variability

From this study crop diversification is a major practice in Taita Hills. Several forms of diversification have been embraced by farmers in this region which include crop variety, trees for timber, trees for firewood, cash crops, horticulture, fodder and drought resistant crops. This study determined that adoption of drought tolerant crops was the most common form of crop diversification as it was the most preferred and practiced method while cash crops and trees for timber were rare. This could be attributed to farmer's perception of climate change as most people sited drought and low rainfall amounts as the climatic factor that has affected them most in the recent past. It can also be attributed to the fact that most of the farmers practice farming solely for subsistence and thus obtaining food is of more importance to them. This further results in reduced incomes from farms and hence reduces the chances of using other strategies which are deemed long term like the adoption of cash crops and trees for timber to adapt to climate change.

Studies in other areas have shown that adoption of drought tolerant crops is a common practice among many farmers as it helps them reduce risks associated with crop failures as a result of drought. However, some studies found that for crop diversification to be effective as a strategy, it was used in combination with other strategies like growing of fast maturing plants and adjustments in planting dates (Shiferaw *et al*, 2014). In Ghana, a study conducted there found that a greater percentage of farming households (73 %) are adopting drought tolerant crops as a strategy to cope with effects of drought in the area (Antwi-Agyei *et al*, 2014). Further, the study found that economic means determined the choice of adaptation strategy used by a household to cope with climate variability.

4.7.2 Factors influencing crop diversification

This study found that age, marital status and duration of residence influenced the preferences of farmers towards the various forms of crop diversification. However, gender, occupation and source of income of the respondents did not affect any of the seven diversification forms practiced in this area. Age has a role to play in choosing crop variety and trees for firewood as forms of crop diversification, however all the other forms were not affected by this demographic factor. This study found that farmers in the age groups of 31-60 years were the majority to embrace this form of diversification as compared to those below 30 years. This can be attributed to the farming experience of these farmers hence they are able to easily switch to other crops when faced with climate variability compared to the young farmers. Ndambiri *et al.,* (2012) support these findings that the age of a farmer greatly influences the choice of an adaptation strategy to climate change. However, this study disagrees with Sichoongwe *et al*., (2014) which found that as people in rural areas get older, they practice farming, more as a way of life and for subsistence as compared to younger farmers who will do it more for business. In order to create and maintain the business enterprises, younger farmers will diversify their farming enterprises as compared to older ones, who farm only to get their daily subsistence.

Marital status was significant in relation to horticulture as a form of crop diversification, and it was rated high to individuals married to more than one spouse. This is because in the Taita Hills, like in most rural settings, women do much of the agricultural work while the men are in the towns. Thus, in polygamous marriage where there are several women and larger households, they are all likely to adapt more to climate variability based on observed climatic changes in order to cater for their food requirements. The women are likely to try out new crops to meet the household needs as well as increase income by selling produce in local markets. These finding is supported by Nhemachena and Hassan, (2007) that the marital status of the head of the household positively influences crop diversification as an adaptation strategy.

Duration of residence had a positive relationship with cash crop farming as a diversification method. This study therefore found that cash crop farming was practiced by farmers who had stayed in the region for less than 10 years but was not common amongst the other residents, with actually those who had stayed for over 30 years not practicing it at all. This can be as a result of them trying out different kind of crops that are favored by the climatic condition of this region thus they diversified. But those who had stayed for longer period have the knowledge and information of the past changes in climatic conditions hence likely not to diversify. Despite occupation not being significant in relation to choosing the various diversification forms, it is worth noting that in this region the people mainly rely on subsistence farming as the main source of their livelihoods.

CHAPTER FIVE

5.0 RESULTS FOR PERFORMANCE OF SWEET POTATOES IN RELATION TO PAST WEATHER

5.1 Assessment of sweet potato production in relation to past weather

This objective was achieved using weather parameters and comparison with other crop data to determine vulnerability of sweet potato to climate variability. To achieve the best growth of sweet potatoes, temperatures need to be between 21^0C and 29^0C and soils well moist. The rainfall, temperature and other crop production trends over time (1989-2014) assisted in understanding the past sweet potato production in the area.

5.2 Rainfall and temperature Pattern for the Period 1989-2014 for Taita Taveta

The average annual rainfall reported for the period under study was 756.09 mm, with the highest annual rainfall amounts being recorded in 1998 (1357.67mm) and this could be attributed to El Nino rains that were experienced in East Africa in 1997-1998. The lowest was recorded in 2003 (364mm). The rainfall was fluctuating throughout the period in consideration. **Figure 4** shows the variability of rainfall and trends (1981-2014) for the study area

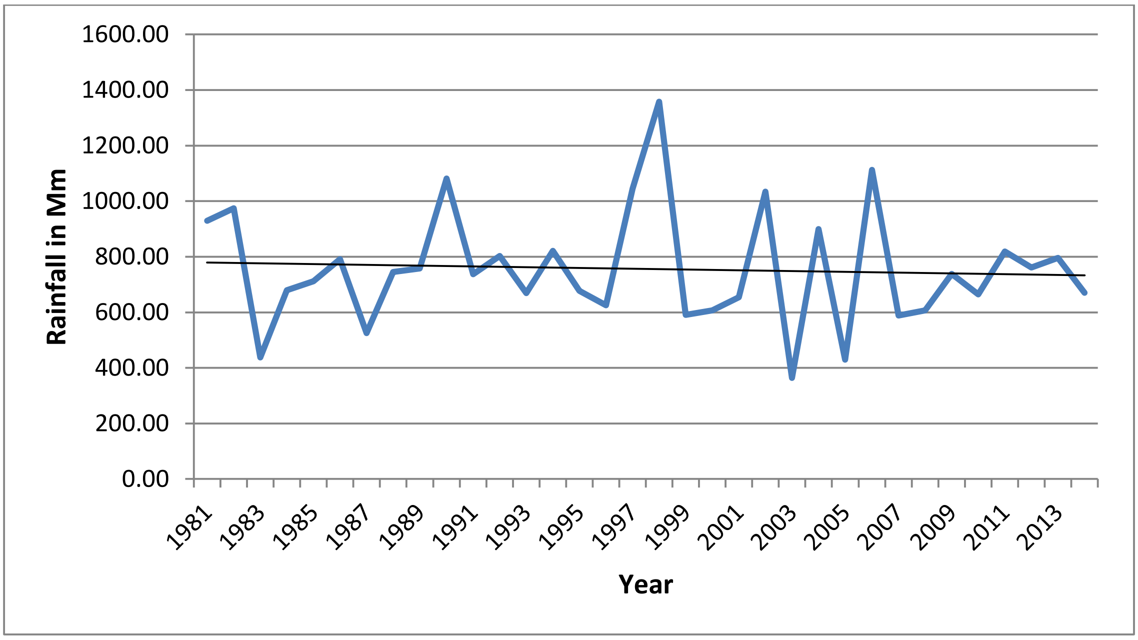

Figure 4: Rainfall pattern for the period 1981-2014

Source: Kenya Meteorological Department.

Temperature reported similar inconsistent trend as rainfall with a high of 26 ^{0}c in 2003 and low of 24.9 ^{0}C in 1989. The average temperature was 25.4 ^{0}C as illustrated in figure 5 below.

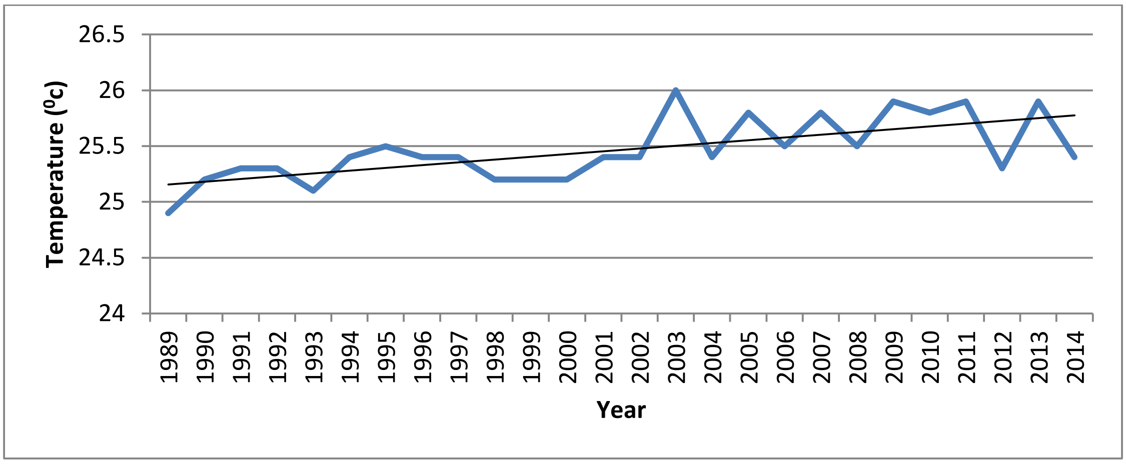

Figure 5: Periodic temperature trends 1989-2014.
Source: Kenya Meteorological Department.

5.3 Sweet potatoes production trends over time (1989-2014) in comparison with common crops in Taita Hills

To ascertain the trend of production overtime, data for various crop production and weather pattern were extracted and presented in **Table 7**, below. From the year 1989 to 2014 there was an increase in production of sweet potatoes overtime apart from year 2010 when the production decreased to 520 tonnes. The total annual rainfall and temperatures was 665 mm and 25.8^{0}C for that year respectively. Other root crops, such as cassava generally showed variation in production over the years with peak performance recorded in 1990 (5491tonnes) with annual rainfall and temperature at 1081 mm and 25.2^{0}C respectively and the lowest in 1993 (55 tonnes) with rainfall and temperature at 669.67 mm and 25.1^{0}C respectively.

Cereals had varied production trends. Millet was generally stable over the years as compared to maize yields which recorded high variations over the years. The highest millet production was 32.94 tonnes in the year 1993. In this year temperatures was 25.1^{0}C and rainfall was 669.67 mm. The peak production for maize was recorded in 2009 at 1504 tonnes. The temperatures and rainfall were 25.9 ^{0}C and 737.67 mm for 2009. Green grams had generally steady production as compared to beans and cowpeas. Cowpeas recorded variations but not as much as beans. Peak production for green grams, beans and cowpeas was in 2001 (199.8 tonnes), 2009 (1138.7 tonnes) and 2002 (783 tonnes) respectively. In the year 2001, rainfall was 654.33 mm and temperature 25.4 ^{0}C while in 2009, temperature was 25.9^{0}C and 737.67 mm rainfall.

Table 7: Taita Taveta district rainfall, temperature and past crop production data

Source: Kenya Meteorological Department and Ministry of Agriculture.

Weather (rainfall and temperatures) and crops production trends over time (1989-2014)									
Year	Rainfall in mm	Temperature in 0C	Maize tons/Ha	S/potatoes tons/Ha	Beans tons/Ha	Green grams tons/Ha	Cow peas tons/Ha	Cassava tons/Ha	Millet tons/Ha
1989	929.33	24.9	1,270	540	751.5	5.94	23.49	2,055	4.14
1990	974.33	25.2	1,493	607	850.5	16.29	34.92	5,491	7.65
1991	437.67	25.3	333	347	450.5	6.66	17.28	4,200	3.69
1992	680.00	25.3	941	160	859.3	17.37	44.64	371	14.67
1993	711.33	25.1	764	126	605.3	69.57	60.03	55	32.94
1994	790.67	25.4	911	270	495.7	104.4	160.73	770	32.94
1995	525.33	25.5	317	219	419.7	109.98	235.97	1,080	32.04
1996	745.67	25.4	528	625	863	151.2	17.64	1,950	0.81

1997	758.33	25.4	699	740	538.7	96.93	10.35	3,840	1.26
1998	1081.00	25.2	616	618	500.8	76.23	124.38	1,796	6.93
1999	737.33	25.2	568	770	356.3	97.05	132.46	2,270	13.5
2000	802.33	25.2	482	650	399.6	179.1	202.48	965	9.54
2001	669.67	25.4	680	858	417.4	199.8	254.51	2,780	7.11
2002	821.33	25.4	529	776	771	30.87	783	2,940	3.6
2003	677.00	26	314	680	280	90	190.96	3,580	30.06
2004	625.67	25.4	765	890	781.2	85.5	76.05	3,410	0.72
2005	1045.00	25.8	342	630	288.57	90.4	28.26	274	1.1
2006	1357.67	25.5	1,390	836	947.16	88.2	54.684	281	3.2
2007	590.33	25.8	797	620	724.4	86.1	313.92	2,590	12.6
2008	607.33	25.5	186	680	182	67.68	0.45	576	8.73
2009	654.33	25.9	1,504	135	1138.7	3.24	14.67	132	1.89
2010	1034.33	25.8	1,170	520	1035	6.66	29.7	158	2.88

2011	364.00	25.9	249	800	3078	74.16	0.63	824	5.4
2012	900.00	25.3	890	852	772.9	38.37	255.96	943	2.7
2013	429.33	25.9	699	959	448.3	62.73	218.86	3611	5.04
2014	1112.67	25.4	823	802.9	460.3	67.8	239.38	795	4.68
Average	756.10	25.5	740.8	604.3	708.3	73.9	135.6	1836.0	9.6

The average annual temperature and total annual rainfall for 2002 was 25.4^{0}C and 821.33 mm. Sweet potatoes and maize had contrasting pattern of production as shown in figure 6 below. This could be attributed to two factors, climate variability and increased acreage of the crops planted. However, the latter is less likely as people in the Taita Hills, due to their preference for maize farming, are less likely to increase acreage of other crops compared to maize crop. The contrast in production can thus be explained by changes in weather patterns.

When the weather fluctuates, it favours production of one crop over the other. Short rainfall durations led to an increase in sweet potato yields whereas sufficient amounts accounted for the increased maize production. Maize being a rain-fed crop, cannot withstand high temperatures and low rainfall amounts. It requires sufficient amounts of water during flowering and grain filling and any changes in water amounts will result in reduced yields.

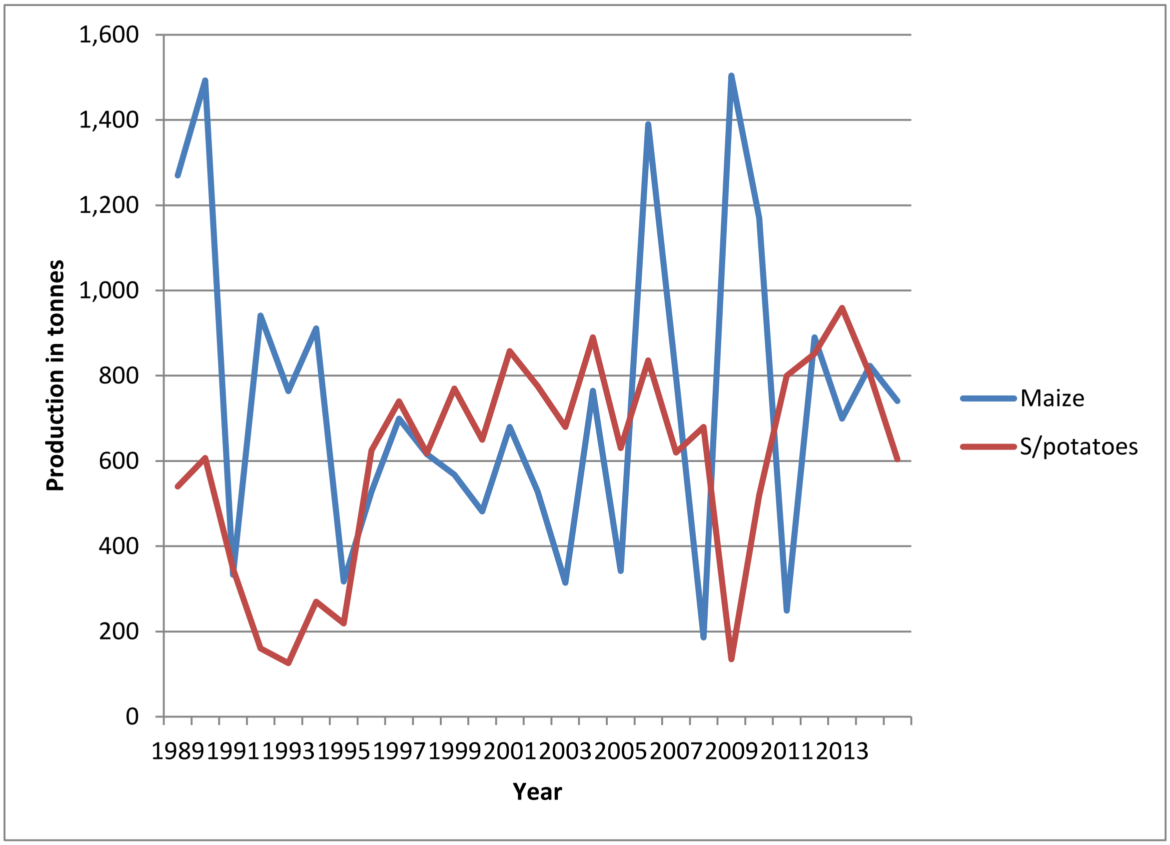

Figure 6: Maize and sweet potato production for Taita Taveta district for 1989 – 2014.

5.4 Correlation of crop production and weather pattern (annual rainfall and temperature)

The generated data was subjected to Pearson correlation to find out whether there was significant association in production against weather (rainfall and temperature). The results are tabulated in **Table 8,** below. Maize, green grams, beans and cow peas showed positive correlation with rainfall however only maize had significant (P≤0.01) correlation. On the other hand; Cassava, millet and sweet potatoes showed negative correlation with rainfall. For temperature, no crop showed any significant correlation but maize, green grams, cassava and millet showed negative correlation while sweet potatoes, beans and cow peas showed positive correlation.

Table 8: Correlation of crop production and weather pattern (annual rainfall and temperature)

	Rainfall	**Temperature**	**Maize**	**S/potatoes**	**Beans**	**Green grams**	**Cow peas**	**Cassava**	**Millet**
Rainfall	1								
Temperature	-.080	1							
Maize	.675**	-.166	1						
S/potatoes	-.088	.125	-.163	1					
Beans	.231	.102	.095	.160	1				
Green grams	.164	-.047	-.151	.270	.729**	1			
Cow peas	.021	.000	-.150	.297	.207	.351	1		
Cassava	-.362	-.084	-.054	.325	-.205	-.130	.111	1	
Millet	-.277	-.032	-.201	-.530**	-.195	.000	.061	-.132	1

5.5 Discussion

5.5.1 Assessment of Sweet Potato Production In Relation To Past Climate

Trend analysis of the rainfall and temperature data for the Taita Taveta County in the last 26 years shows no notable trend. However the annual mean temperatures of this region are actually on the increase since 2000. This may be attributed to climate variability. Increased frequencies of extreme climatic events over a long period lead to climate change. These findings support Bilham (2011), who noted that there are increases in temperature in Kenya and this can be attributed to climate change. These high temperatures may have adversely affected the crop yields, cropping systems, scheduling of field operations and pest conditions as evident from the crop production data for this region.

5.5.2 Sweet potatoes production trends over time (1989-2014) in comparison with other crops.

The production of sweet potatoes has increased over time in the study area. This is in contrast to other root crops, such as cassava that showed variation in production over the years. This can be attributed to growing periods as cassava takes a longer period to mature compared to sweet potatoes. Due to sweet potatoes short maturity period, the low rainfall may be sufficient for its growth in the study area. Therefore farmers may have realized its potential and adopted it as a crop to help them cope with extreme climatic events such as drought. The increase in production can also be attributed to the fact that sweet potatoes are a low input crop and it is able to give substantial yields under extreme climatic conditions. Similar results were reported by (Kaguongo *et al,* 2012) and Githunguri and Migwa, (2004) who noted that sweet potato is a low input crop that is able to give good yields even under extreme conditions.

Cereals production was inconsistent over the years. For example whereas green grams, millet were generally stable maize and beans production fluctuated over the years. This is probably, because millet and green grams are drought tolerant than maize and beans. Similar results were reported by (Bilham, 2011) who reported that maize is a rain-fed crop and therefore may not withstand the high temperature and low rainfall such as the one recorded in the study area. The results are further supported by Omoyo *et al,* (2015) who found that increased temperatures affect maize yields by up to 60 %. Further, maize was found to be extremely sensitive to water shortages during flowering and grain filling and hence for yields to be assured, onset and cessation of rainfall should be in tune with this phase of maize growing.

Sweet potatoes and maize had contrasting pattern of production. There is an inverse relationship between maize and sweet potatoes whereby when production of one increases the other decreases. This can be attributed to changes in rainfall amounts, whereby low rainfall leads to low maize production but the production of sweet potatoes increases because it’s a drought resistant crop. In addition, the mean annual temperatures in this study area are on the rise, hence have adverse effects on maize production. These findings agree with (Bilham, 2011) that maize is sensitive to extreme temperatures hence any further increases in temperature will lead to reduction in maize yields hence switching to other crops may be advisable.

The contrast in yields can also be attributed to farming practices in the area. Sweet potatoes are normally consumed as an alternative crop and is normally preserved in the fields and only harvested when need arises- piecemeal harvesting, when maize is not readily available. However, piecemeal harvesting affects the quality of tubers as the tubers are attacked by pests (*Cylas sp)* in the fields. This is the major challenge facing sweet potato production in the Taita hills. Most of the farmers grow sweet potatoes for domestic consumption during the dry spells when food availability is a challenge. Piece meal harvesting is the main method of harvesting the crop. This in turn leads to major destruction by the *Cylas Sp*. Pest. These findings are supported by Ebregt *et al,* (2007) and Nicole (1997) who found that piecemeal harvesting of sweet potatoes affects the quality of tubers as it encourages the growth and multiplication of pests (especially the rough sweet potato weevil) that destroys the tubers. The yield quality reduces as the crop is retained in the ground. It also reduces the chances of crop rotation as there can never be rotation if the crop is yet to be harvested. Piecemeal harvesting also reduces tuber quality as plants in the garden during the dry season are more susceptible to attack by the sweet potato weevil.

Plate 2: Sweet potato weevil, *cylas sp.*
Photo by B. Monchari, 2014.

Plate 3: Damage caused by sweet potato weevil *cylas sp*.
Photo by B. Monchari, 2014

Plate 4: A farmer displaying sweet potato harvest after one year in the field
Photo by B. Monchari, 2014.

The variety grown takes a relatively longer time to mature than the improved sweet potato varieties used in the study.

When correlated with weather variables, maize, green grams, beans and cow peas showed positive correlation with rainfall however only maize had significant correlation. On the other hand; Cassava, millet and sweet potatoes showed negative correlation with rainfall. For temperature, no crop showed any significant correlation but maize, green grams, cassava and millet showed negative correlation while sweet potatoes, beans and cow peas showed positive correlation. There is need therefore for farmers to increase the acreage under cassava millet and sweet potatoes going forward. Being drought tolerant, the crops will help cushion farmers against crop failures as they can survive short rainfall durations. Also, improved sweet potato varieties will mature within a short time and thus the short rainfall durations will be sufficient.

CHAPTER SIX

6.0 RESULTS FOR THE PERFORMANCE OF IMPROVED SWEET POTATO

6.1 Assessment of yield performance among five selected improved sweet potato varieties in Taita Hills.

The five varieties performed significantly different in the three sites. In Werugha, the performance of the genotypes did not show any significant difference (P≥0.05) in total yield and marketable yield but a significant difference was observed at P≤ 0.05 for those attacked by insect pest (*Cylas sp.*) with a mean yield of 0.04 (Table 9). The mean yield ranged from 339.2 to 565.9(Kg/ha) while that for marketable yield ranged from 127.27 to 380.49 (Kg/ha). Pest attack on Ejumla was significantly higher than the other varieties with a mean of 0.08Kg/ha (**Table 9**, below).

Table 9: Performance among five varieties in werugha in kg/ha

May 2014- March 2015 Cropping Season

Genotype	Total yield	Marketable yield	Pest attacked yield
Bungoma	451.9a	319.03ab	0.06ab
Kipenda Roho	565.9a	277.58ab	0.02b
Mtwapa8	535.5a	380.49a	0.02b
Riziki	339.2a	178.06b	0.0b
Ejumla	360.0a	127.27b	0.08a
Mean	450.49	256.49	0.04
Genotype	NS	NS	*
C.V.	88.85	89.09	189.5
LSD	344.94	196.92	0.06

Key: means with different letters in columns are significantly different based on LSD at *P≤ 0.05, ** 0.01, *** 0.001 and NS- not significant. C.V. – Coefficient of Variance and LSD is least significance Difference

In Josa site, the yield was significantly different P≤0.01(**Table 10,** below) for both total yield and marketable yield. The mean total yield ranged from 940 to 3462.4 Kg/ha whereas that of marketable yield ranged from 418.2 to 2357.2 kg/ha. The amount of yield attacked by insect pest was significantly different P≤0.001 with the mean yield attacked by insect pests ranging from 0.01 to 0.28Kg/ha, with Ejumla recording the highest pest attack.

Table 10: Performance among five varieties in Josa in kg/ha.
May 2014- March 2015 cropping season.

Genotype	Total yield	Marketable yield	Pest attacked yield
Bungoma	3462.4a	2357.2a	0.27a
Kipenda Roho	1425.5bc	830.7b	0.09b
Mtwapa8	2455.0b	1898.2a	0.13b
Riziki	1199.9bc	637.6b	0.01b
Ejumla	940.0c	418.2b	0.28a
Mean	1896.56	1228.36	0.16
Genotype	**	**	***
C.V.	79.8	99.18	87.47
LSD	1304.4	1049.9	0.12

Key: means with different letters in columns are significantly different based on LSD at *P≤ 0.05, ** 0.01 and *** 0.001. C.V. – Coefficient of Variance and LSD is least significance Difference

In Mwatate, the yields were generally low compared to the other sites. The total yield was significantly different P≤0.01 and the mean yield ranged from 25.2 to 436.6 kg/ha as shown in **Table 11**, below. Assessment for marketable yield was not significant and the means ranged from 8.75 to 184.24 kg/ha. Yield attacked by pests was significantly different P≤0.01 and the means ranged from 0 to 0.14Kg/ha and yield from Ejumla recorded the highest pest attack.

Table 11: Performance among five varieties in Mwatate in kg/ha**.**
May 2014- March 2015 Cropping season

Genotype	Total yield	Marketable yield	Pest attacked yield
Bungoma	25.2b	8.75b	0.0b
Kipenda Roho	42.4b	13.58b	0.0b
Mtwapa8	257.4ab	184.24ab	0.1b
Riziki	418.8a	192.49a	0.05b
Ejumla	436.6a	97.09ab	0.14a
Mean	236.07	99.23	0.04
Genotype	**	NS	**
C.V.	121.15	207.45	134.43
LSD	246.46	177.4	0.047

Key: means with different letters in columns are significantly different based on LSD at *P≤ 0.05, ** 0.01 and *** 0.001. C.V. – Coefficient of Variance and LSD is least significance Difference

6.2 Performance among five varieties in the three sites during May 2014- March 2015 cropping season

The performance of the five varieties was significantly (P≤ 0.05) different. The mean yield ranged from 578.9 to 1313.2 (Kg/ha) with a mean of 861.04(Kg/ha). Bungoma outperformed the other varieties with a yield of 1313.2(Kg/ha). Marketable yield were also significantly (P≤ 0.01) different among the varieties. Bungoma and Mtwapa8 recorded the highest yield (895 and 831(Kg/ha) respectively) while Ejumla was the lowest (214.2Kg/ha). Pest attack on yield was significantly (P≤ 0.001) different among the five varieties with Ejumla recording the highest attack (0.17g/ha) as shown in **Table 12** below.

Table 12: Performance among five varieties in the three sites in kg/ha.

May 2014- March 2015 cropping season

Genotype	Total yield	Marketable yield	Pest attacked yield
Bungoma	1313.2a	895.0a	0.11b
Kipenda Roho	677.9b	373.9b	0.04c
Mtwapa8	1082.6ab	831.0a	0.05c
Riziki	652.6b	336.0b	0.02c
Ejumla	578.9b	214.2b	0.17a
Mean	861.04	528.02	0.08
Genotype	*	**	***
Site	***	***	***
G*S	***	***	***
C.V.	123.26	154.28	125.2
LSD	516.56	396.5	0.05

Key: means with different letters in columns are significantly different based on LSD at *P≤ 0.05, ** 0.01 and *** 0.001. C.V. – Coefficient of Variance and LSD is least significance difference

The sites differed significantly (P≤ 0.001) in all the parameters measured (**Table 13**, below). Josa recorded the highest total yield and Marketable yield (Table 12) despite it recording the highest pest attacked yield (0.16 kg/ha) whereas Mwatate recorded the least total yield and marketable yield. Variety site interaction significantly (P≤ 0.001) influenced the performance of the five varieties in this study.

Table 13: Means for performance in yield, marketable yield and pest attack in the three sites. May 2014- March 2015 cropping season

Trait	Werugha	Josa	Mwatate	LSD
Yield	450.5b	1896.6a	236.1b	400.13
Marketable yield	256.5b	1228.4a	99.0b	307.12
Pest	0.04b	0.16a	0.04b	0.04

Key: means with different letters in rows are significantly different based on LSD. LSD is least significance difference among the means.

6.3 Discussion

6.3.1 Assessment of yield performance among five selected improved sweet potato varieties in Taita Hills.

Yield variations were observed between the different varieties and in sites. The total mean yield, marketable yield and pest attack yield was 861.04 Kg/ha, 528.02 Kg/ha, and 0.08 Kg/ha respectively. This marketable yield is well below average yield for sweet potato growing regions of the world of 13.2t/ha as per 2010 (Richardson, 2009). Total yield, Marketable yield and Pest attack on yield significantly different among the five varieties. Bungoma outperformed the other varieties with a total yield and marketable yield of 1313.2 Kg/ha and 895.0 Kg/ha respectively. Ejumla recorded the highest attacked yield which affected significantly its total yield and marketable yield. The variations observed may be attributed to variations in yield components such pest attack, leaf morphology, storage root shape and colour, number and size of tubers, germination rate and other climate adaptability factors. Similar results were reported by Osiru *et al*., (2009) who noted variation in sweet potato root yield among genotypes, locations and cropping seasons. The said yield components were not assessed in this study and therefore a grey area for future research. The pest attack may be attributable to variations in the resistance of different sweet potato varieties to insect pests.

Notable difference was also observed in sites. Josa recorded the highest total yield and marketable yield despite it recording the highest pest attacked yield (0.16 kg/ha) whereas Mwatate recorded the least total yield and marketable yield. A variation in yield production between these sites is an indication of differences in environmental conditions and soil factors. From the area ecological data Werugha is a highland, Josa a midzone while Mwatate is a lowland. According to Taita District Development Plan, (2009) the mid zone receives moderate rainfall and is characterized by higher temperatures and evaporation which may be favorable for growth of sweet potatoes. The lowlands are arid and semi-arid and are characterized by high temperatures and unreliable rainfall whereas the highlands receive high amounts of rainfall and low temperatures. Similar results were reported by Osiru *et al.*, (2009) in their analysis of stability of yields from sweet potato cultivars in diverse environments. They noted that yelds in different locations varied and this can be as a result of weather and climatic factors as well as length of the growing period. Also, different varieties respond differently to environmental conditions in specific locations. Similar results were recorded by Ngeve(1993) and Nawale & Salvi (1983). In Werugha, the performance of the genotypes did not differ significantly in total yield and marketable yield but a significant difference was insect pest attack (*Cylas spp*). The mean yield ranged from 339.2 to 565.9(Kg/ha) while that for marketable yield ranged from 127.27 to 380.49 (Kg/ha). Pest attack on Ejumla was significantly higher than the other varieties with a mean of 0.08Kg/ha. The variety also recorded very low yields. The low yield recorded by this variety may be attributed to highland climate factors which may not favour the physiological growth of this particular variety. This finding contrast Mcharo *et al*., (2001) who noted in the tropics, physiological growth and accumulation of dry matter is expected to be higher in the high altitudinal zones.

In Josa site, the yield was significantly different for both total yield and marketable yield. The mean total yield ranged from 940 to 3462.4 Kg/ha whereas that of marketable yield ranged from 418.2 to 2357.2 kg/ha. The amount of yield attacked by insect pest was significantly different with Ejumla recording the highest pest attack. This area with highest yield suggest that the conditions in the mid zone average rainfall of 700-900 mm per annum and also characterized by higher temperatures and evaporation favoured the performance of the crop better. It can also be attributed to moisture and temperature amounts. In Mwatate, the yields were generally low compared to the other sites. The total yield was significantly different and the mean yield ranged from 25.2 to 436.6 kg/ha. Assessment for marketable yield was not significant and the means ranged from 8.75 to 184.24 kg/ha. Yield attacked by pests was significantly different and the means ranged from 0 to 0.14 kg/ha and yield from Ejumla recorded the highest pest attack. The low yield in Mwatate was expected as this is a lowland area classified as arid and semi-arid (Pellikka *et al.*, 2004). The rainfall is mostly unreliable in terms of amount and distribution and the area experiences frequent droughts. This affects soil moisture content and thus total tuber weight. Saraswati, (2007) found that soil moisture content affected the overall tuber yield in sweet potatoes.

CHAPTER SEVEN

7.1 SYNTHESIS AND DISCUSSION

The present study assessed whether crop diversification can help cushion small scale farmers in the Taita Hills from effects of climate variability. It further assessed how this can be linked with improved seeds, with a focus on sweet potato varieties to help improve yields and thus help reduce vulnerability due to impacts arising from climate variability and change.

Most of the respondents in the study cited farming as the main source of livelihood with most of them depending on rain-fed agriculture. Several crops are planted in the area but maize and beans are the main crops as they are planted by most farmers. Both crops are sensitive to changes in rainfall amounts and hence over reliance on these two crops increases the vulnerability of the farmers as crop failures are experienced in case of extreme climatic events.

Most of the respondents are aware of climate variability as they have been impacted directly or indirectly. Drought, below average rainfall and erratic rainfall patterns were cited by farmers as the factors that affected them most in the past. Rainfall unpredictability has led to a sharp drop in production, particularly for the main crops in the area.

From the study, there is a high level of crop diversification among farmers in the Taita Hills. Given that subsistence farming is the main source of livelihood for most of the respondents, climate variability could have led to serious effects hence the need to adapt. Crop diversification helps cushion farmers against harsh climatic conditions. Most farmers employ different forms of crop diversification including change in crop variety, cash crops, horticulture, fodder and drought resistant crops. Most farmers adopted drought resistant crops and this can be linked to their perception of past climatic events.

Assessment of crop performance in relation to weather in the past revealed that several crops are planted by farmers. Crops performed differently over the years. Millet production was more stable over the years. Millet is a drought resistant crop. Green grams had generally steady production as compared to beans and cowpeas. Whereas sweet potatoes showed a general increasing trend over time, other root crops such as cassava showed a variation in production.

Planting more of the stable crops would ensure farmers get better yields and hence cushioning them from total crop failures.

When correlated with weather variables, maize, green grams, beans and cow peas showed positive correlation with rainfall however only maize had significant correlation. On the other hand; cassava, millet and sweet potatoes showed negative correlation with rainfall. For temperature, no crop showed any significant correlation but maize, green grams, cassava and millet showed negative correlation while sweet potatoes, beans and cow peas showed positive correlation.

Maize, a main crop in the Taita Hills and sweet potatoes were found to have contrasting yields over the years. When yields from the maize crops were low, the yields from sweet potatoes were high and thus cushioned farmers from the effects of drought. This can also be tied to climate variability and the effect there of on the performance of these two crops. Sweet potatoes are thus an alternative crop that can help cushion farmers in case of extreme climatic events.

Planting the right seed varieties combined with good farming practices can help improve yields and thus cushion farmers from the impacts of extreme climatic events like total crop failures. Sweet potato production in the Taita Hills has been hampered in the past with recycling of seeds, and piece meal harvesting. This has led to low yields and increased damage by sweet potato weevils. The sweet potato variety grown in the Taita Hills takes relatively long to mature. This increases the chances of destruction by sweet potato weevils. Improved varieties can therefore help shorten the duration that the crop takes to mature in the field, helping farmers realize better yields as well as reduced damages by pests. There was varied production from the five varieties tested in the area. There is need therefore to combine improved seed varieties with proper farming practices to help improve yields in the area.

CHAPTER EIGHT

8.0 CONCLUSION AND RECOMMENDATION

8.1 Conclusion

In conclusion, the study found that there is practice of crop diversification. Adoption of drought resistant crops is the most common at slightly more than half of the respondents practicing it. There is however over reliance on maize and beans as the main crops in the study area. Adoption of fodder crops was among the least meaning that farmers in the Taita Hills still heavily rely on agricultural crops for their daily upkeep.

Several factors influence the choice made by farmers in adopting crop diversification as a form of adaptation. Age, level of education, marital status and duration of residence are key social demographic determinants to adoption of crop diversification. This can be linked to past experiences and access to information as far as climate variability and change in the area is concerned.

The production of sweet potatoes has increased over time in the study area. Cereals production was inconsistent over the years. Sweet potatoes and maize had contrasting pattern of production. There is an inverse relationship between maize and sweet potatoes whereby when production of one increases the other decreases. Maize, green grams, beans and cow peas showed positive correlation with rainfall however only maize had significant correlation.

There were marked variability in production from different sweet potato varieties and between sites. Yield variations were observed between varieties and in sites. The total mean yield, marketable yield and pest attack yield was 861.04 Kg/ha, 528.02 Kg/ha, and 0.08 Kg/ha respectively. Bungoma was the best among the five varieties while Ejumla was the most susceptible to pest attack. Josa recorded the highest total yield and marketable yield despite recording the highest pest attacked yield (0.16 Kg/ha) whereas Mwatate recorded the least total yield and marketable yield.

8.2 Recommendations

1. Climate variability is real in the area based on the weather trend and therefore there is need for community awareness to advocate for upscaling on the adoption of crop diversification as it can help cushion farmers against extreme climatic events.
2. Yield components such as leaf morphology, storage root shape and colour, number and size of tubers, germination rate and other climate adaptability factors were not assessed in this study and therefore a grey area for future research. In addition, there is need for further research on the role of taste and availability of markets in adoption of sweet potatoes as an alternative crop to maize.
3. From this study, there was no correlation between weather and some of the tracked crops such as maize, millet and green grams; therefore there is need for experimental study in the area to evaluate this from a practical field dimension.

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APPENDICES

Appendix 1: Key informant Schedule

The following is a set of questions that will be administered to Agricultural Extension officers in the Taita Hills during the period of the study.

Name of officer____Date_______________
Interviewer____
Area of Jurisdiction____
1- General Farming practices
How many farmers are in your area of jurisdiction?
What is the average size of farms in your area of jurisdiction?
How much of the farm area is under food crop production?
What are the main economic activities carried out by farmers in your area?
What crops are most preferred by farmers in your area?
What is the food situation in your area?

2- Improvement of farming practices
What crops have been promoted in your area in the recent past?
What is the rate of uptake of these crops?
What are some of the factors that have influenced farmer uptake of crops that have been promoted in the area?
How has the promotion of these crops helped in the food situation in your area?
Besides crops, what farming practices have been promoted in the area?
Has crop diversification been encouraged in the past?
What is the uptake of crop diversification by farmers?

Appendix 2: House hold survey Questionnaire

I am a student at the University of Nairobi currently conducting research on the impacts of climate change on smallholder farmers and the formulation of suitable climate change adaptation strategies to help in reducing the impact of climate change on agriculture. The information you provide will be used solely for research purposes and will be treated with utmost confidentiality.

Name of the Interviewer ________________________________Date: (DD/MM/YYYY) _________________

Region ____

District ____

Village ____

Location of Household in GPS Coordinates

Latitude (N/S) _________________________________

Longitude (E/W) ______________________________

Elevation (m.a.s.l) ______________________________________

Indicate time in 24 hour system

Start of Interview (HRS/MIN)____

End of Interview (HRS/MIN) ____

HOUSEHOLD ID: ______

	CODE	RESPONSE
Name of the Respondent (Optional) Address Mobile Phone Number	(Mark N/D if the information is not available)	
Age		
Gender	1. Male 2. Female	
Marital Status	1. Never Married 2. Married and living together 3. Married but not living together 4. Married to more than one spouse 5. Widowed 6. Divorced	
Ethnicity (Optional)	(Mark N/R if there is no response)	
Religion (Optional)		
Occupation		
Respondent's Relationship with household head	1. Mother 2. Father 3. Husband 4. Wife 5. Child 6. Grandchild 7. Other Relative (Specify)	
Head of Household (indicate male/female/child headed)	1. Adult Male Headed 2. Adult Female Headed 3. Boy Child Headed (< 18 years) 4. Girl Child Headed (< 18 years)	
Respondent's Highest level of education	1. Primary 2. Secondary/High School 3. Tertiary / College(Diploma) 4. University (specify; undergraduate, graduate, PhD) 5. Technical (e.g. tailoring, carpentry etc) 6. Other (Specialties) 7. No formal Education	
Duration of residence in Jimma Highlands/Mt. Kilimanjaro/Taita Hills*(Indicate area clearly)*	1. Not a resident (Indicate where from) 2. <1 year 3. 1 year – 5 years	

	4. 5.1 years – 10 years 5. 10.1 years – 15 years 6. 15.1 years – 20 years 7. 20.1 years – 25 years 8. 25.1 years – 30 years 9. >30 years	
Main Source of Household Income (Indicate only one) (*From Code 3-6 indicates income earned outside of the respondent's own farm)	1. Subsistence Farming 2. Cash Crop Farming 3. Short Term Agricultural Wage Labour (<3 Months) 4. Short Term Non-Agricultural Wage Labour (<3 Months) 5. Permanent/ Salaried Agricultural Related Employment 6. Permanent/Salaried Non-Agricultural Related Employment 7. Business (Specify) 8. Remittances (Indicate Source) 9. Pension 10. Government Welfare 11. Other(Specify)	
Other Sources of Household Income (Specify)		
Household size (members currently living in the household)		
Number of dependants (Count only those dependants currently living in the household but not contributing to the household income in cash or in kind)	1. 1-3 2. 4-6 3. 7 and above	

Climate Impacts to the Household

1 Has your household been impacted/affected by climate events in the last 10 years (Yes/No)

2 If yes, which climate shocks (climate events that significantly affected household income) have affected your household during the last 10 years?

Type of climate event	When
Key 1. Drought 2. Above average rainfall 3. Below average rainfall 4. Floods 5. Erratic rainfall patterns 6. Hailstorms 7. Lightning 8. Fire Outbreaks 9. Landslides 10. Strong Winds 11. Loss of top soil (Soil Erosion) 12. Frost 13. Above average daily temperatures 14. Below average daily temperatures 15. Others (specify)	

When was the last drought the household experienced? ______________ (year)				**When was the last year the household experienced too much rain/flooding? ____________ (year)**			
During the last large drought, did you change your farming practice (crop and livestock)? _______ (yes: 1, no: 2)				During the last year with too much rain, did you change your farming practice (crop and livestock)? ________ (yes:1, no: 2)			
If no, why did you not change your farming practice (use key) (*For both drought and too much rain section*)							
1. No access to money 2. No access to credit 3. No access to land 4. No access to equipment 5. No access to extension services 6. No inputs (e.g. fertilizer/seeds) 7. Shortage of labor 8. No information on climate change and appropriate adaptations 9. Other (Specify)							
If you changed the farming practices please answer the following questions							
Drought				Flooding/Too much rain			
If yes, what did you do? (key)	If yes, how? (key)	If yes, who? (member id)	Indicate source of information for change **Key:** 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)	If yes, what did you do? (key)	If yes, how? (key)	If yes, who? (member id)	Indicate source of information for change **Key:** 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)
Change in crop variety				Change in crop variety			
Change in crop type				Change in crop type			
Diversification of				Diversificatio			

crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticulture 3. Drought resistant crops 4. Trees for timber 5. Trees for firewood 6. Other (Specify)				n of crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticultu re 3. Drought resistant crops 4. Trees for timber 5. Trees for firewood 6. Other (Specify)			

Crop production in the last 12 months

Does your household normally undertake crop farming? 1. Yes-Rain-fed 2. Yes-irrigated 3. Yes R&I 4. None	Did your household grow any crops during the last 12 months? 1. Yes 2. No		Name all crops that the h/hold farmed in the last 12 months by season and acreage			
	Long rains (LR)	Short rains (SR)	LR		SR	
			Crop Name	Code	Crop Name	Code

Appendix 3: Region Cross Tabulation

If yes, Which climatic event * region Crosstabulation

			region			Total
			high zone	mid zone	low zone	
If yes, Which climatic event	drought	Count	68	50	73	191
		% within If yes, Which climatic event	35.6%	26.2%	38.2%	100.0%
		% within region	55.3%	44.6%	60.8%	53.8%
	above average rainfall	Count	4	3	2	9
		% within If yes, Which climatic event	44.4%	33.3%	22.2%	100.0%
		% within region	3.3%	2.7%	1.7%	2.5%
	below average rainfall	Count	21	21	26	68
		% within If yes, Which climatic event	30.9%	30.9%	38.2%	100.0%
		% within region	17.1%	18.8%	21.7%	19.2%
	floods	Count	3	3	10	16
		% within If yes, Which climatic event	18.8%	18.8%	62.5%	100.0%
		% within region	2.4%	2.7%	8.3%	4.5%
	erratic rainfall pattern	Count	23	33	7	63
		% within If yes, Which climatic event	36.5%	52.4%	11.1%	100.0%
		% within region	18.7%	29.5%	5.8%	17.7%
	hailstorms	Count	1	0	0	1
		% within If yes, Which climatic event	100.0%	0.0%	0.0%	100.0%
		% within region	0.8%	0.0%	0.0%	0.3%

	lightning	Count	0	0	1	1
		% within If yes, Which climatic event	0.0%	0.0%	100.0%	100.0%
		% within region	0.0%	0.0%	0.8%	0.3%
	landslides	Count	1	0	0	1
		% within If yes, Which climatic event	100.0%	0.0%	0.0%	100.0%
		% within region	0.8%	0.0%	0.0%	0.3%
	strong winds	Count	0	1	1	2
		% within If yes, Which climatic event	0.0%	50.0%	50.0%	100.0%
		% within region	0.0%	0.9%	0.8%	0.6%
	soil erosion	Count	1	1	0	2
		% within If yes, Which climatic event	50.0%	50.0%	0.0%	100.0%
		% within region	0.8%	0.9%	0.0%	0.6%
	frost	Count	1	0	0	1
		% within If yes, Which climatic event	100.0%	0.0%	0.0%	100.0%
		% within region	0.8%	0.0%	0.0%	0.3%
Total		Count	123	112	120	355
		% within If yes, Which climatic event	34.6%	31.5%	33.8%	100.0%
		% within region	100.0%	100.0%	100.0%	100.0%