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Assessment of Conservation Agriculture as an Adaptation Option to Climate Change in the Taita Hills, Kenya

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Declaration

I declare that this research project is my original work and it has not been presented for a degree in any other University.

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Abstract

Climate Change and Variability affects water supply and food security, especially in developing countries where many small-scale farmers rely on rain-fed agriculture for food production and as a main source of livelihood. The extent of the effects of climate change and variability on these small-scale producers largely depends on their level of adaptation, adaptive capacity, exposure and vulnerability. This study evaluates the effectiveness of Conservation Agriculture (CA) as a possible adaptation tool for farmers to climate change and variability in the Taita Hills, Kenya. A mixed research methodology was used entailing literature review, participatory methods, household surveys and experimental field assessments. It emerged from the results that both the long and short rainy seasons have become unpredictable and the amount of rainfall received was inadequate resulting in crop loss for farmers. 44% of the household survey respondents reported drought to be the major climate event causing crop losses among other events such as erratic rainfall patterns, above average rainfall and below average rainfall. Other factors reported to cause crop loss included insect pests and diseases, input factors and soil factors. In coping with drought, farmers reported a number of adaptation measures the most common one being buying food, reported by 70.9% of the respondents. While 39.7% of the respondents were aware about CA, only 3.2% practiced it on their farms. Finally, experimental assessments showed that CA has great potential in enhancing farmers' adaptation to climate change as opposed to conventional practices especially in the low-altitude agro-ecological zone. The smallholder farmers possess a lot of traditional knowledge especially on Integrated Pest Management (IPM) that is an important CA component. The study recommends that agricultural extension to farmers be improved to create awareness on more sustainable adaptation practices and farmers be included in decision making regarding adaptation to climate change as they have a lot to offer.

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Abbreviations

ANOVA	Analysis of Variance
ASALs	Arid and Semi-arid Lands
CA	Conservation agriculture
CA-SARD	Conservation Agriculture for Sustainable Agriculture and Rural Development
CHIESA	Climate Change Impacts on Food Security and Ecosystem Services in Eastern Africa
FAO	Food and Agriculture Organization
FDG	Focus Group Discussions
GHG	Greenhouse Gas
GoK	Government of Kenya
IAAST	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Centre for Research in Agro-forestry
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
JJAS	June July August September
KARLO	Kenya Agricultural and Livestock Research Organization
KII	Key informant interview
LR	Long Rains
MAM	March April May
OND	October November December
RCP	Representative Concentration Pathway
SPSS	Statistical Package for Social Sciences
SR	Short Rains
TTCG	Taita Taveta County Government

CHAPTER 1

INTRODUCTION

1.0 Background

Climate change has been reported as one of the most serious global issues at the moment as it has intensified the risk of natural disasters all over the world (IPCC, 2007). According to the IPCC, its effects can already be seen by increases in the intensity and frequency of extreme weather events such as floods, droughts, forest fires, storms, rising sea levels, changes in rainfall patterns and a rise in global temperatures that reduce agricultural production in already fragile areas. The developing world is at most risk of these consequences due to their dependence on natural resources as the major income source, limited resources to adapt to the changes and a delayed recovery from the impacts due to lack of planning. The World Food Program (2011) notes, that climate change will increase the number of people at risk of under nutrition and hunger. This is of major concern considering the fact that world population currently stands at seven billion people and is expected to rise to nine billion by 2050. Most of this population growth is expected to occur in Asia and sub- Saharan Africa (FAO, 2010). This is likely to bring about changes in consumption levels and the United Nations Food and Agriculture Organization (FAO) estimates that feeding the world population in the future will require a rise in agricultural production of up to 70% (Burney et al., 2010). Climate change is expected to make agricultural production more erratic and reduce productivity to much lower levels in areas where it is already low and coping strategies are limited (IPCC, 2007).

Countries in East Africa are highly vulnerable to climate change mainly due to their reliance on rain-fed agriculture. Given the multiple roles that agriculture plays in economic development, alleviation of poverty, food security and job creation, East African countries are likely to feel the most impacts given the climate risks that increase vulnerability of the agriculture sector

(Waithaka *et al*., 2013).

Like other countries in East Africa, Kenya is under the uncertainty and risks associated with climate change. Habitat reduction and destruction puts the already fragile ecosystem of the country under more intense pressure. Furthermore, the vulnerability of the country is worsened by weak institutional capacities, inadequate technology and poor information infrastructure making it difficult to put in place more effective response measures to climate change. Environmental degradation due to deforestation, urbanization and development has contributed to climate change and food insecurity in most parts of the country. It is reported that currently nearly ten million Kenyans currently suffer from chronic food insecurity and between 2-4 million require emergency food assistance at any one time (Patel *et al*., 2012).

Small holder farmers in the Taita Hills are particularly vulnerable to changes in climate that reduce productivity and have negative effects on their weather-dependent livelihood systems. The farmers face additional challenges of land degradation due to poor soil fertility management and continuous cropping. Furthermore, frequent droughts and floods have caused failure and damage to crop and livestock systems resulting in persistent food shortages. This further increases the risk of farmers due to their low capacity to adapt because of various socio-economic, demographic and policy trends (Waithaka *et al.*, 2013).

Regardless of the rise in frequency of extreme events, decreasing rainfall and rising temperatures, more food production has to be achieved to meet the rising demand (Mrabet, 2011). For this reason, maintaining and enhancing food security requires a change in agricultural production systems towards high productivity with lower output variability in the face of climate risks or a shift to other livelihoods. Adaptation is recognized as one of the most important components for responding to the changes in climate.

There are several definitions of adaptation. It may be defined as the adjustment of human and natural systems to respond to actual or expected climatic stimuli or the effects of the same in order to regulate the possible harm or take advantage of beneficial opportunities that may occur from this stimulus (IPCC, 2001). Adaptation is also defined as an adjustment in ecological-socio-economic systems in response to actual or expected climatic stimuli and their impacts (Smit and Skinner, 2006). Brooks (2003) defines adaptation as the behavioral and characteristic adjustment of a system to enhance the ability of that system to cope with external stress. Fankhauser (1999) notes that adaptation can be reactive or anticipated based on timing, and planned or autonomous depending on how spontaneously the adaptation practices occur. Planned adaptation is that which occurs because of deliberate policy decision based on awareness that conditions have changed or are expected to change and actions need to be taken in order to maintain a desired state. For example, the government can decide to make more investments in irrigation infrastructure and efficient water use technologies as part of plans to address climate change in its development programs. Autonomous adaptation on the other hand refers to actions taken independently by individuals or communities to adjust to their own perceptions of climate risk. These actions are usually short term and reactive in nature for example, a farmer can make a personal decision to change a maize variety because the old one is not performing well under the current climate conditions. These responses are meant to complement each other so that adaptation works more effectively in minimizing the impact of climate change on communities' livelihoods.

Research indicates that if well implemented and managed, adaptation efforts are likely to significantly reduce vulnerability by making production systems more resilient and bring about sustainable development with great benefits to our environments (Smit and Skinner, 2002). These include the use of sustainable production practices such as conservation agriculture (CA), which have the capacity to increase yields with minimal detrimental effects to the environment and less depletion of natural resource. CA is defined as a sustainable farming approach based on three major principles namely; minimum tillage, permanent soil cover and crop rotations (SUSTAINET, 2010).

This study assesses the possibility of using CA as a possible adaptation option to climate change in the Taita Hills, Kenya.

1.1 Problem Statement

A wide range of potential agricultural adaptation options has been documented, representing practices that can be taken to minimize the adverse impacts of climate change. These include technological developments such as crop improvement, government programs such as seed and fertilizer subsidies, and farmer insurance schemes as well as use of climate-smart technologies including CA (Smit and Skinner, 2002). However, most of them are represented in literature as possible adaptation options but have not actually been adopted. There is need to assess these options and determine what works for farmers in different areas including the Taita Hills.

In addition, the small fragmented land holdings in the Taita Hills are characterized by frequent cultivation and minimal soil conservation. This is unsustainable, considering the increased frequency of droughts in the area due to climate change and increased soil erosion due to deforestation. Intensive agriculture characterized by regular use of synthetic pesticides and frequent cultivation leads to degradation of suitable habitats for natural enemies of insect pests, declining soil fertility and creation of favorable opportunities for certain pests to thrive causing further losses (Abrol, 2013). Soil erosion is also a common occurrence in the area and this is characterized by deep gullies in most of the areas that have been deforested. CA is a viable climate-smart technology that has successfully been used to improve crop yields in other parts of Kenya, for example, in Siaya and Mumias Counties (District, 2007). It has been proven to sustain food production as well as improve soil properties to increase fertility in these areas. However, whether it can have similar positive impacts in the Taita Hills is a question to be answered. There is need to evaluate whether it can work for the Taita Hills farmers for recommendation as a possible adaptation option.

The study therefore assesses the possibility of using CA practices in order to increase crop production, enhance food security and raise agricultural returns for farmers in the Taita Hills in southeast Kenya. This kind of transition can lead to increased food production that enhances food security, protects the natural wealth such as soil moisture and soil fertility, and also brings about significant mitigation benefits by increasing farmland carbon sinks (FAO, 2010).

1.2 Research Questions

1. What are the trends in climate variables in the Taita Hills?
2. What is the impact of the observed climate trends on common bean production?
3. What are the adaptation options currently being implemented in response to climate variability and change, and what are the opportunities and challenges in the uptake of these options by the farmers?
4. Can these opportunities be harnessed, and the challenges ameliorated by CA in a bid to strengthen adaptation to climate change?

1.3 Objectives

The general objective of this study was to assess the viability of CA as a possible climate change adaptation option for smallholder farmers in Taita Hills, Kenya. To achieve the overall objective, the specific objectives were:

1. To establish the trends in climate variables, mainly temperature and precipitation in the

Taita Hills over a period of 30 years.

2. To determine the impacts of the climate trends on common bean production

3. To identify the current adaptation options and analyze the opportunities and challenges in their uptake

4. To assess viability of CA as a possible adaptation option for the farmers to climate change

1.4 Justification and Significance

CA has been proven to improve and maintain crop yields as well as enhance resilience against climate hazards, especially drought. The practice stimulates biological functions of the soil thus sustaining its productivity. By maintaining a constant crop cover or mulch, the growth of weeds is hindered therefore minimizing competition with the planted crops and reducing labor requirement for weed control. CA will also be particularly beneficial to the many smallholder farmers who do not have access to animal or mechanical tillage as well as irrigation infrastructure. The permanent or semi-permanent soil cover in CA protects soil from the forces that degrade it for example, wind, rainfall and above average air temperatures (Derpsch, 2005).

Additional reductions in labor are realized during land preparation and amount of inputs used; fertilizers or manure through spot planting. It also helps in boosting crop production through timely planting and improves the food security and livelihoods of farming households (Harford *et al*., 2009). The technology also helps in conserving soil water by reducing run-off and through increased infiltration due to the permanent soil cover and mulch.

CA has been shown to be of great benefit in years experiencing sporadic or poor rainfall due to the high residual moisture levels, which enable seeds to germinate and sustains the crop (Mloza-banda *et al*., 2010). It can enhance the commonly practiced rain-fed agriculture in Taita Hills whereby the farmers constantly suffer from decreased soil fertility and diminishing soil water dynamics. In Mbeya district Tanzania, introduction of the zero-tillage practice into the dominant rain-fed production system resulted in a 360% increase in sunflower production and 26-100% increase in maize production (Shetto & Marietha, 2007).

The crop rotation principle enhances soil fertility when legumes are included. Sequencing of crops according to seasons in the crop rotation cycle also minimizes the buildup of insect pests and diseases while optimizing nutrient use between the different types of crops (Bullock, 1992).

Furthermore, some of the adaptation strategies put in place by the community only make them more vulnerable e.g reliance on food aid, necessitating the need for more sustainable strategies. Efforts by the agricultural offices to offer subsidies in form of free seed of alternative drought-resistant crops such as sorghum have also not been widely adapted as follow up activities by extension officers show that most farmers do not plant the seed because it is not a preferred staple crop in the area.

The benefits arising from IPM include increased returns for farmers arising from higher agricultural production, protection of beneficial species and non-target organisms such as predators, parasitoids and pollinators, reduced degradation of soil, water and air quality as well as improved health of agricultural workers and farm families (Sandler, 2010). Thus, the system offers an opportunity for all farmers in the Taita Hills to not only improve yields, income, food security and livelihoods affordably, but also protect the environment by enhancing carbon sequestration from the farmland carbon sinks. Common beans were used in the demonstration trial plots for assessment of the practice since beans are readily available, affordable and play an important role in the diets and food security of the region.

1.5. Study Area

1.5.1 Location and Description

The Taita Hills are located in Taita Taveta County within the Coast Region that lies in southeastern Kenya (latitude 3°25'S and longitude 38°20'E). The hills form the northern most part of the 850km^2 stretch of the Eastern Arc Mountains in Kenya. The hills lie within the Tsavo ecosystem which is mainly semi-arid. The research transect was 22km long and covered an area of 1km on either side of the road extending from the low zone of Mwatate at 800 m above mean sea level (a. m. s.l) to the highlands of Vuria that lie approximately 2, 200 a.m.a.s.l (Figure 1). The different altitudinal zones depict different agro-ecological zones within the Taita Hills.

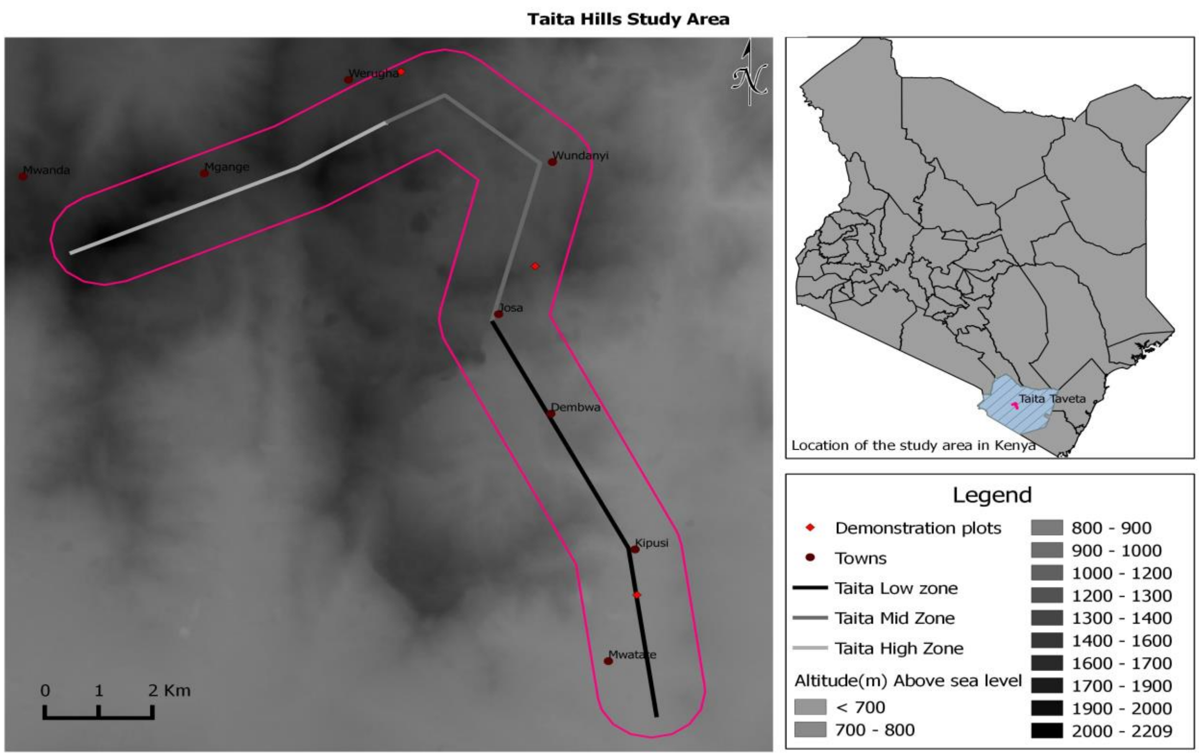

Figure 1: Geographical Location of the study area in the Taita Hills (Akinyi, 2015).

1.5.2 County Population

A steady increase in the county population has been observed over the census years (KNBS, 2010).

Table 1: Percentage Population increase over Census years in the Taita Hills

Census year	Population	% increase
1969	110,742	-
1979	147,597	33.3
1989	207,273	40.4
1999	246,671	19.0
2009	284,657	15.4

Further projections show the county population to increase to 329,383 and 345,800 in the years 2015 and 2017 respectively (Table 1). This population increase has a direct impact on access to resources such as land, basic needs such as food, water, housing, and social services like education and health.

The ratio of males to females is 1.04, which means that for every 100 females, the males are 104. For the population below 15 years of age, the ratio of males to females is 1.02, 1.08 for the population between 15 and 64 years and 1.05 for those above 30 years. For those that are 40 years and above, the ratio is 0.99 hence as age advances, the ratio decreases an indication that the death rate among adult males is higher compared to that of adult females (TTCG, 2013).

The county has approximately 54,732 households, the population density being 16 persons per square kilometer. The rise in population poses various challenges for individuals in different age groups. One major consequence of high population is land fragmentation especially in the highlands (NEMA, 2013). This is worsened by high poverty levels, limited technical and material resources, which combined with the small land holdings result in inadequate investment in soil conservation practices. People migrating to lower drier areas where land may be available usually apply the same farming techniques used previously in the highlands and these are not suitable for drier areas.

1.5.3 Livelihood zones

Six livelihood segments have been identified in the county (Figure 2). These include: mixed farming component comprising food crops and livestock farming practised by approximately 34% of the population; mixed farming component comprising of food crops, horticulture and dairy practised by an approximated 21% of the population; 11% of the population practice mixed farming comprising of irrigation, livestock and food crops, 20% make a living out of casual wage labor, 13 % out of trade and business and 1% out of formal employment (NDMA, 2013).

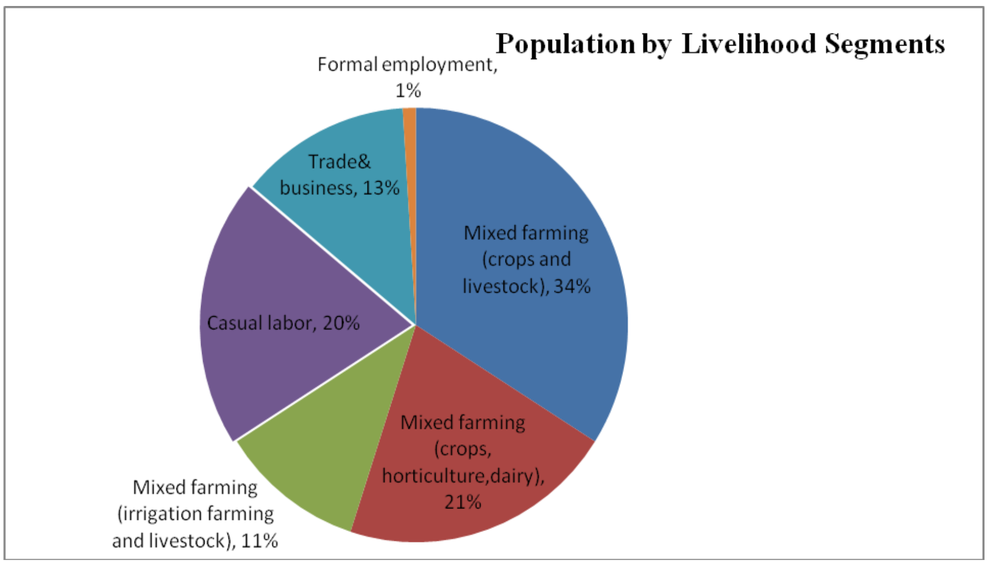

Figure 2: Taita Taveta County Population by Livelihoods (*Adapted from NDMA, 2013*).

Based on Figure 2 above, 66% of the population in the county relies on farming as their major source of livelihood. This contributes to the vulnerability of these farmers to climate change impacts because both crops and livestock are under the direct influence of climate. In addition, the on-going relief operations in the county such as the food for assets (FFA) and cash for assets (CFA) programs sponsored by the World Food Program show that the food produced is not adequate to feed the population. Average monthly income for households in the county is Ksh. 2000 hence it is impossible for most farmers to invest or save and this has contributed to high absolute poverty levels of 66% (NEMA, 2013).

1.5.4 Vegetation

A number of cloud forests are indigenous to the Taita Hills but they have suffered significant degradation and vegetation losses from as far back as 1960s when the government started subdividing and allocating land. The forests are known to harbor rich concentrations of plants and animals that are endemic to the region and are therefore considered to be among the world's 25 biodiversity hotspots (Myers *et al*., 2000).

They are also a source of the streams that provide water to the lower regions. The large diversity of unique flora and fauna has however been seen to portray signs of vulnerability to the impacts of climate change. Clark (2010) argues that the rising population is the major driving force to environmental degradation while scarcity of land on the hills has led to clearing of virgin lands in the lowlands.

According to Pellikka *et al*. (2009), half of the indigenous cloud forests in the Taita Hills have already been cleared to provide land for agriculture and currently only 1% of the original forests are preserved. Apart from the main rivers and springs originating from the Taita Hills, the county has other water resources such as Lake Chala and Lake Jipe, which are in Taveta district located in the lower zone. In addition, the county is well endowed with mineral resources especially in the low zone consisting of both gemstones and industrial minerals that are mainly controlled by outside investors.

1.5.5 Climate

The Taita Hills experience a bimodal rainfall pattern with long rains occurring in the March-May period while the short rains occur between the months of October and December. The altitude difference within the county ranging from 480 m.a.s.l to about 2,200 m.a.s.l for the lowlands and highlands respectively is responsible for two distinct climate characteristic with regard to precipitation and temperature.

Annual precipitation varies ranging from 500 mm in the lowlands to 1,500 mm in the highlands. The lowlands also experience higher average annual temperatures of up to 26.4°C while the highlands experience lower annual temperatures of up to 18.2°C. Average annual temperatures for the county are 23°C.

A combination of higher rainfall and cooler temperatures make the highlands more suitable for production of maize, beans and horticultural crops. The lowlands on the other hand are majorly arid and semi-arid hence are only suitable for short-maturing and drought tolerant crops such as cowpeas, green grams, sorghum, millet, hybrid maize varieties and sunflower. The lowlands are also suitable for other activities such as sisal farming and ranching (Muinde, 2011).

Three agro-ecological zones are distinguished in the Taita Hills and these include the high, medium and low potential areas. The high potential area comprises of the highlands that lie at an altitude range of 1680-2200 m.a.s.l and experience 900-1200 mm of rainfall annually. The medium potential area is the midland zone lying at 910-1520 m.a.s.l and experiences 700-900 mm of rainfall annually. The low potential area comprises of the lowlands that lie at an altitude of 610-980 m.a.s.l and experience 480-680 mm annually (NEMA, 2013).

1.5.6 Land Use

According to Maeda *et al*. (2010), the most dominant type of land use in the Taita Hills is intensive subsistence agriculture characterized by staple crops such as maize, beans, potatoes, cassava, cabbages, tomatoes and bananas. Land use in the foothills and plains that surround the hills is predominantly extensive agriculture and grazing. Large forests that have remained fragmented are found in the most remote areas of the hills.

Mutsotso *et al*. (2011) notes that the crop varieties initially planted from as far back as 1967 have persisted to the present, the only variation being an increase in the intensity of cultivation characterized by continuous cropping, intensive cultivation and high use of agricultural inputs with little increase in acreage under cultivation.

Baseline studies also show that almost all households cultivate Napier grass. The napier grass provides fodder for the small-scale farmers who mainly practice zero grazing of dairy cattle because of small land sizes. It is also grown along bench terraces to make them more stable. Thus, even farmers who do not own cattle grow napier grass as it can stabilize the terraces and can be sold or exchanged for manure when mature. The high population density in the hills coupled with scarcity of available land has brought about changes in land use patterns, which have resulted in land degradation for example in form of deforestation and soil erosion. All these have greatly contributed to the decline in agricultural productivity in the area.

A baseline study of the Taita Hills was conducted by the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa Project (CHIESA) in 2012. The study, which entailed focus group discussions (FGDs) comprising of 150 farmers and household questionnaire surveys comprising of 300 households from six locations lying at different altitudinal gradients showed that the Taita Hills have been impacted by climate variability. Both male and female farmers noted that there has been a decline in their farm productivity arising from successive droughts and inadequate farm inputs. Farmers in the area have also noted a shift in climatic patterns with the onset of seasons (especially the rainy seasons) either delaying or being prolonged. Consequently, they have suffered increased crop failure resulting in economic losses and increased prices of food crops in the area. In addition, they have noted that crop pests and diseases are increasingly affecting their crops.

1.5.7 Suitability of the Taita Hills as a Study Area

The Taita Hills form a suitable study area because the area possesses a unique ecosystem comprising of different agro-ecological zones that lie at different altitudinal zones. While the low-lands of Mwatate are classified as arid and semi-arid lands, the high zones in the Taita Hills are characterized by arable lands since they lie on the windward side thus enabling good agriculture (Pellikka *et al*., 2004). Moreover, this ecosystem is threatened by climate extremes such as droughts and floods, with local farmers reporting cases of crop failure and higher incidences of existing and new pests and diseases unlike in the past. In addition, some of the adaptation strategies put in place by communities only make them more vulnerable for example reliance on food aid, necessitating the need for more sustainable strategies. For instance, while supply of relief food may be effective in the short term, its sustainability over subsequent years is not guaranteed. Carrying out the studies at different altitudinal zones helped to adequately capture both the climatic and non-climatic factors that increase farmers' vulnerability to climate change and existing adaptation strategies that are in place in the low, mid and high altitude zones of the Taita Hills.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The predicted global climate change especially increased air temperature and decreasing precipitation is bound to have great impacts on the world's agricultural production and supply patterns. It is estimated that between now and 2050 world population will have increased by two billion people, and the rise will mostly be in the developing countries. This means that the world will have to increase agricultural production by 70% during this period in order to meet the demands of the growing population (Burney *et al*., 2010). In Africa, it is estimated that over 70% of the population depend on subsistence rain-fed agriculture. However, this is also the same area that will be worst hit by climate change impacts because of limited adaptive capacity (Chinowsky *et al*., 2011).

Long-term changes in patterns of air temperature and precipitation are expected to bring about a shift in planting seasons, pest and disease incidences and modify the set of crops grown hence affecting production, incomes and livelihoods (Stern Review, 2006). Climate variables such as air temperature and precipitation play a critical role in crop production just like other agricultural inputs, for example certified seeds and fertilizers. Visible impacts have already been noted on yields and the pace of growth due to global changes in temperature and rainfall (Lobell *et al*., 2011). As climate patterns change, there arises a shift in distribution of the various agro-ecological zones, habitat ranges of plant pests and vectors of plant diseases that may have serious effects on food production.

With the increasing average annual temperatures, agricultural productivity is projected to decrease forcing many small-scale farmers to resort to unsustainable practices such as intensive agriculture in order to increase yields. This practice involves frequent cultivation, high use of pesticides and fertilizers that subsequently damage the natural resource base, mainly soils and lead to green house gas (GHG) emissions (Fischer *et al*., 2002).

2.1 Projected Climate Scenarios for East Africa

The implications of anthropogenic climate change for environment and society not only depend on the Earth's system response to changes in atmospheric composition, but also on the driving forces and the adaptation and mitigation strategies put in place by humans through changes in technology, economies, lifestyle and policy. The fifth assessment report (IPCC, 2014) offers strong evidence that there has been warming across Africa in the last 50-100 years, with an increase in surface temperatures by 0.5-2°C. Data from 1950s onwards shows variation in the magnitude and frequency of certain extreme weather events due to climate change that have affected the livelihoods, health and food security of the people within the African continent. East Africa in particular is noted to have experienced a considerable increase in seasonal average temperatures from early 1980s onwards. Countries lying to the west of the Indian Ocean, East Africa included have experienced warmer temperatures and frequent heat waves in the period between 1961 to 2008. In the 21st century, temperatures in Africa are expected to rise faster than the global average increase. It is projected that there will be an increase in the number of days warmer than 2°C above the 1981 to 2000 average by the end of the 21st century (James and Washington, 2013).

Rainfall in East Africa has also been noted to be highly variable over space and time mainly due to the influence of El Niño Southern Oscillation (ENSO) among other processes. Several models suggest that rapid warming of the Indian Ocean could be the reason for the low rainfall recorded over the eastern Africa region over the last 30 years for the March to May (MAM) rainfall season. The past 60 years have also recorded low rainfall amounts during the monsoon rainfall season for a large part of the Horn of Africa (IPCC, 2014).

Further, while there is a lack of evidence about the trends in extreme rainfall, droughts and extreme temperature, there has been a high frequency of observed extreme events in eastern Africa majorly droughts and storms over the last 30 to 60 years, which is largely attributed to continued warming of the Indian Ocean. However, it is not clear whether the changes are because of anthropogenic factors or natural climate variability (IPCC, 2014).

The IPCC (2014) reports a number of scenarios, known as Representative Concentration Pathways (RCPs) that show the results of different emission levels on global warming between the present day and 2100. These include the highest emission scenarios (RCP 8.5), two intermediate emission scenarios (RCP 4.5 and RCP 6.0) and the lowest emission scenario (RCP 2.6). In all scenarios, the CO_2 concentrations are higher in 2100 compared to the levels today. Regardless of actions taken to reduce emissions, climate will continue to change up to around 2050 (middle of this century). The lowest emission scenario (RCP 2.6) assumes sustained reductions in GHG emissions such that global warming is maintained below 2°C by 2100. For the highest emission scenario, warming is estimated to still be at 4°C by 2100. Warming is expected to continue beyond 2100 under all emission scenarios except in the lowest scenario. This implies that if appropriate mitigation policies are not put in place, climate change will not only create new risks, but also intensify existing ones thus posing more challenges in food production, human security and livelihoods.

In Africa, there is high confidence in projections that climate change will amplify existing stress on agricultural systems and water availability especially in semi-arid and arid environments. Projections for the medium to high emission scenarios show a likely increase in the minimum and maximum temperatures over equatorial East Africa with warmer days by the middle and end of the 21st century. Further to this, global projections show that rainfall is likely to increase especially during the short rains in eastern Africa but this may not translate to water surplus because the expected temperature rise will result in high levels of evapo-transpiration resulting in a reduction in water resources availability and high likelihood of surface run off. Consequently, the IPCC Special Report on Managing the Risks of Extreme Climate Events and Disasters to Advance Climate Change Adaptation shows that despite the extreme wet days by the middle of 21^{st} century in eastern Africa, there is high confidence that the frequency of extreme of days will also increase. There is high confidence for extreme temperature, extreme rainfall and sea level rise in East Africa that are likely to magnify the impacts of climate change (IPCC, 2012).

The fifth assessment report of also indicates that interaction between climate change and non-climate stressors and drivers will exacerbate vulnerability of agricultural systems especially in the arid and semi-arid lands (IPCC, 2014). There is a high likelihood that changes in precipitation and increasing temperatures will reduce cereal productivity to further intensify food security challenges. Past studies by Slingo *et al*. (2005) revealed that agriculture in Africa is bound to be one of the most vulnerable sectors to climate change. This is mainly due to total reliance by a large part of the population on rain-fed agriculture as a source of livelihood (Benhin *et al*., 2010). The slightest changes in rainfall and temperature are likely to result in significant effects on crop production through increased incidence of pests and diseases and occurrence of extreme events such as drought (Slingo *et al*., 2005). This is in addition to the multiple stresses that agriculture is already experiencing from poor land use practices, high population growth rates and urbanization that have led to conversion of part of agricultural and most of virgin land into settlement areas and also raised the demand for food and other resources like water and energy. This poses a danger of seriously damaging the natural resource base on which the agriculture sector depends further adding to food insecurity (IAASTD, 2008).

It is also important to note that access to land is becoming a serious problem in Africa. In Kenya particularly, following the land adjudication and consolidation process by the government that occurred in the 1960s, land sizes have grown increasingly smaller. Normally a father is expected to subdivide his land to his sons in equal measure. However, with the increasing population demand for land has increased and the amount of land owned by an individual has become smaller. Rising population has placed pressure on land resources, which has subsequently increased food insecurity. This is because small-scale farmers are trying to intensify land use for both food and cash crops as a means to live by. As farmers strive to make the most out of the scarce land resources, there are little investment efforts in protecting and nourishing the soil so as to maximize production and at the same time enhance sustainability. Therefore, pressure on land coupled with the projected increased stress on agricultural systems requires that more efforts be made to conserve and use the resources sustainably.

2.2 The need for Soil Conservation Policies

While agriculture has been adversely affected by the impacts of climate change, it is also a contributor to climate change through the emission of GHGs. Findings by the IAASTD (2008) indicate that the path currently taken by agriculture is unsustainable and following it will ultimately compromise the planet's ability to support life. According to Downing *et al*. (1991), 85% of Africa's waters are used for agricultural purposes and the farming techniques used are relatively primitive. Temporal and spatial differences in rainfall and temperature are projected to shift the agro-ecological zones thus impacting on both irrigated and rain-fed agriculture (Kurukulasuriya and Mendelsohn, 2008).

Soils are an essential natural resource for agriculture hence their health, nutrient status and fertility should be properly maintained, considering it is a non-renewable natural resource. It is projected that there will be a 9% increase in global average soil erosion by 2090 due to changes in climate (Yang *et al*., 2003). Consequently, if adequate investments in soil water management are not made, global irrigation water needs will increase by approximately 20% by 2080 (Fischer e*t al.*, 2007). Studies in the Taita Hills by Maeda (2012) show that if the current trends persist, agricultural areas are likely to occupy about 60% of the land area by 2030. While agricultural activities may be a contributing factor to climate change, variations in temperature and precipitation patterns triggered by climate change have serious impacts on sustainability of agricultural systems.

Based on the simulations of future agricultural expansion and climate change scenarios, Maeda *et al.* (2010) add that land use changes will accelerate soil erosivity in the area and thus recommend that the highlands of the Taita Hills be prioritized for soil conservation policies in the next 20 years. This is because changes in the volume and intensity of precipitation will increase the energy available in rainfall to detach and carry sediments thus accelerating soil erosion.

The annual crop production report of Mwatate District (GoK, 2009) shows that, out of the district's total population of 83,583 people, 37% are food insecure. They relied on relief food from the World vision between the months of August and December the same year. This means that if food production has to be increased, enactment and implementation of soil conservation policies in the area has to be prioritized as good soils are crucial to good yields. Crop production losses also arise from weeds, diseases and pests, which create serious inefficiencies in resource use for example, fertilizer, water, labor and energy. A reduction in these losses can result in substantial increases in food supply.

2.3 Role of Conservation Agriculture in Adaptation

One of the core reasons why CA is very important is because of the consequences that arise from conventional agricultural practices (Derpsch, 2009). These consequences include practices such as removal and burning of crop residues, continuous tillage, deforestation, overgrazing, excessive application of inorganic fertilizers, mono cropping and improper use of pesticides.

This is accompanied by serious consequences such as loss of soil fertility and significant reductions in yields, higher risks of droughts and floods, health and food insecurity issues, soil degradation, emission of green house gases, loss of biodiversity and damage by insect pests and diseases.

The Food and Agricultural Organization (FAO), reports that tillage-induced soil erosion accounts for losses of more than 150 tons/hectare of soil every year (FAO, 2001). While continuous cultivation brings about short-term increases in crop yields due to enhanced mineralization of soil organic matter, it leads to long-term destruction of the soil life and structure. This exposes the soil to compaction subsequently reducing water storage and infiltration capacity. Continuous soil degradation poses a threat to food security and affects the livelihoods of many households across the world. The benefits of conservation agriculture are realized by elimination of the aforementioned consequences through reduced erosion and protection of the soil.

Principles of Conservation Agriculture

According to Kassam *et al*. (2009), the concepts under which CA is underpinned aim at conservation of resources while profitably managing sustainable production, intensification and ecosystem services. They note that optimum CA entails three major principles:

- Minimal soil disturbance, which stresses the need for direct seeding. Once the soil condition has been well developed, tillage should be eliminated altogether. Soil disturbance from cultural practices such as weeding should be as minimal as possible.

- Maintaining a permanent or semi-permanent organic soil cover all year round. This can be in form of intercrops, cover crops or mulch acquired from residues of the previous crop.

- Diversification of crop rotations, association and sequences adapted to the local environmental conditions. These help in maintaining above and belowground biodiversity fix nutrients such as nitrogen into the soil and suppress build up of pests.

According to FAO (2010), a climate-smart agricultural practice is a practically proven technique or approach that can achieve a triple gain for adaptation, mitigation and food security. CA has been promoted as one such practice.

Figure 3 below summarizes the core principles of CA, which work hand in hand to promote sustainable agriculture.

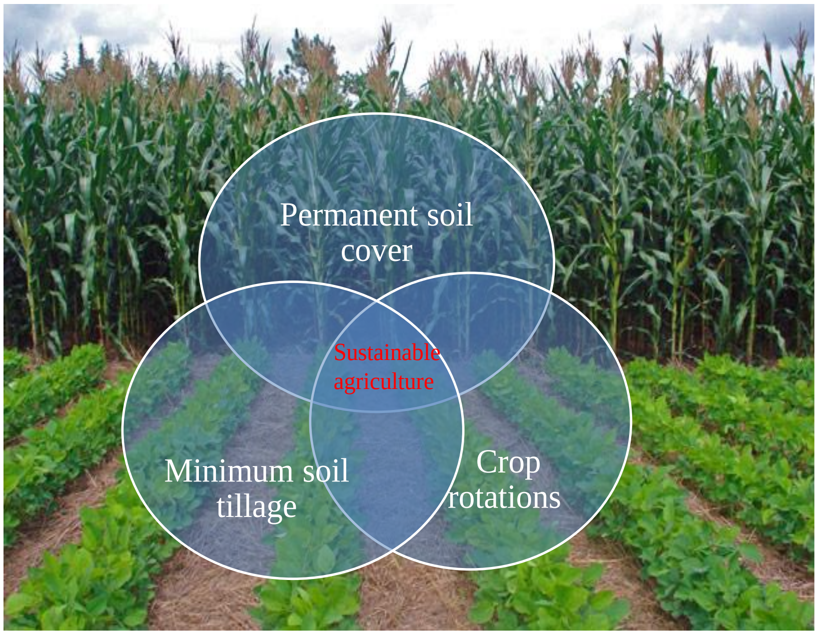

Figure 3: A holistic cropping system for Sustainable Agriculture (adapted from Derpsch, 2001).

Conservation Agriculture as a Mitigation Option

The intensification of agricultural production is noted to be a major factor that influences emission of GHGs (Reicosky and Archer, 2007). The amount of carbon emitted due to soil respiration as a result of ploughing and mixing crop residues as well as burning the residues is 10 times the amount of CO_2 emitted by industries. CA production systems help to offset short-term emissions of CO_2 from anthropogenic activities in croplands (Schlesinger and Andrews, 2000).

CA systems promote soil carbon sequestration by increasing carbon inputs into the soil and minimizing the carbon outputs. Sequestered atmospheric carbon is stored in long-lived organic pools of matter within the soil. This in turn helps in improving soil quality and at the same time mitigating greenhouse gases (FAO, 2001).

CA also helps in mitigating soil erosion. Erosion has the most severe impact on soil organic matter of all the known soil-degrading processes. The minimum tillage vegetation cover on the soil preserves the integrity of the top soil to increase infiltration and resist vents of water erosion. A study by Mrabet (2011) shows that, erosion risk is minimized when the soil surface is constantly covered especially during the rainy season.

Global Adoption of Conservation Agriculture

CA practices have already been applied on more than 100 million hectares of land globally and most of the practices present win-win scenarios in terms of high agricultural productivity, low production cost and better management of natural resources (Derpsch *et al*., 2009). 47% of the technology is practiced in Latin America, 39 % in the USA and Canada, 9% in Australia and 3.9 % in the rest of the world, Africa included. This clearly shows that the adoption rates in Africa are very low and there is a need to promote it widely.

The approach encompasses farming practices characterized by: minimum or zero mechanical soil disturbances, maintenance of carbon-rich organic matter mulch covering and feeding the soil for example from the straw and crop residues and also rotations and associations of crops including nitrogen-fixing legumes (FAO, 2010). These practices offer an essential strategy for meeting the future food demands by the projected high human populations (Dumanski *et al*., 2006).

Types of Conservation agriculture

A number of CA techniques have been tried in various parts of the world including zero-tillage, minimum tillage, agro-forestry system, crop rotation and IPM. A detailed description of some of these practices is given below.

One form of CA is the no or zero-tillage system whereby soil cultivation is replaced by the use of herbicides, mulch application and manual weeding. Minimum tillage is another CA practice that entails limited tillage for seedbed preparation, weed control and planting thus allowing the soil to retain all the organic materials and this has a fertilizing effect on the growing crops. Minimum tillage differs from conventional tillage in that seedbed preparation is only done once unlike the three to six cultivations done before planting under the conventional system (Aune *et al*., 2006). The practice is beneficial in terms of soil moisture conservation, organic matter conservation and reduction in labor and fertilizer costs (Jat *et al*., 2006). The area under minimum tillage in the USA, Brazil, Argentina, Paraguay and Uruguay has been noted to expand greatly. Studies indicate that the method has potential to address problems of erosion, desertification and soil degradation thereby leading to social, economic and environmental sustainability (Derpsch, 2005).

Another form of CA is the agro-forestry system, which involves planting of trees in agricultural lands to control erosion, maintain fertility, protect watersheds and enhance carbon sequestration. This creates both environmental and productivity benefits and also provides fodder, timber, fuel wood and fruits for food. Fertilizer trees that fix nitrogen such as *Sesbania sesban* have been successfully used in maize fields in southern Africa to double maize yields (Kwesiga *et al*., 2003).

IPM is another form of CA that is a decision- making process that provides guidance for farmers to effectively manage pests with little or selective use of pesticides. The approach focuses on methods that are least toxic and may entail combining cultural, mechanical, chemical or biological methods. It involves setting thresholds, monitoring pest activity, employing preventive measures to reduce pest populations, and controlling them with pesticides if they do not respond to the other methods (Harford et al., 2009). Chidawanyika *et al*. (2012), note that climate change influences the biology and distribution of insect pests and diseases as well as their natural enemies. This shows the importance of combining different methods of pest control as is required in IPM in order to control them more effectively.

Abrol (2013) gives an overview of the different IPM techniques as described below. Cultural pest control methods that have been tried include the use of pest resistant or tolerant varieties of crops for problems like *Fusarium* wilt on tomatoes and angular leaf spot on cucumber. Use of clean seeds, proper spacing, fertilization and weeding is another cultural practice to keep away pests by keeping the plants healthy. Healthy plants have the capacity to withstand pest damage. Drought stressed plants are more susceptible to attack hence it is important to keep the soil moisture content at appropriate levels during dry periods. Addition of organic matter is one way of retaining soil moisture and nutrients. Crop rotations assist in pest control by depriving the pest of their host thereby disrupting their lifecycles. Intercropping is another cultural control method that involves physical separation of pests by growing two different crops in close proximity of each other.

Physical pest control methods involve handpicking of visible slow moving insects such as leaf miners, caterpillars and scale insects. Other methods are water spraying to dislodge insects, pruning to make the plants less dense so that beneficial insects can locate their prey easily. Biological control methods involve the use of predatory insects and parasitoids. For instance, a predatory insect known as the ladybird beetle has been used to control aphids while the parasitoid *Diadegma semiclausum* has been used to control the diamondback moth, a destructive pest of brassica crops in Kenya. Pesticides are usually taken as a last option and when used, it is advisable to go for the least toxic to humans, environment, and most pest-specific to minimize non-target effects.

If properly employed, IPM can bring about incidences of food surplus even with the uncertainties in climate. This will in turn increase returns for farmers to improve their livelihoods and build their resilience to climate shocks. As a result, farmers' vulnerability to climate change will be reduced, as their adaptive capacity will be high. There have been success stories with use of the CA technology in parts of western Kenya where projects by ICRAF, KARLO and CA-SARD have had impacts. For instance, small-scale farmers in Siaya district have incorporated leguminous crops and agro-forestry trees such as *Sesbania sesban* and *Calliandra* into their staple crop farming areas to increase soil fertility and improve productivity since most of the arable land is reclaimed from rocky areas (K'Owino, 2010).

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

The research design employed in the study entailed both qualitative and quantitative approaches including literature review, baseline study of the target area, data collection, data analysis and interpretation of results.

3.1 Sources of Data

The study obtained data from both primary and secondary sources. Primary sources included all the original data collected to address the objectives of the study. Secondary sources provide interpretation or analyses based on the primary sources and are therefore used to support a specific argument or persuade the reader to accept a given point of view.

3.1.1 Secondary sources of data

Secondary sources of data included scientific articles, unpublished reports, books and data archives to get information on the problem, what has already been done with regard to the research problem as well as possible gaps that can be filled.

3.1.1.1 Climate data

Data on climate variables majorly temperature and precipitation was obtained from the Kenya Meteorological Department (KMD). Three weather stations were selected such that each of the three agro-ecological zones was represented. Selection of the stations was based on the station that had the longest period of recorded data and with the least gaps. Maktau weather station was chosen to represent the low altitude agro-ecological zone. The data available ranged from 1965-1996. The mid-altitude agro-ecological zone was represented by the Wundanyi weather station with data from 1961-2003. The high altitude agro-ecological zone on the other hand was represented by Mgange weather station with data from 1977-2006. The records were of mean monthly rainfall amounts for each of the zones. These were analyzed to show the trends for the major rainfall seasons, March to May (MAM) and September to December (SOND). However, there were no available records for temperature data in any of the stations.

3.1.1.2 Crop production data

Data on crop production was obtained from annual food and crop situation reports collected from Wundanyi and Mwatate district agricultural offices in the area. Emphasis was put on maize and bean crops data, which are the major staple crops in the area. The data available comprised of annual crop yields in kilograms per hectare over a duration of four years (2009-2012).

3.1.2 Primary Sources of Data

Primary sources included household surveys, key informant interviews (KIIs) and focus group discussions (FGDs) carried out on a sample of the population.

3.1.2.1 Sampling

The total population of Taita Hills is 284,657 people (KNBS, 2010). A sampling process was done in order to get a representative group of respondents from this general population at different altitudinal gradients in the Taita Hills. This was aimed at capturing possible differences in perception regarding the impacts of climate change as well as adaptation strategies employed in the various agro-ecological zones. The target study population comprised of households in the Taita Hills located at different altitudinal gradients from Mwatate in the low altitude agro-ecological zone to Mwanda in the high altitude agro-ecological zone.

3.1.2.1.1 Sample Size

The study sample size was determined using the equation suggested by Yamane (1967);

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = Sample size

N= Population size

e=0.05 (Precision level, assuming the confidence level is 95% i.e ±5)

The sample size was calculated to be 399.43, which was rounded off to 400 households. However, 600 households were visited to ensure that the number of valid questionnaires was not greatly affected by cases of poor reporting of answers by enumerators, lack of response from respondents or failure of enumerators to indicate the date and location of questionnaire. These are factors that rendered a questionnaire invalid and led to disqualification of information from analysis.

3.1.2.1.2 Sampling Procedure

The Taita Hills are located at different attitudinal gradients and therefore it was necessary to stratify the population first before random sampling was done. The population was divided into three strata based on the three agro-ecological zones of the Taita hills. Simple random sampling was then done to select households from the identified strata. The resulting households constituted respondents to which the questionnaires were administered.

Random sampling of the households was done by digitizing the households contained in an aerial image of the Taita Hills study area (Figure 4). The households were then randomly selected, using the open source Quantum GIS, for the household survey.

Figure 4: Othorphoto Map showing Randomly Sampled Households in Wundanyi (CHIESA, 2013)

3.1.2.2 Household surveys

A semi structured questionnaire was prepared for use in household surveys (Annex 1) and FGDs (Annex 2). A questionnaire is defined as a sequence of questions used to acquire information from an informant when asked by an interviewer or completed independently by the respondent. An unstructured questionnaire is a question guide used to direct an interview on a given topic without any predetermined sequence of asking the questions. A structured questionnaire is one in which the questions asked are determined in advance and in the same style and sequence they are written. A semi-structured questionnaire is a combination of structured and unstructured questionnaires whereby some questions are predetermined while others evolve as the interview proceeds (Mellenbergh, 2008).

Respondents were drawn from different social classes and agro-ecological zones. The questionnaire was designed to collect data mainly on farmers' perceptions of climate change, incidences of pests and diseases, and the major pests causing losses in maize and common bean production in the area, adaptation options being used with regard to crop pests and diseases and the soil management practices currently being used by farmers. For purposes of survey, households were selected using random stratified sampling. In total, 600 households were surveyed along the study area, 200 households at each of the three zones between January to April 2014.

Prior to actual data collection, the questionnaires were pre-tested on random households to assess their effectiveness in adequately answering the objectives of the study as well as facilitate planning for the number of days to be spent in data collection. In addition, the pretests allowed for the challenging questions in the questionnaire to be addressed before actual data collection began.

3.1.2.3 Focus Group Discussions and Key Informant Interviews

An FDG schedule and Key informant checklist were used for the FDGs and KIIs, respectively. A focus group is an organized discussion between 6-12 people from the same background that is used to gather information on a particular topic of interest. The small group of people provides an opportunity for all respondents to participate and give their opinions. Participants in the FDGs were drawn from the different agro-ecological zones i.e. the low, mid and high zones. Purposive sampling was used to select FGD participants and a number of factors were considered in selection. They had to be farmers with farms in the different altitudinal zones either in Mwatate, Wundanyi or Werugha (Figure 1). Thirty-six participants were invited, 12 in each location. Gender allocation was six male to six female. These included literate, semi-literate and illiterate farmers. In this case, the literate are those who can read and write, the semi-literate are those can read but cannot write beyond elementary level while the illiterate are those who can neither read nor write.

Interviews were also conducted with selected key informants to provide additional data. Interviews are a way of collecting data from individuals through conversations by talking and listening to them systematically (Kvale, 1996). Face to face interviews guided by semi-structured questionnaires were conducted with key informants including officers from different agricultural offices that is, the District Agricultural Officer (DAO), Ward Agricultural Officer (WAO), crops officers as well as Agricultural Extension officers (AEOs). Key informants are people who have firsthand knowledge regarding a particular area of interest and can therefore give insight and on the nature of problems and offer possible solutions.

3.1.2.4 Experimental plots

One experimental plot was identified in each of the three agro-ecological zones, that is, the high zone, middle zone and low zone and these include Werugha, Wundanyi and Mwatate respectively to serve as demonstration sites.

One farmer was randomly selected from each location along the transect to provide land on which learning plots were to be set up. The mother baby trial approach suggested by Snapp (2002) was used. The approach has been successfully used by the Center for International Tropical Agriculture (CIAT) together with other collaborators to promote activities that enhance land productivity in western Kenya. One mother trial experiment was set up at each location to serve as a learning point for farmers on the concepts of CA. These locations included Mwatate at 860 meters above sea level (m.a.s.l), Wundanyi at 1524 m.a.s.l and Werugha at 1634 m.a.s.l. The target villages were Kipusi Village in Mwatate, Mulava village in Wundanyi and Malela village in Werugha (Figure 1).

The target was 20 participants at each location comprising both male and female farmers. In order to ensure inclusion of youth, the minimum age requirement for the participants was 20 years. The participants were required to own a piece of land in Werugha, Wundanyi or Mwatate depending on where they came from so that they can apply the practices learnt during the demonstrations. In addition, they comprised of both literate and illiterate farmers since most of the learning occurred by doing rather than by reading and writing.

The treatments included an absolute control plot where no input was applied, two farmer practice plots; one with organic manure and the other inorganic fertilizer demonstrating the conventional practices employed by farmers and a CA system plot with IPM practice to demonstrate the possible sustainable technologies for improved crop production (Figure 5). The CA system consisted of several practices including mulching, IPM and minimum tillage. The aim was to set up a simple demonstration experiment that is easy to understand for the participants. According to Machado and Girma (2013), demonstration trials are impossible to replicate since they are usually exploratory in nature and aimed at enabling the observer to learn a specific new technique. Having replicates in this case can therefore be very confusing to the learner.

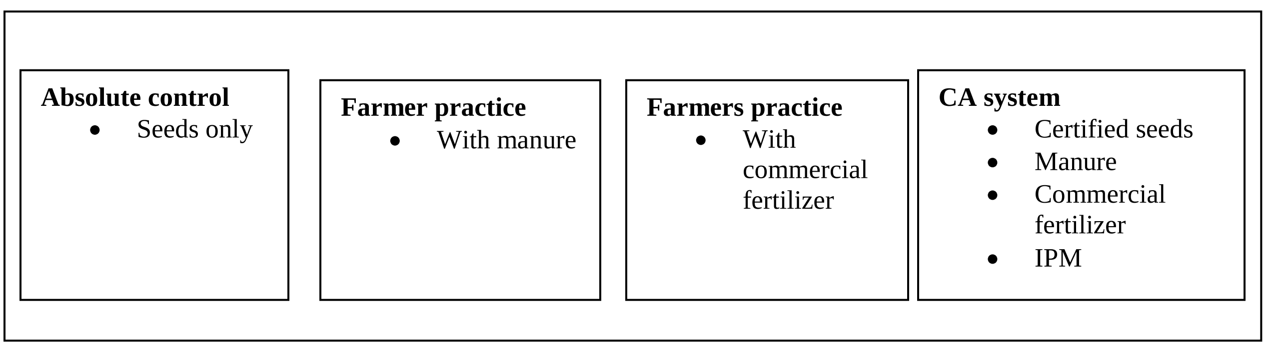

Figure 5: Experimental layout

The Rose cocoa (GLP 2) bean variety was used in the high and mid-zones as it is well suited to the prevailing conditions. However, in the lower dry zone the Katumani B1 (KB1) bean variety was used for demonstration as it is suited to dry areas. The plots were set up in a demonstration strip design and seeds planted 30cm between rows and 15cm within rows at a seed rate of one seed per hole. Each treatment covered an area of 2m by 3m. The experiment was carried out for two seasons, one during the March to May (MAM) rainfall planting season and another during the June July August September (JJAS) season. The JJAS season is not a main planting season in the Taita hills. However, due to the late onset and early cessation of rains some farmers extend their cropping patterns into the JJAS season. The goal was therefore to assess whether CA can sustain crop production during the season which is usually characterized by low temperatures. Incentives were given to farmers in form of certified seeds for planting as well as commercial fertilizer.

Observations commenced two weeks after planting, the established seed crop was monitored for insect pests, and diseases and the information recorded. Weekly monitoring by farmers continued and data on crop condition and growth was recorded up to the 7^{th} week after maximum pod setting when final data collection was done. This involved data on the number of leaves per plant, number of pods per plant, plant height and biomass as indicators of crop performance. Malik *et al*. (2007) in their study found that plant height, number of leaves per plant and number of pods are the most important traits that determine the economic yield of leguminous crops.

Data on the number of leaves and pods per plant and plant height was obtained first by marking the net plot. This was done by excluding the border rows after which at least ten plants were uprooted from the center rows to serve as a representative sample for each of the treatments. The number of leaves and pods of each of the uprooted plants were counted and recorded. Plant height at maturity was based on the distance from the ground surface to the top of the main stem. Field biomass data was obtained by uprooting all the plants with the pods and leaves intact from each plot and weighed using a weighing scale in kilograms.

Prior to the set up of the experimental plots, the researcher, with the help of extension officers facilitated theoretical lessons for the farmers so they can clearly perceive the differences between the various practices. This necessitated the need for interpreters who could explain in the local language. Thus, farmers' participation in carrying out the agronomic practices was enhanced with guidance on the CA and IPM practices to employ. Farmers were also actively involved in the data collection process. This was essential to build the capacity of farmers in using the two practices. After learning the practices, the farmers could then apply them in the production of other crops such as maize and crucifers on their farms.

3.2 Conceptual Framework

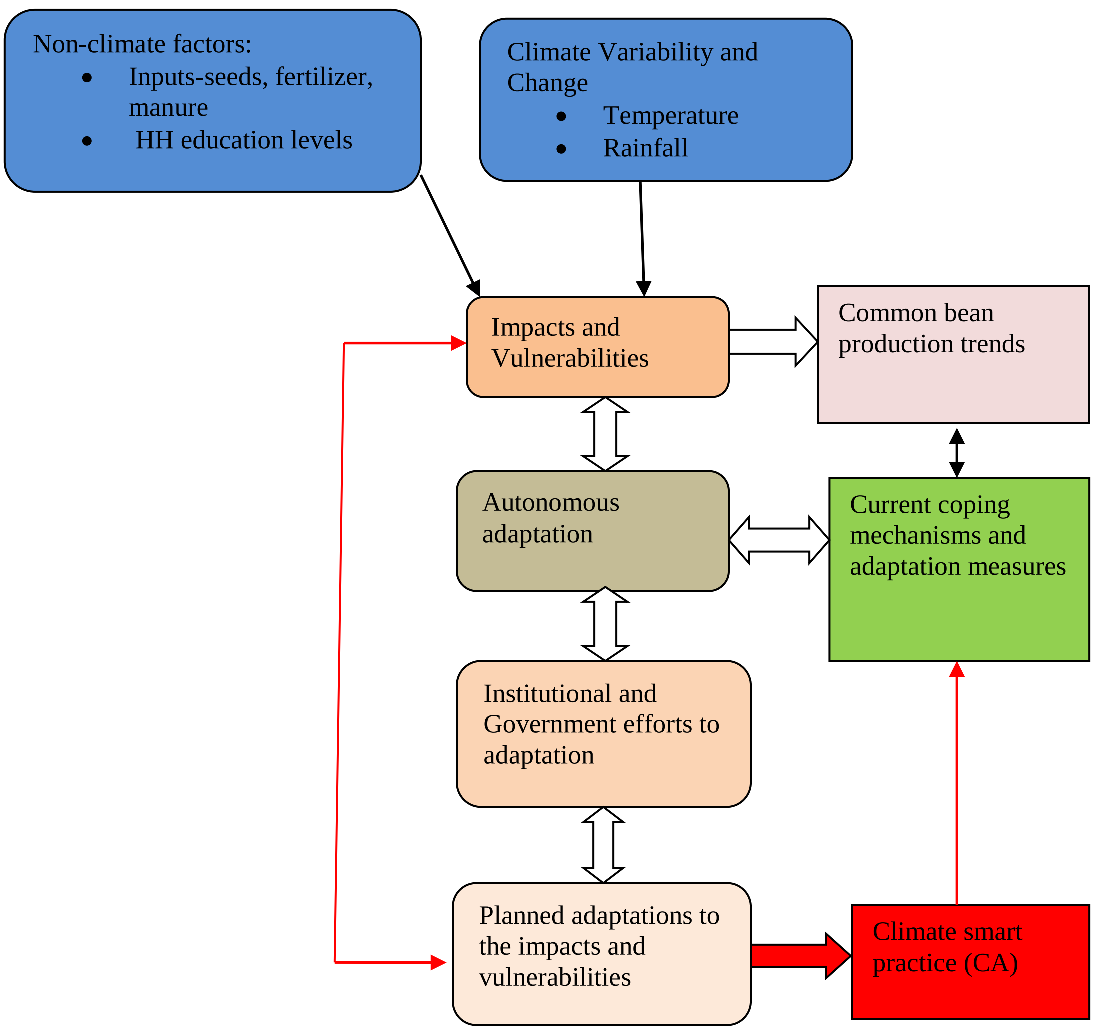

Figure 6: Conceptual Framework for the Taita Hills, Kenya.

The conceptual framework in Figure 6 above demonstrates how climatic and non-climatic factors interact to enhance the impacts and vulnerabilities of farmers to climate change. Emphasis is placed on the resulting effect of these CC impacts on maize and common bean production in the Taita Hills. Further, it shows the current efforts towards adaptation to CC in the area either autonomously by farmers, efforts by government and relevant institutions as well as possibilities for planned adaptations through climate smart practices such as conservation agriculture.

3.3 Farmers' Participation during Demonstrations

The researcher allowed for interactive theoretical sessions between the farmers, researcher and agricultural extension officers before set-up of the demonstration plots. This provided an opportunity for farmers to give their views and ask questions before the demonstrations were set up. Farmers also participated in land preparation, set up and data collection as shown in the various photographs below.

Plate 1: Farmers going through a theoretical session before setting up the experiments, Kipusi village-Mwatate.

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Plate 2: Farmers participate in setting up the experimental treatments, Malela village-Werugha

Plate 3: Farmers apply appropriate agronomic practices in planting Malela village-Werugha

The land preparation practice used by most farmers in the low zone as shown below is locally referred to as (*kukwangura*) and it involves light digging of the top soil, which encourages hard pan formation that hinders optimum crop growth.

Plate 4: A farmer demonstrates the conventional planting practices, Kipusi village-Mwatate

Plate 5: Farmers participate in the data collection process, Mlaba Village- Wundanyi

3.3 Data Analysis

3.3.1 Trend Analysis

Trend analysis was performed on rainfall and temperature data. First the data was aggregated into the two major seasons, March to May (MAM) and October to December (OND). Time-series plots were then generated and a linear trend line drawn to show whether the trends are increasing or decreasing. The slope of the trend lines was determined and a student t-test used to show whether the slopes were significantly different.

3.3.2 Analysis of Questionnaires

Analysis of questionnaires was done first by sorting them to determine the percentage with null responses or errors by enumerators. These were set aside as invalid and therefore not included in analysis. The remaining questionnaires were grouped according to the region from which they were collected and the information transcribed to observe any emerging response patterns. Open-ended questionnaires on the other hand were analyzed manually by grouping those with similar responses to draw out perceptions and frequencies from the responses.

Tabular comparisons of data from the annual food and crop situation reports were also used to show variation in production of common beans.

Further analysis was done in SPSS on data regarding the current adaptation options and challenges in their uptake for closed-ended questionnaires. Conclusions were drawn from the obtained percentages, graphs, means and frequencies.

3.3.3 Analysis of Experimental Data

Data from the experimental plots was organized and analyzed using the excel spreadsheet to generate means of the various treatments. Analysis of Variance (ANOVA) was used to determine whether there is a significant difference between the means.

CHAPTER 4

RESULTS AND DISCUSSION OF RAINFALL TREND ANALYSIS

4.0 Introduction

This chapter describes in detail the trends in rainfall of the Taita Hills over the past 50 years, and how they compare with the perceptions of farmers on the major climate shocks experienced in their households. Data on the rainfall trends is presented graphically to show the variations at different altitudinal zones in the area. Generally, the rainfall patterns in the three agro-ecological zones examined show a declining trend over the period examined. There was no available data on temperature thus the trends could not be generated.

4.1 Time Series Analysis of Rainfall Data

The Taita Hills experience two major rainfall seasons, the long rainy season experienced between March and May, also referred to as MAM seasonal rainfall and the short rainy season between October and December, also known as OND seasonal rainfall which in turn give rise to two planting seasons. The long rains season is a period during which most parts of the country receive rain. It lasts for a longer period and is more widespread compared to the short rains season. The Annual Food and Crop Situation Report shows that farmers rely on both seasons for cultivation of maize, which is the staple crop (GoK, 2012). The report further adds that currently the short rains season has been noted to be more reliable than the long rains season. This is because the long rains season is characterized by, among other factors, unreliable rainfall patterns whereby onset of rain is delayed and cessation occurs very early in the season. The three weather stations selected show an overall declining trend in the amount of rainfall received in the various agro-ecological zones since the 1960s.

4.1.1 The Long Rainy Season

Time series analysis of available MAM rainfall data for three zones along the transect was done as representative of the low, mid and high zones in the Taita Hills. The trends show a steady decline in the amount of rainfall received in the three areas, Mgange (high altitude zone - Figure 7), Wundanyi (mid altitude zone - Figure 8) and Maktau (low altitude zone - Figure 9). The time series plot for Wundanyi shows a decline in the amount of rainfall received, the average for years between 1993 to 2006 being less than 600mm. This is an area that initially received between 900 and 1200mm of rainfall per season thus indicating a large deficit in the mentioned years. Time series analysis of Maktau in the low zone shows the highest amount of rainfall recorded to be 626.4mm in 1967 otherwise there is a general declining trend in the years following 1967 with most of them receiving less than 350mm of rainfall. This is below the average precipitation range for the lowlands which lies between 350-400mm. Furthermore, the optimum rainfall conditions for productive agriculture in the lowland areas is 450mm, considering the maize variety grown. However, the time series shows the amount of rainfall received to be less than 450mm for the period rainfall was recorded in the weather station at Maktau. No data was available for the year 1998 in Mgange hence the gap in the time series plot.

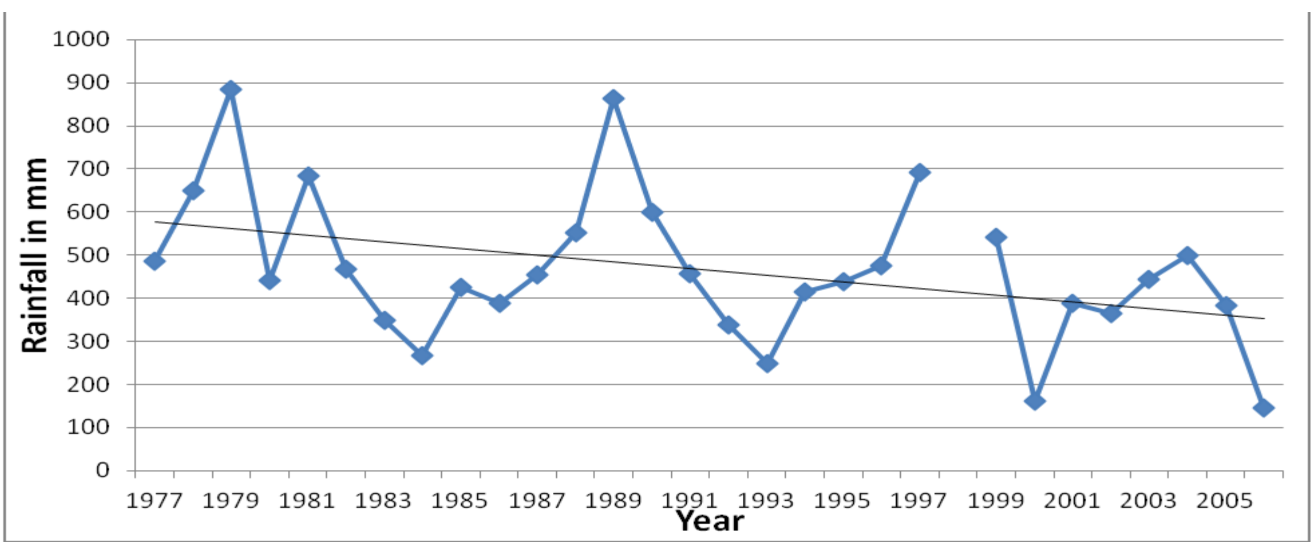

Figure 7: Time series plot of MAM rainfall season for Mgange-1605 m.a.s.l

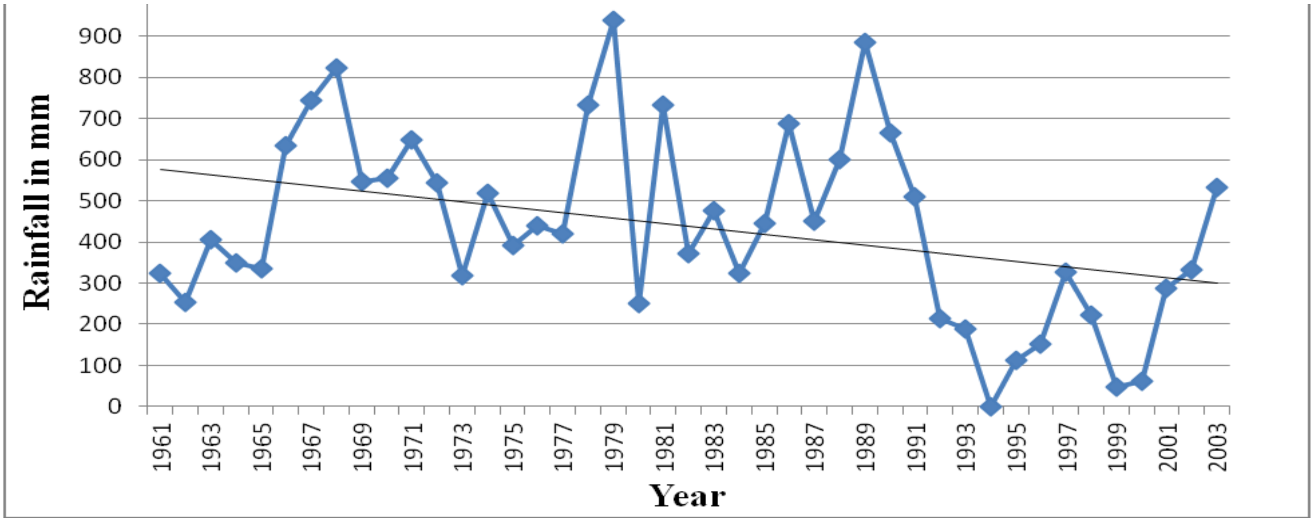

Figure 8: Time series plot of MAM rainfall season for Wundanyi-1480 m.a.s.l

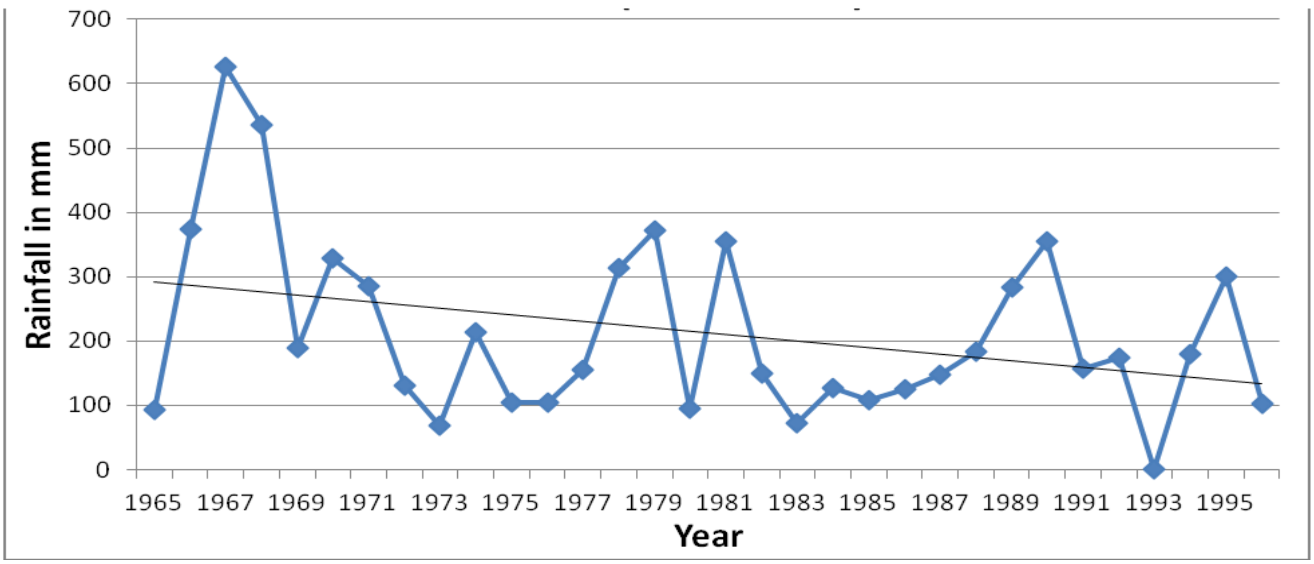

Figure 9: Time series plot of MAM rainfall season for Maktau-700 m.a.s.l

4.1.2 The Short Rainy Season

Time series analysis for the short rains season (OND) also shows a general declining trend of observed rainfall in the high altitude zone (Figure 10), mid altitude zone (Figure 11) and low altitude zone (Figure 12). While there is a very slow declining trend in the amount of rainfall received in Mgange, there is a steep decline in the amount of rainfall received in Wundanyi and Maktau. The highest amount of rainfall for Mgange area was observed during the El nino rains of 1997 being 1400mm but the average annual rainfall for the rest of the years is below 700mm.

Average annual rainfall in Wundanyi remained below 800mm and there is a continuous decline to about 150mm in 2003. The highest rainfall observed in maktau was 350mm in 1967. Average rainfall in the years after 1967 remains below 300mm and declines to below 50mm in 1996.

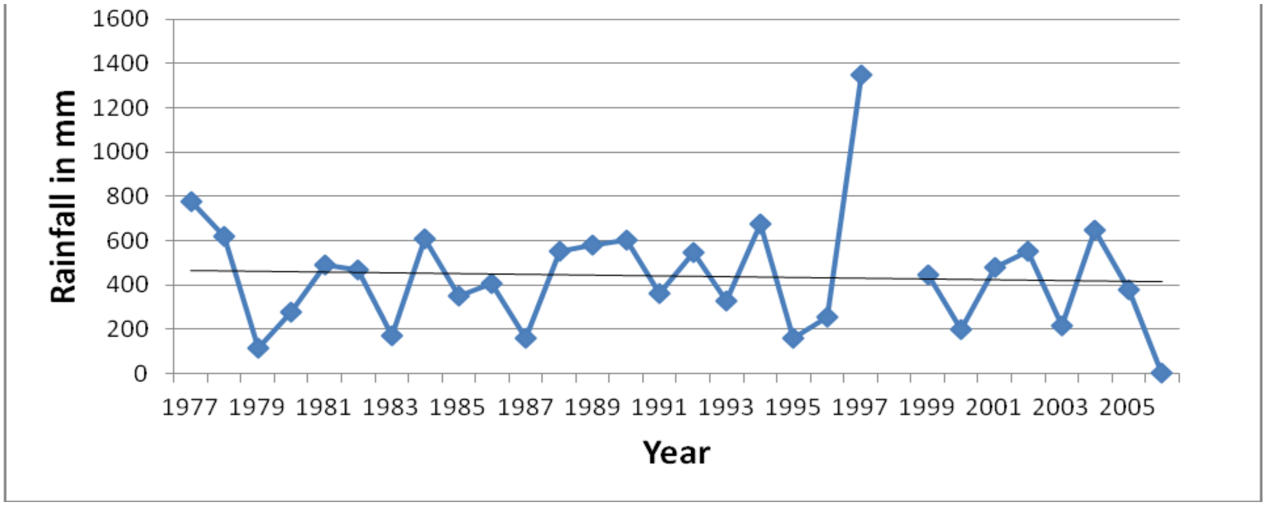

Figure 10: Time series plot of OND rainfall season for Mgange-1605 m.a.s.l

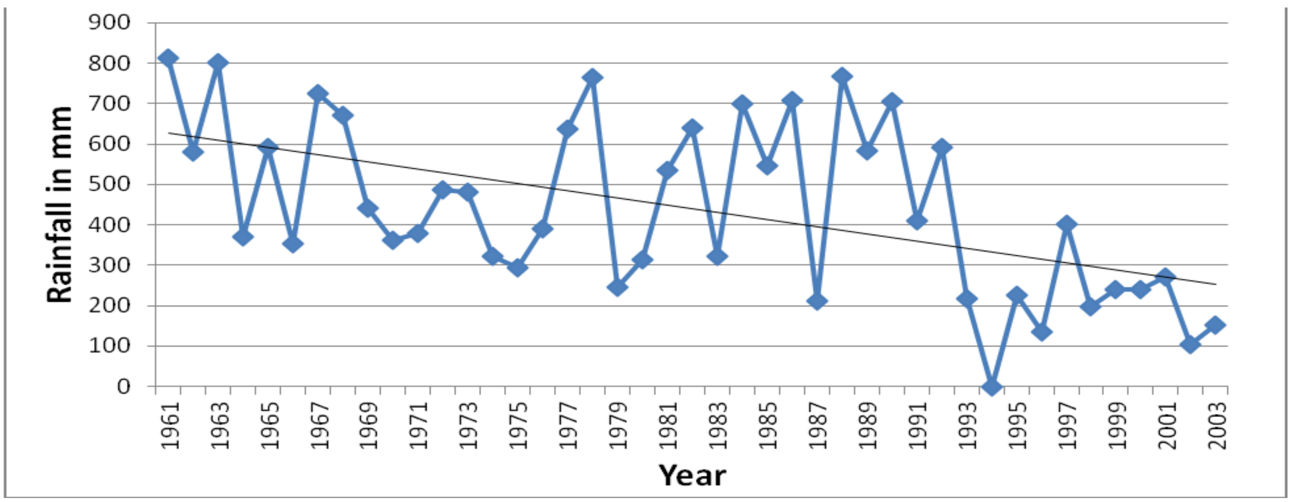

Figure 11: Time series plot of OND rainfall season for Wundanyi-1480 m.a.s.l

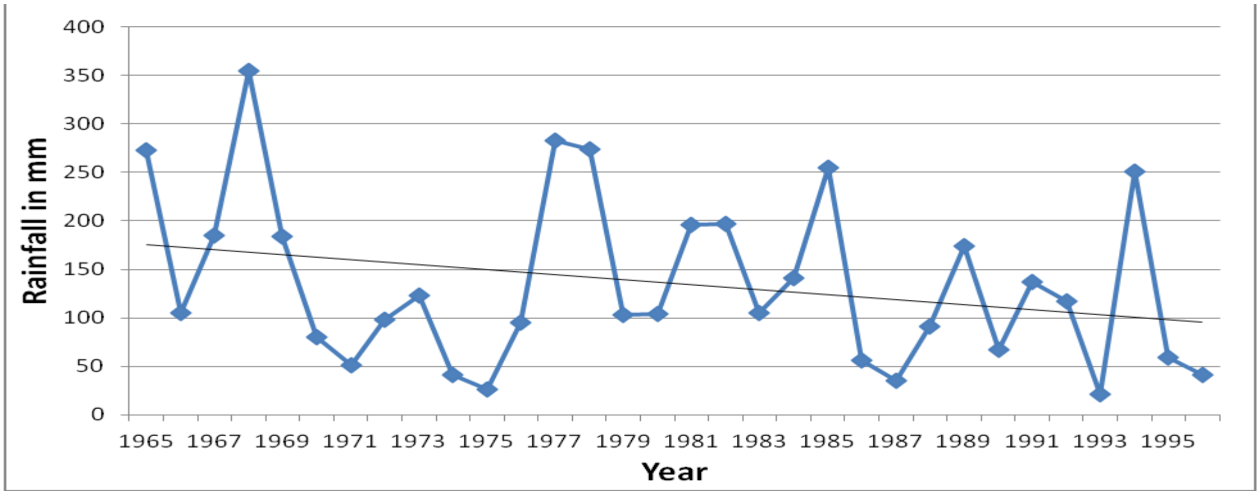

Figure 12: Time series plot of OND rainfall season for Maktau-700 m.a.s.l

4.2 Farmers' Perceptions of Variations in Rainfall

Results of the focus group discussions indicated that households in Taita hills are aware of the variations in rainfall that have been happening in the area over the last 20 years. Pauw (2013) notes that an understanding of how farmers perceive climate-induced risks gives an insight to the adaptation options and responses they have put in place.

Farmers were therefore asked about the changes in precipitation over the years by comparing how it was a long time ago and how it had changed in the past two decades. They mentioned droughts, below average rainfall, above average rainfall and erratic rainfall patterns characterized by early cessation and late onset of rainfall as the most serious precipitation changes that impacted on their farming activities. The participants felt that currently the droughts were more frequent and prolonged, the rainfall amounts had been decreasing and there was a shift in rainfall patterns making the rainy seasons very unpredictable. They reported that in the past there was an even distribution of rainfall over the seasons which enabled them to plan their agricultural activities effectively, with knowledge on exactly when to expect significant wet and dry spells. Respondents also reported a general increase in temperatures compared to the past such that even months that used to be extremely cold such as July were no longer as cold.

These perceptions arose from the day to day experiences as observed by farmers such as declining amount of water in rivers, drying up of some streams, reduced productivity of farms, and increase in frequency of droughts and high incidences of pests and diseases. These observations are also reported by the 2012 Annual Food and Crop Situation report, which indicate that there was poor performance of both MAM and OND seasons due to prolonged droughts and erratic rainfall patterns characterized by delays in onset of rainfall and early cessation.

In particular, the respondents reported drought as the most serious event as it usually resulted in loss of the entire crop, while the other variations including decreased rainfall amounts and erratic rainfall patterns resulted to a decline in crop yields and food shortages. Drought has already been indicated as a threat to food security in Kenya and is reported by the GoK (2012) as an important cause of crop losses for farmers in the Taita Hills. Observations from the IPCC (2014) show that rainfall in East Africa is likely to increase in the 21st century, which will be indicated by an increase in the number of extreme wet days to roughly 20%. However, even if the amount of rainfall recorded in the preceding years increased, it may not translate into improved agricultural production because projected increases in temperature will lead to high evapo-transpiration rates causing water scarcity problems despite increase in rainfall.

Therefore, information from the focus group discussion is in agreement with that provided by trend analysis of both the long and short rainy seasons for all the three agro-ecological zones: rainfall has shown a general declining trend over the years and this has negatively impacted livelihoods in the area where majority of farmers rely on rain fed agriculture.

CHAPTER 5

RESULTS AND DISCUSSION OF THE IMPACTS ON LIVELIHOODS

5.0 Introduction

This chapter describes in detail the trends in crop production data of maize and beans and how this has influenced food security in the study area. It explores the link between the observed climate trends and the crop production trends. In addition, the results also present other factors affecting crop production in the area. These include perceptions of farmers on factors that make them vulnerable to the impacts of climate change such as drought, insect pests and diseases, declining soil fertility and input factors.

5.1 Food Security Trends

In their Long Rains Assessment report, Ouma and Musyoka (2013) note that the county was placed in Phase 2 of the Integrated Food Security Phase Classification (IPC). IPC refers to a set of standardized tools which provide a common standard to classify the level of severity and magnitude of food security. This approach is based on international standards thus allowing for comparison of the food security situation over time across different countries. There are five phases of food security classified by IPC. These include phase 1 comprising of the generally food secure, phase 2 comprising of the moderately/borderline food secure, phase 3 which includes those undergoing acute food and livelihood crisis, phase 4 which indicates the need for humanitarian emergency and finally phase 5 that indicates a humanitarian catastrophe. Phase 2 is characterized by unstable accesss to food resources, chronic dietary diversity deficit and an acute malnutrition that is more than 3% but less than 10%. Having been classified under stressed phase 2 of IPC, Taita Taveta county therefore had a population of 44,000 people in need of food. The 2013 food security situation was based on the performance of the short rains season in 2012. The county was still placed in the stressed phase 2 by the August 2013 food security assessment report due to poor performance of the long rains season between March and May 2013. The mixed farming livelihood zone (Crops and Livestock) is noted to be the most affected because of direct impact from the failed long rains season (Figure 2).

In addition, respondents of the household survey indicated that farmers obtained much lower yields for the staple crops planted during both the long rains and short rains seasons than what they expected. Furthermore, they did not get enough to allow them to sell part of the produce as all their harvest was consumed at the households and could not sustain them through the year. They usually supplemented their household food with food bought from the market.

The area of land under maize, green grams and cowpeas planted for rain-fed agriculture increased in the whole county in 2013 compared to the longterm average as shown in Table 2. This was because of timely onset of rains and availability of seeds supplied under the traditional high value crops program (GoK, 2012). The program is an initiative by the Kenyan government that was established in 2006 to boost production and consumption of alternative cereal and non-cereal crops as well as improve food security in dry areas. However the increase in land size under agriculture and timely onset of rains did not translate to high crop production. This was due to early cessation of rain and a prolonged dry spell, both of which were mentioned as major problems experienced by farmers during the survey, resulting in withering of most crops and below average production compared to the longterm average. There was no available data for common bean production in the same year.

Table 2: Long Rains Production of three Food Crops compared to Long term Average

Crop	Area planted current year 2013 (Ha)	Long Term Average area planted (Ha)	Current year production (90 kg bags) Projected/actual	Long Term Average production (90 kg bags)	Percentage(%) increase in Planted Area	Percentage (%) increase in Production
1. Maize	6,274	3,710	36,777	46,790	**69.1**	**-21.4**
2. Green grams	1,567	555.5	8,089	5,840	**182.1**	**38.5**
3. Cow peas	483	392.5	2,362	3,641	**23.1**	**-35.1**
Total	**8,324**	**4,658**	**47,228**	**56,271**	**78.7**	**-16.1**

(Adapted from the Long Rains Assessment Report, 2013- % increase calculation added by author)

Annual food and crop situation reports from Mwatate district show the negative impact of poor rainfall distribution on crop production (GoK, 2012). This is characterized by too much rainfall within a short time, late onset and early cessation of rainfall. Specifically, the year 2009 was characterized by failed long rains (LR) in most parts of the district especially in the lower zones where there is adequate land for farming (Table 3). This in addition to lack of certified seed by the farmers contributed to poor crop performance and increased food insecurity (GoK, 2010). Out of the 34,500 90kg bags of maize expected during the long rains, only 476 bags were achieved. For common beans on the other hand, the target for the long rains was 3400 bags but only 37.5 bags were achieved. The short rains (SR) were however above average in the same year for the high and low zones and this, coupled with supply of relief seed to farmers led to an increase in crop yield during the short rains. The target for maize was 34,000 bags while the actual yields obtained were 43,200 bags which exceeded the target. In addition, the hectarage achieved in the short rains was much higher compared to that achieved in the long rains due to increased land preparation campaigns by the government in readiness for relief seed supply and forecasted El nino rains (Table 3). In 2010 and 2011 (Tables 4 & 5), while the long rains were fair and and allowed for average crop yields, distribution of the short rains was poor and cessation was sudden leading to low average yields. Only 6,600 bags of maize and 1,456 bags of beans were achieved in the short rains, which was much lower than the targeted 27,000 bags of maize and 2,650 bags of beans.

Table 3: Target versus Achieved Maize and Bean Production in 2009

	Target Ha		**Achieved Ha**		**Target Production (90kg Bags)**		**Achieved Production (90kg Bags)**		**Deficit =Target-Achieved**	
Season	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**Ha**	**Production (90kg bags)**
Maize	1850	1700	248	2700	34500	34000	476	43200	**602**	**24824**
Total (LR+SR)	**3550**		**2948**		**68500**		**43676**			
Common beans	340	325	5.75	120.75	3400	3250	37.5	966		
Total (LR+SR)	**665**		**126.75**		**6650**		**1003.5**		**538.25**	**5646.5**

(Adapted from the Annual Crop Production Report for Mwatate, 2009-totals and deficits calculated by author)

Table 4: Target versus Achieved Maize and Beans Production in 2010

	Target Ha		**Achieved Ha**		**Target Production (90kg Bags)**		**Achieved Production (90kg Bags)**		**Deficit=Target-Achieved**	
Season	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**Ha**	**Production (90kg bags)**
Maize	1600	1350	1175	872	32000	27000	17675	6600	**903**	**34725**
Total (LR+SR)	**2950**		**2047**		**59000**		**24275**			
Common beans	270	265	207	168	2700	2650	1696	1456	**160**	**2198**
Total (LR+SR)	**535**		**375**		**5350**		**3152**			

(Adapted from the Food and Crop Situation Report for Mwatate, 2010)

Table 5: Target versus Achieved Maize and Bean production in 2011

	Target Ha		**Achieved Ha**		**Target Production (90kg Bags)**		**Achieved Production (90kg Bags)**		**Deficit= Target-Achieved**	
Season	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**Ha**	**Production (90kg bags)**
Maize	1700	1950	1132	1700	28900	33150	17598	20400		
Total (LR+SR)	**3650**		**2832**		**62050**		**37998**		**818**	**24052**
Common beans	340	330	251	208	3400	3300	2346	1248		
Total (LR+SR)	**670**		**459**		**6700**		**3594**		**211**	**3106**

(Adapted from the Food and Crop Situation Report for Mwatate, 2011)

Table 6: Target versus Achieved Maize and Bean Production in 2012

	Target Ha		**Achieved Ha**		**Target Production (90kg Bags)**		**Achieved Production (90kg Bags)**		**Deficit= Target-Achieved**	
Season	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**Ha**	**Production (90kg bags)**
Maize	1700	1960	917	1380	28900	33320	4300	11040		
Total (LR+SR)	**3660**		**2297**		**62220**		**15340**		**1363**	**46880**
Common beans	340	321	139	266	3400	3210	152	1330		
Total (LR+SR)	**661**		**405**		**6610**		**1482**		**256**	**5128**

(Adapted from the Food and crop Situation Report for Mwatate, 2012)

In 2012 (Table 6), distribution of both the long and short rains was poor, which led to total failure in the months of May and December when the crops were at their most critical stages of growth (GoK, 2012). The short rains also came early in the lower zones resulting in low yields. The district had deficits in both the number of hectares achieved and production, the deficits being 1,363 ha and 46,880 bags for maize and 256 ha and 5,128 bags for beans.

Tables3, 4 ,5 & 6 above clearly show that Mwatate district has failed to meet its food production targets for the fours years considered (2009-2012). Poor performance of the staple crops is attributed to both climatic and non-climatic factors. The main climatic factors are poor distribution of rain over time and space as shown by the rainfall trends discussed earlier while the non-climatic factors include availability and access to certified seed as well as poor farming methods that degrade the soils resulting in declined soil fertility (GoK, 2011). It is thus crucial that adaptation measures are put in place to prepare for such changes and this includes sensitizing farmers on the possible methods that can sustain crop production through periods of unpredictable climate patterns.

5.3 Farmers' Perception on crop production

Survey results indicated that farmers were aware of the influence that different climate factors had on crop productivity. Both participants of the focus group discussion and household surveys reported that currently food shortages are on the rise and farmers do not obtain enough yields as they did in the past. The main reasons reported for this were climate events including; erratic rainfall patterns, above and below average rainfall, strong winds, floods and frost. Other factors mentioned were high occurrence of pests such as bean aphids, bean weevils and cutworms, soil factors especially poor soil fertility, poor agronomic practices and lack of inputs. In addition, the FGDs as well as existing government reports indicates that the short rains season is more reliable and suitable for crop production than the long rains season. The interaction of climate factors with various non-climate factors made the farmers more vulnerable and contributed to the constant crop losses that farmers record every season. It is important to note that if these trends continue the food security situation could worsen in the coming years.

5.3.1 Climate Events

Forty four percent (44%) of the respondents from the household survey reported droughts to be the major climate event that most affected their crop production activities. 18.3% reported erratic rainfall patterns, 6% reported above average rainfall, 25.6% reported below average rainfall, 3.4 % reported strong winds while 1.8% and 0.9% of the respondents reported floods and frost as the major climate events affecting crop production (Table 7).

Table 7: Climate Events affecting Crop production as Reported by Smallholder Farmers in the three Agro-ecological Zones

Climate event	**High Zone (1500-2000m.a.s.l)**	**Mid Zone (1100-1500m.a.s.l)**	**Low Zone (700-1100m.a.s.l)**	**Total Respondents**
Drought	62	41	89	**192**
Erratic rainfall pattern	28	41	11	**80**
Above average rainfall	10	7	9	**26**
Below average rainfall	41	31	40	**112**
Strong winds	2	7	6	**15**
Floods	1	0	7	**8**
Frost	2	2	0	**4**

Farming among the Taita hills households is mostly rain fed and this implies that it is under the direct influence of rainfall. Drought as reported by respondents means the total lack of rainfall for a prolonged period of time, which usually results in complete crop failure. Below average rainfall on the other hand is a reduction in the amount of rainfall that may allow crop production leading to low yields but does not necessarily result in total crop failure. Erratic rainfall patterns as reported by farmers are characterized by a shift in the patterns of rainfall such that there is either late onset or early cessation of rainfall.

5.3.2 Pests and Disease Occurrence

The respondents also noted that the occurrence of pests and diseases was a major factor contributing to crop losses. 49.4% attributed crop losses to insect pests, 6.7% attributed the losses to diseases. The major common bean pests mentioned were aphids, cutworms and post-harvest bean weevils while the major diseases mentioned were bacterial wilt and blight. While only 9.2 % of the respondents were aware about integrated pest management (IPM), most farmers had knowledge of traditional methods of pest control such as the use of ash and soil, botanical methods such as the use of wild sunflower and mechanical methods such as handpicking and spraying with water even though they rarely employed the practices. Since IPM requires integration of traditional, biological, mechanical and chemical methods of pest control, respondents reported a number of barriers to its effective use as shown in Table 8 below.

The Mwatate annual food and crop situation report notes that farmers have a continuous cropping cycle whereby harvesting and land preparation coincide (GoK, 2012). The soil is not allowed to rest and this is responsible for insect pest specialization as they have a constant supply of food and a permanent habitat for multiplication. The continuous cropping cycle is enhanced by the sole reliance by most people in the area on farming as the sole livelihood source. Diversification to off-farm livelihood sources can cushion farmers against constant crop failures and even enable them to allow their farms to rest and regain fertility.

5.3.3 Soil Factors

63.3 % of the respondents considered their soils to be moderately fertile, 15% thought it was poor while 18.7% reported their soils to be very fertile. 3% of the respondents on the other hand did not know the fertility status of their soils. When asked whether there had been a change in the fertility of their soils considering the quantity of yields obtained over the last 10 years, 55.9 % indicated that it had declined, 25.2% reported it remained the same while 15.2% reported that it had improved. Decline in soil fertility was attributed to various reasons the main one being continuous ploughing reported by 22.9% of the respondents. 13.5 % attributed the decline to droughts, 13.7% cited the use of inputs, 9 % floods, 2.2% lack of inputs and those whose soil fertility had improved attributed it to improved land use practices. However, a larger percentage (29.7%) did not know the reason for the decline in the fertility of their soils.

Table 8: Farmers' Perceptions on Soil Factors Affecting Crop Production

Soil Factors	High Zone	Mid Zone	Low Zone	Total
Soil Fertility N=401				
Very Fertile	32	15	28	75
Moderate	89	76	89	254
Poor	20	24	16	60
Do not know	1	1	10	12
Change in Soil Fertility N=401				
Improved	17	27	17	61
Same	37	19	45	101
Declined	86	69	69	224
No response	2	1	12	15
Reasons for Decline in Soil Fertility				
Continuous tillage	38	28	26	92
Droughts	30	10	14	54
Use of inputs	12	40	5	57
Floods	5	11	22	38
Lack of inputs	5	3	1	9
Improved Land Use Practices	13	7	12	32
Do not Know	31	40	48	119

5.3.5 Input Factors

Farm inputs are an essential component for optimum crop production and data on input use for the two major staple crops, maize and beans was investigated. Out of the interviewed respondents of the survey, the various inputs used in producing maize include commercial fertilizer used by 24.2% of the respondents; improved seed variety reported by 35.9%, manure reported by 30.7 % and pesticides 4.5%. However, the inputs used in common bean production were minimal including commercial fertilizer reported by only 2% of the respondents, improved seed reported by 6.2 %, manure reported by 4.7% and pesticides reported by 0.2% of respondents. 4 % of the respondents reported that poor seed quality contributed to crop losses on their farms. Farmers attribute the use of poor quality seed, lack of fertilizer and manure amendments during planting as the major reasons for recorded poor yields year in year out. This indicates that most farmers have a poor financial status, which limits their access to good quality inputs such as certified seeds and fertilizer. Organic (manure) and inorganic (fertilizer) amendments are very crucial for nourishment of the soils after every harvest to build organic matter and soil structure.

CHAPTER 6

RESULTS AND DISCUSSION OF CURRENT COPING AND ADAPTATION STRATEGIES

6.0 Introduction

This chapter examines the coping strategies farmers have put in place in response to climate change. It outlines the actions taken by households in the study area to cope with various climate events that impact on crop production, especially drought. The chapter also explores the factors that influence the uptake of sustainable agricultural practices, specifically CA and IPM as well as the barriers to their uptake. Further, it discusses the merits and demerits of these coping strategies with regard to effective adaptation and sustainability.

6.1 Coping Strategies Currently Employed by Farmers

Due to their dynamic nature, societies use all possible strategies to reduce vulnerability to climate impacts. As a result, they have developed a number of coping mechanisms in order to live with climate variation and uncertainty. The actions taken by individuals and households change constantly with different situations. In many parts of Sub Saharan Africa, households rely on a combination of informal risk sharing arrangements and self-insurance. These include actions such as sharing food, remittances, child labor, informal cash in-kind loans or sending children to live with relatives. While food secure households rely more on cash loans from neighbors, relatives and money-lending organizations, food insecure households have limited networks of relatives and neighbors who can give cash loans. Hence, they often rely on neighbors and relatives as well as providing labor in-kind payment (Shuaibu *et al.*, 2014). Respondents reported various ways in which they are coping up with the climate events impacting their households. In coping with drought most of the respondents (70.9%) reported that they bought food, 6.6 % sought off-farm employment, 2.8 % ate different types of food, 4.7

% borrowed from friends and relatives, 2.8 % relied on food aid from the government and only 2.3 % changed their farming practice (Table 9).

Table 9: Actions taken by respondents to cope with drought (N=213)

Action	High Zone Respondents	Mid Zone Respondents	Low Zone Respondents	Total Respondents
Did nothing	4	1	8	**13**
Assistance from friends/relatives	3	3	4	**10**
Relied on savings	5	2	1	**8**
Government food aid	2	3	1	**6**
Changed farming practice	0	2	3	**5**
Bought food	48	35	68	**151**
Sought off-farm employment	5	5	4	**14**
Ate different types of food	2	1	3	**6**

To identify the various agronomic practices employed in crop production, farmers were asked whether they practiced fallowing on their farms and based on the results, 40.6% practiced fallowing while 59.4% did not. Crop residues are important in supplementing the soil with organic matter. However, 45.4 % stated that they slashed their crop residues and stored them as forage while the rest of the respondents stated other uses such as slashing and selling the residues, exchanging residues for manure, doing nothing and leaving it on the surface and for trash line making.

Farmers were also aware of a number of traditional and botanical insect pest control methods even though most of these practices were not used as farmers reported them to be time consuming. These include using homemade solutions of wild plants such as wild sunflower (*Tithonia diversifolia*) and wild sage (*Lantana camara*) to control aphids common beans and most horticultural crops. However, making a liquid solution from wild sunflower takes 21 days by which time the pests, especially aphids have spread and caused losses. Other practices mentioned but were rarely used include the use of ash, mud, pepper, garlic, and neem.

Most of the respondents stated that they cope with droughts by buying food but only a small percentage noted that they changed their farming practice. These coping mechanisms are not sufficient or sustainable to address the challenges and they are even more limited for the poor, landless, unemployed, women, children and large sized households who are more vulnerable (Shuaibu *et al*., 2014). For example, while buying food may help them cope in the short term, it is important to find long term sustainable solutions for example a shift into sustainable farming practices. Only a few farmers mentioned seeking off-farm employment as a way of coping with climate change. It is important that all farmers be encouraged to diversify to other livelihood sources that do not involve farming so that when their crops fail, they can have another income source that is not linked to rain cycles. For instance, the case of Sakai, in Eastern Kenya is a success story that demonstrates how livelihood diversification can help farmers arid and semi-arid areas cope with drought. The farmers were facilitated with small loans from the UN-funded small budget pilot program that they used to set up small business such as egg hatcheries, paraffin shops and small lending banks. These enterprises helped families pay for food purchase and emergency health care during droughts (Leber, 2010).

The results also show that while most farmers are aware that continuous tillage is a major factor contributing to diminishing soil fertility, they continue tilling the soils without using any amendment measures thus worsening the soil condition. Studies by Derpsch (2005) show the long-term consequences of continuous tillage in destruction of soil structure, soil organic matter, nutrient and moisture loss and advice on soil conservation through minimum tillage. Even though quite a number were aware about sustainable crop production practices such as CA and IPM, almost all those who were aware did not put them to practice in order to improve productivity because they lack knowledge of the benefits of such practices and do not have the know-how to put them into practice.

6.2 Uptake of CA and IPM

CA aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources. This enhances environmental conservation as well as sustained agricultural production. CA has also been shown to reduce crop vulnerability to extreme climate events. For instance, in drought conditions, it reduces crop water requirements by 30%, makes better use of soil water and facilitates deeper rooting of crops. In extremely wet conditions, CA facilitates rainwater infiltration, reducing the risk of soil erosion and downstream flooding (Mrabet, 2011). IPM has also been recognized as an important component of CA and an alternative technique towards development of environmentally sustainable agriculture. It is an ecosystem-based approach to crop production and protection that combines different insect pest management strategies and practices to grow healthy crops while minimizing the use of pesticides (EPA, 2012). With proper planning and implementation, IPM can provide immediate and effective solutions on farmer problems with pests without jeopardizing resilience of the farm to climate change effects (Abrol, 2013). 39.7% of the respondents stated that they were aware about CA and 9.2% stated that they apply IPM practice on their farms having heard about the two practices in seminars, from neighbors, from agricultural extension officers and others from the radio. However, only 3.7% of those who were aware about CA practiced it on their farms. The respondents stated various barriers to IPM use, 35.2% mentioning lack of technical information about IPM as the main barrier, 12 % indicated lack of and inadequate extension services, 10.7% reported a lack of technical know-how and 8.2% cited affordability of the method. Similarly, the respondents who were aware about CA gave various reasons for not practicing it as shown in Table 10 below. These results imply that more efforts need to be made in empowering farmers with knowledge and practical skills necessary to enable them put the practices into practice.

Table 10: Barriers to IPM and CA practice in the various agro-ecological zones

Barrier	**High Zone Respondents**	**Mid Zone Respondents**	**Low Zone Respondents**	**Total Respondents**
INTEGRATED PEST MANAGEMENT (N=265)				
Affordability	7	12	14	**33**
Lack of technical know-how	13	7	23	**43**
Lack of/ inadequate extension services	21	14	13	**48**
Lack of technical information	67	36	48	**141**
CONSERVATION AGRICULTURE (N= 105)	**High Zone Respondents**	**Mid Zone Respondents**	**Low Zones Respondents**	**Total Respondents**
Small farm size	5	2	2	**9**
Expensive	1	3	4	**8**
Not profitable	29	5	10	**44**
Risk prone	1	7	8	**16**
No specific reason	10	4	13	**27**

CHAPTER 7

RESULTS AND DISCUSSION OF CONSERVATION AGRICULTURE ASSESSMENT

7.0 Introduction

This chapter describes how the conventional farming practices in the area compare with modern climate smart technologies, particularly CA. It examines the differences in various yield indicators and biomass totals as recorded from the practices examined for two seasons. The chapter also shows how the common bean crop performs under different conditions in the three agro-ecological zones in order to give insight on the best practice for each zone.

7.1 Experimental Results of CA Assessment

The field experiment was set up in different agro-ecological zones to establish whether there was any difference between the climate-smart practice based on CA and the conventional practices used by farmers in crop production (Figure 5). This was to generate results to support recommendation of the practice to policy makers and agricultural officers to enhance its uptake adaptation by farmers. Farmers actively participated in setting up the experiment whereby they were encouraged to incorporate their own sustainable methods into the CA plot to give them a sense of ownership and involvement. This is important because not all conventional practices are unsustainable and farmers are rich in traditional knowledge and skills that can complement modern practices. Some of the practices suggested by farmers include the use of mulch and several traditional insect pest control methods that were incorporated into the IPM practice of CA. For instance, when they observed aphid pests, they poured wood ash on and around the affected plants to control them. The first assessment was during the MAM rainy season and the second during the June July August (JJAS) season.

7.1.1 Results from 1st Season Analysis

During the MAM season, results from the high zone of Werugha (1647m.a.s.l) showed that the control recorded the highest plant height (62.2cm). There were no significant differences in plant height between the CA (58.4cm) and farmers' fertilizer (55.6cm) treatments. Plant height was lowest in the farmers' manure treatment (44.4cm). The average number of pods was highest in the CA treatment (46.8), which was significantly different from the other treatments (farmers' manure treat=30.6, Farmers' fert. treat=33.5 and control=34.9) (Figure 13). However, there were no differences in biomass yields between the CA treatment (6666.7kg/ha) and the farmers' treatment with manure (6666.7kg/ha). Both treatments gave biomass slightly higher than that recorded in the farmers' treatment with fertilizer (5666.7kg/ha). The lowest biomass was recorded in the control (5000kg/ha) (Figure 14). Plant biomas was obtained by calculating the equivalent of the biomass obtained on the weighing scale in tonnes and converting land area into hectares (ha) such that biomass is represented in tonnes/ha.

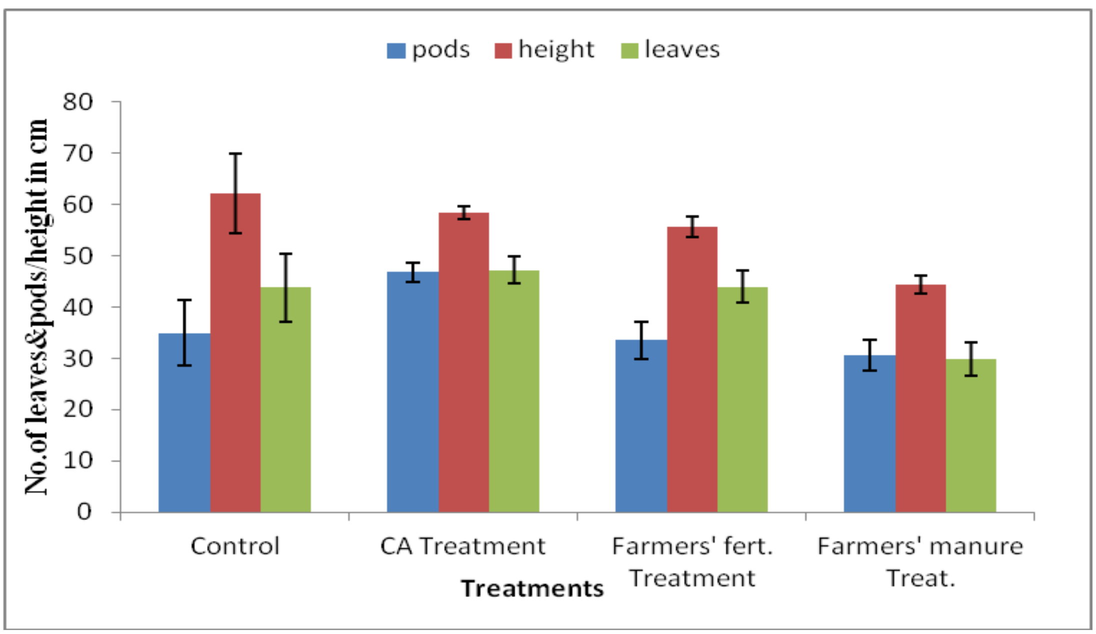

Figure 13: Differences in common bean (*Phaseolus vulgaris*) plant height, leaves and pods due to different treatments in the High Zone

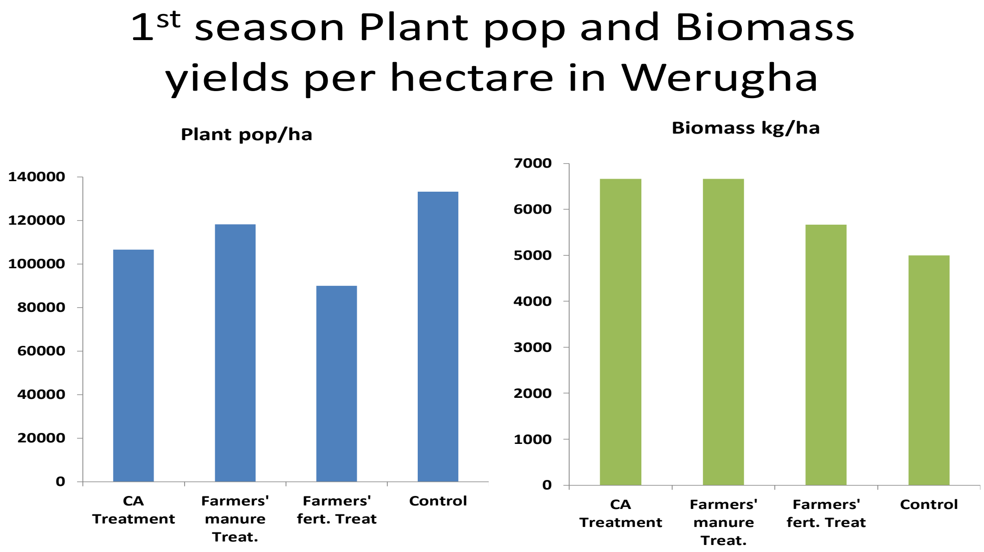

Figure 14: Plant population and Biomass yields/ha in the high altitude zone (1647m.a.s.l).

The photograph below shows performance of the different experimental treatments during the MAM season including the CA treatment with a cover of mulch versus the conventional practices of farmers with manure and fertilizer as well as the control. There is no visible difference between the various treatments, as they seem to be performing equally well.

Plate 6: Performance of different experimental treatments in the high altitude zone in Malela village, Werugha

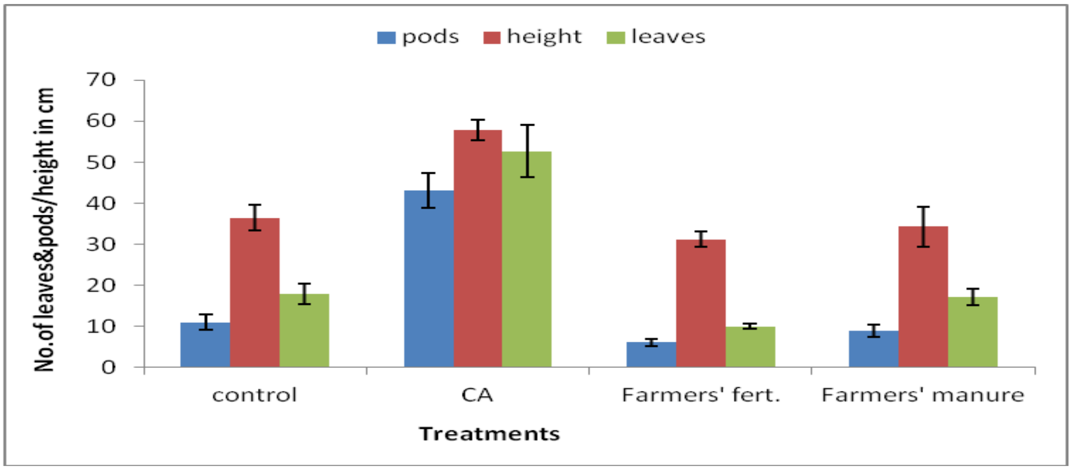

Figure 15: Differences in common bean (Phaseolus vulgaris) plant height, leaves and pods due to different treatments in the mid altitude Zone

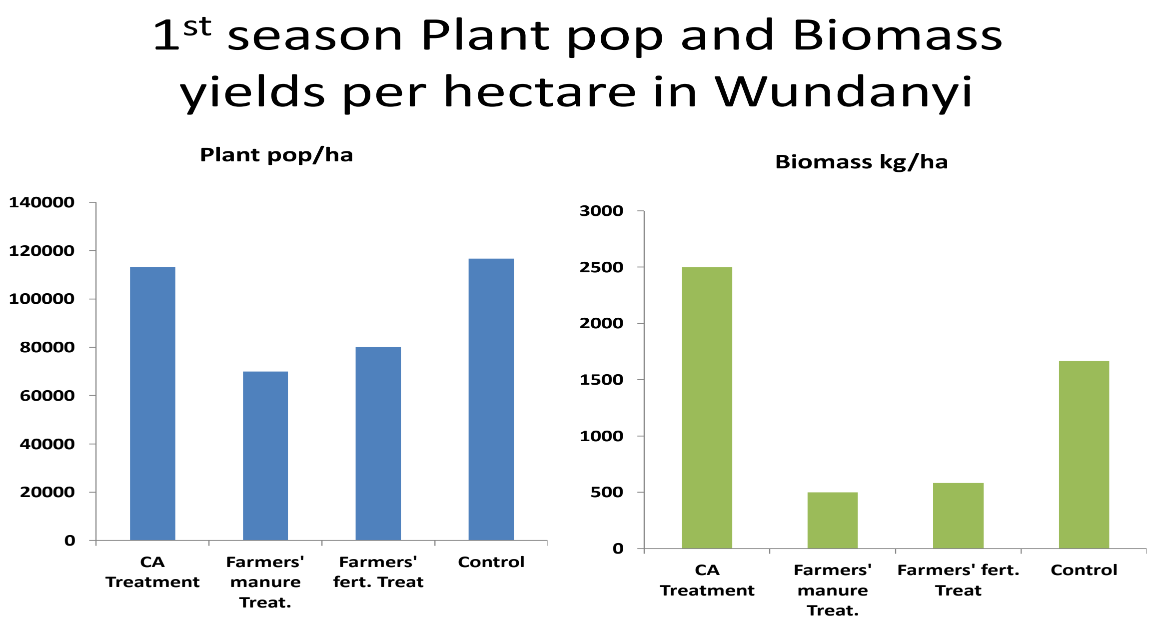

Figure 16: Plant population/ha and Biomass yields in the mid-zone (1480m.a.s.l).

Results indicates that in the mid zone (Figure 15), the CA treatment recorded the highest number of leaves (52.7), pods (43.1) and plant height (57.8cm) and these results were significantly different from the other treatments ($p<0.05$). The farmers' fertlizer treatment had the lowest plant height (31.2), leaves (10) and pods (6.1). Biomass was highest in the CA treatment (2500kg/ha) and lowest in the farmers treatment with manure (500kg/ha). The farmers' practice with fertilizer recorded a biomass of 583.3kg/ha while the control recorded 1667.7kg/ha biomass (Figure 16).

As shown in the photograph below, the CA plot (covered in mulch) is characterized by healthier plants, absence of weeds hence eliminating the need for extra labor costs towards weeding. Plants in the conventional farmer practices on the other hand portray stunted growth with unhealthy plants and yellowing of leaves

Plate 7: Performance of different experimental treatments in the mid zone at Mlaba village, Wundanyi

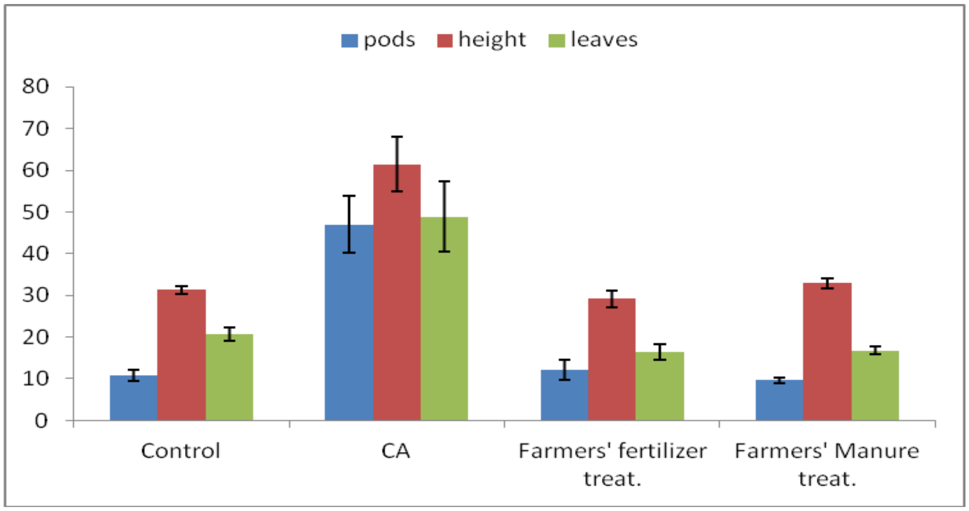

Figure 17: Differences in plant height, leaves and pods due to different treatments in the low altitude zone

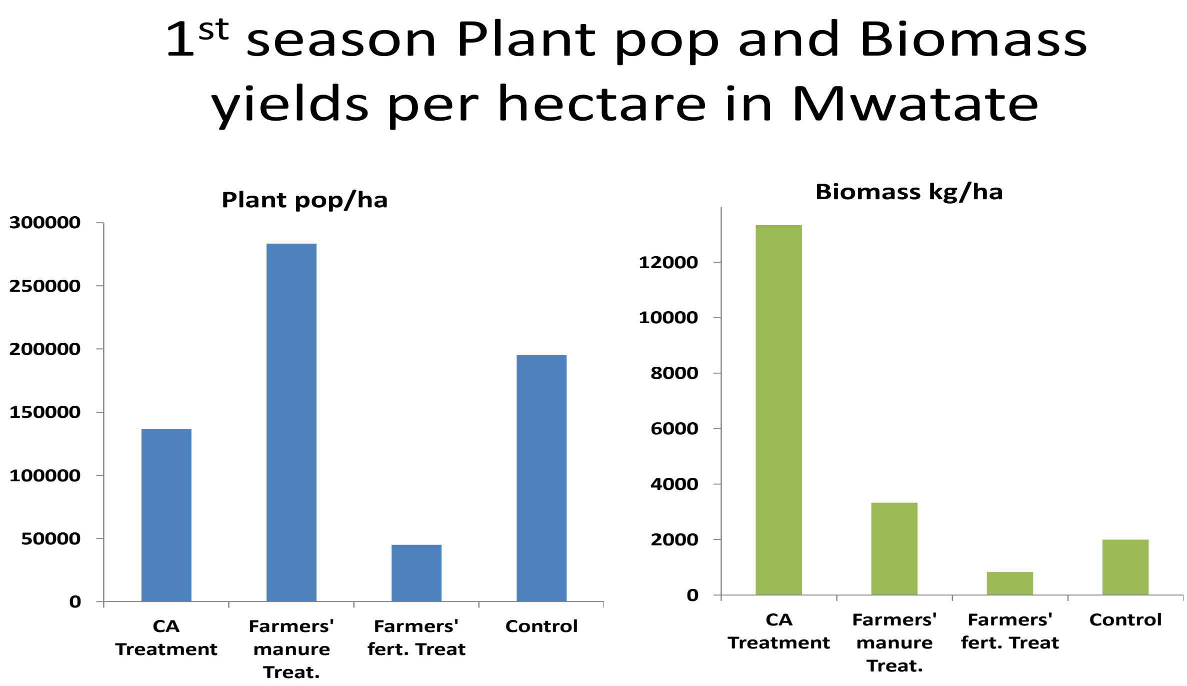

Figure 18: Plant population and biomass yields/ha in the low zone (700m.a.s.l).

Results (Figure 17) indicated that the CA treatment had the highest number of pods (46.8) in the low zone. The number of pods in the farmers' practices with fertilizer (12.1) and manure (9.7) were not significantly different from the control (10.8) ($p<0.05$). The highest height was recorded in the CA treatment (61.4cm) and this was significantly different from all the other treatments (Farmers' manure treatment=32.9cm, farmers' fertilizer treatment=29.2cm, control=31.3cm). The highest number of leaves was recorded in the CA treatment (48.9) and this was significantly different from the farmers' treatment with fertilizer (16.4), farmers' treatment with manure (16.8) and the control (tc=20.7). The highest biomass yields were recorded in the CA treatment (13333.3kg/ha) while the farmers' practices with manure and fertilizer and the control recorded 3333.3kg/ha, 833.3kg/ha and 2000kg/ha of biomass respectively (Figure 18).

The photograph below shows the importance of soil protection in the arid and semi-arid areas of the low zone using mulch and the role that good agronomic practices plays to minimize growth of weeds, promote growth of healthy plants and consequently improve crop yields. The conventionally grown farmers' practice plots are characterized by poor crop growth and exposure to surface run-off.

Plate 8: Performance of different experimental treatments in the low zone

7.1.2 Results from 2nd Season Analysis

Analysed data from the high zone (Figure 19) shows that during the JJAS season, the CA treatment recorded the highest average plant height (CA=61.5cm), leaves (64.5) and pods (37.7) and this was significantly different from the other treatments. The rest of the treatments were not significantly different from each other. The highest biomass yields were recorded in the farmers' practice with manure (F. manure) treatment (10000kg/ha) and was almost similar to that recorded in the CA (9666.7kg/ha) treatment. The farmers' practice treatment with fertilizer recorded a biomass of F.fert=6666.7kg/ha while the control recorded 3333.3kg/ha of biomass (Figure 20).

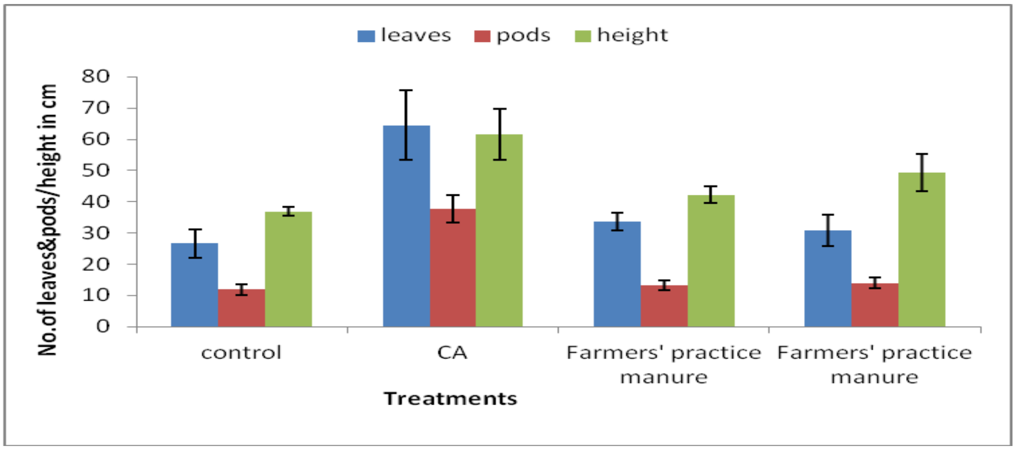

Figure 19: Leaves, Pods and Height responses to different treatments in the High Zone

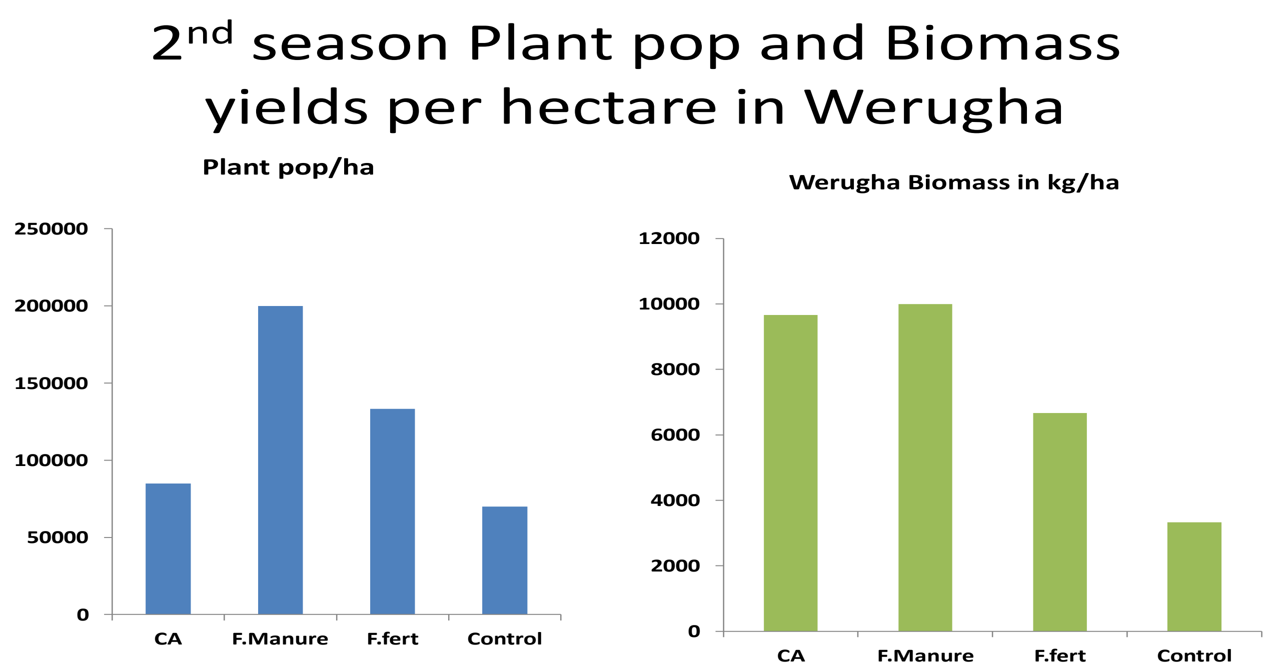

Figure 20: Plant Population and Biomass yields/ha in the high zone

Based on the second season data of the mid zone, results (Figure 21) show that the farmers' practice treatment with fertilizer had the highest plant height (59.6cm), followed by the CA treatment (CA=49.1cm), the control (37.5cm) and the farmers' practice with manure (33.2cm) respectively. The average number of leaves was highest in the CA treatment (30.9) and was not significantly different from the farmers' practice with fertilizer (27.1). The number of leaves in the control was (17.7) and the lowest was in the farmers' manure treatment (12). The CA treatment recorded the highest number of pods (15.1) and this was significantly different from the farmers' fertilizer treatment (8) and the farmers' manure treatment (4). The number of pods in the control was 5pods. Biomass yields were highest in the farmers' fertilizer treatment (F.fert=5000kg/ha), followed by the CA treatment (CA=4166.7kg/ha). Similar biomass yields were obtained from the farmers' manure treatment and the control (3333.3kg/ha) (Figure 22).

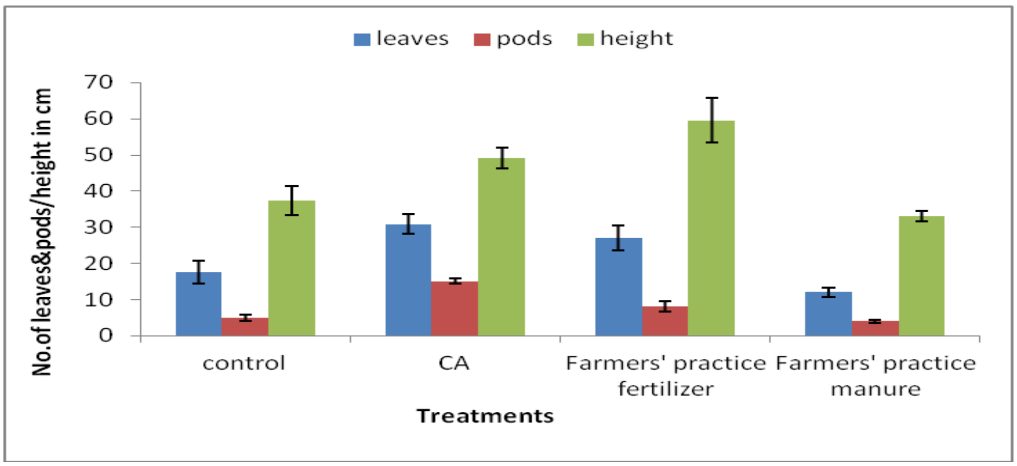

Figure 21: Leaves, Pods and Height Response to different treatments in the Mid Zone

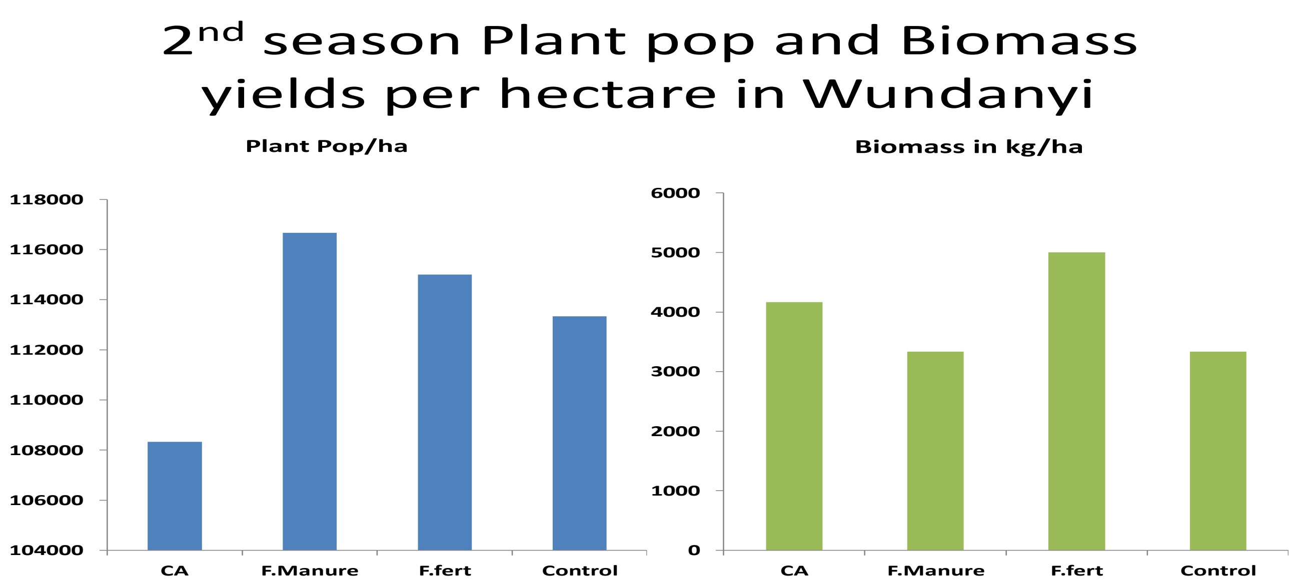

Figure 22: Plant population and Biomass yields/ha in the mid zone.

Results obtained from the low zone (Figure 23) shows that only the conservation CA treatment gave yields during the JJAS season. The average plant height was 42.5cm, average number of leaves was 33.5 while the average number of pods was 16.5. No data was recorded on the rest of the treatments. All the plants in the manure and fertilized farmers' practice plots as well as those in the control dried up following a dry spell and therefore no data was available for the number of leaves and pods, plant height, plant population and biomass (Figure 24).

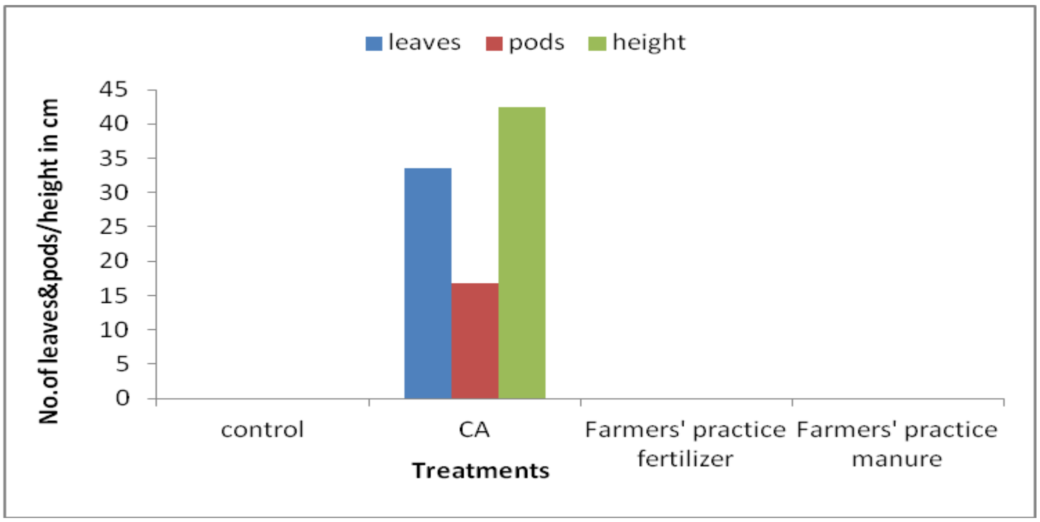

Figure 23: Leaves, Pods and Height responses to different treatments in the low zone

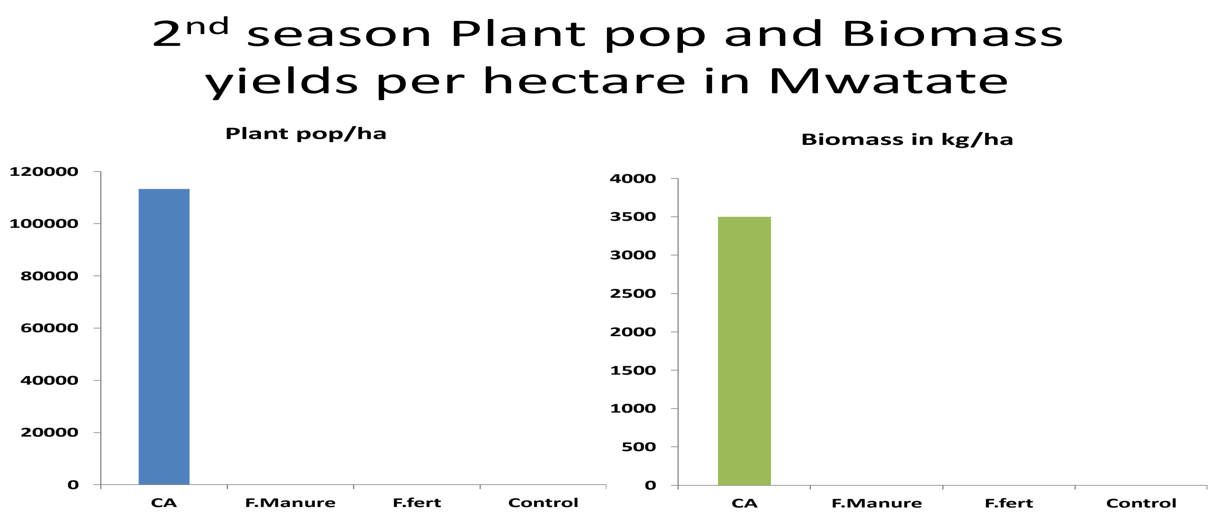

Figure 24: Plant population and Biomass yields/ha in the low zone.

Overall, there was a significant difference in the number of pods, leaves and plant height recorded in the CA treatment compared to all the other treatments except for the results obtained from the mid-altitude agro-ecological zone in the second season. This could be because of high seed rates used in the farmers' practice treatments in this zone. Most farmers believe that the more seeds they plant, the more yields they obtain yet this is not the case. High seed rates lead to high plant densities, which may be a hindrance to optimum leaf and pod production as well as stunted growth due to competition for nutrients. However, as observed from the results, high plant densities do not necessarily translate to high yields. Furthermore, it was also observed by Liu *et al*. (2005) that although plant height had no direct influence on final seed yield, even tall statured bean varieties produced larger number of leaves which in turn supplied greater amounts of assimilates for seed growth resulting in higher seed yield. Similarly plants of bean crops with tall height had longer growth duration which resulted in larger number of pods and seeds.

In the high zone, result show that there was no significant difference in biomass yields from the different treatments in both seasons. In addition, various studies have shown that it may take 2 to 4 years before farmers can notice any major difference in yields after adopting CA (Rusinamhodzi *et al*., 2010, Kassam *et al*., 2009, Derpsch, 2005). This is because the build-up soil structure and restoration of soil fertility does not happen overnight and benefits can be seen in the long term. Furthermore, farmers in the high and mid-zones do not experience extreme conditions of drought as the lower zones. This might explain the minimal or lack of yield increases in the high and mid-zones. The CA treatment shows that a combination of manure and fertilizer as used in the CA treatment will give higher yields as opposed to using manure only or fertilizer only. Furthermore, less weeds were observed on CA treatments due to the effect of the mulch. This could mean less competition for nutrients between weeds and plants and less time spent in weeding. Farmers can use the extra time to engage in other activities for example running small businesses or tending to livestock to provide additional income sources for their households.

During the MAM season, germination percentage in the high zone was very low. This could be as a result of waterlogging because the mulch effect might have caused more water infiltartion creating the need for gapping. According to CGIAR (2014), heavy mulch can cause drainage problems depending on the soil type thus hindering proper germination. For both seasons studied, a large visible difference was noted in the CA treatment in the low altitude agricultural zone. The zone lies in an ASAL chracterized by low rains for most parts of the year and poor soils. The effect of mulch in conserving soil moisture as well as the combined effect of organic and inorganic fertilizers could explain the immediate change in observed yield for the area.

Challenges and Limitations

One major challenge to CA adoption is the lack of mulching materials in the high and mid-zones. Most farmers in the high and mid-zones own livestock and hence utilize the crop residues as fodder. For this reason, obtaining mulch for use in the demonstrations was a big challenge as it had to be sourced from the low zone which is not sustainable. A number of farmers suggested even though the crop residues were used as fodder, there are always remains the animals leave behind after consumption and these include crop residue remains as well as those from grass and other types of fodder. These can be collected, bulked and taken back to the farm for use as mulch.

Another challenge to adoption of the CA practice is rigidity of the farmers' mindset. Having given the farmers incentives in form of seed and fertilizers, farm visits were done to assess whether farmers had put into practice what they had learnt during the demonstrations. In the high and mid-zone, about 90% of the visited farmers planted using the seed but did not mulch their crop in both the first and second season. While this could be due to lack of mulching materials, the farmers did not plant using fertilizer because they believe it will destroy their soils. In the lower zone, about 60% of the visited farmers utilized the CA principles showing their desire to learn and embrace new technologies. Furthermore, a fundamental change of mindset is needed for farmers to abandon the unsustainable traditional farming practices and switch to CA. For instance, farmers in the lower zone need to shift from *kukwangura* to destroy the hardpans that already exist on their soils if they are to reap benefits from their farms.

Based on personal observations during the study, the method of land preparation employed by most farmers in the low-altitude agro-ecological zone could be a contributing factor to low yields. Most farmers prepare their farms by a practice commonly known as *kukwangura.* This is characterized by very shallow cultivation of soils that encourages formation of hardpans. Hardpans encourage surface run-off as water infiltration is hindered. There is also poor root penetration resulting in growth of unhealthy weak plants.

Finally, some farmers are aware of traditional and botanical methods of pest control which are a necessary component of IPM. However, these farmers prefer to use pesticides bought from agrovets unaware of the environmental and human impacts of these chemicals because they believe they are more effective.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Smallholder farmers in the Taita hills are concerned with the changes that have been brought by climate change and are using various ways to cope with the changes. The established rainfall trends, which are in agreement with farmers' perceptions from both focus group discussions and household surveys show that there has been a general decline in the amount of rainfall received in the study area over the years.

This is an area that derives its main livelihood from farming. Farming in the Taita hills is mostly rain fed and is therefore directly impacted by any changes in precipitation. The decline in rainfall amounts received in the area has resulted in various outcomes with regard to crop production. These include total crop failure during periods of total lack of rainfall or decline in crop yields and food shortages when the amount of rainfall is very low or the rainy seasons are erratic.

In order to cope with the challenges of poor crop production and food shortages, farmers have put in place several measures. These include buying food from the market, getting assistance from friends and relatives, relying on government food aid, relying on saving while a few changed their farming practice and sought off-farm employment. Others also reported that they did nothing and waited for the times of adversity to pass. However, most of the current coping measures cannot sustain them in the long term and will only make them more vulnerable.

In order to address these challenges in the long term, farmers need more sustainable adaptation measures. A shift to the CA practice presents a viable opportunity for farmers to realize better yields at minimal costs. It also offers a sustainable production practice that can enable farmers to adapt to as well as mitigate climate change. More importantly, its widespread use in the lower zone that lies in arid and semi-arid areas can facilitate build up and restoration of soil fertility, conservation of soil moisture and soil structure, which are essential for optimum crop growth. As shown in the results, even when all the plants in the conventionally grown farmers' practice plots dried up, yield was still realized in the CA plot. In addition, immediate differences were observed in crop performance and yield in the CA treatment in the lower zone compared to those in the high and mid-zones. This is due to the effect of mulch in preserving soil moisture that sustained the plants during the dry spell. In the low zone, 70% (14 out of 20) farmers who received seed and fertilizer during the first season noted that their crop yields improved by almost double, when they used a combination of certified seed, fertilizers and mulch. However, in the second season, most farmers in the low zone recorded up to 90% crop losses because of a disease they say occurs at intervals of two or three years after the long rains. While they do not know the name of the disease, most of them noted that it was a soil disease brought about by soils that were washed down from the high zones by rainwater. The study also established that farmers are rich in local knowledge regarding insect pest control that can be useful for integration into the IPM component of CA for effective and affordable management of insect pests and diseases.

8.2 Recommendations

Smallholder farmers especially in the low altitude zone of the Taita hills should invest more in soil conservation activities for example by maintaining a permanent mulch cover on their soils. Since most of them use their crop residues as fodder for their livestock, they can use other locally available materials such as dry grass or left over animal feed as mulch.

The government should provide funding and incentives for widescale CA adoption since it is a proven climate smart food production strategy especially for the low-altitude drier areas in the Taita Hills. This will provide facilitation for extension officers to go out to the field and set up more demonstration areas for the practice as well as distribute certified seed and fertilizer to more farmers to practice CA on their farms. The strategy offers both adaptation and mitigation benefits in that while it helps farmers to increase food production under umpredictable climatic conditions,it also helps in reducing carbon emmissions that arise from continuous tillage in agriculture.

The agricultural offices should educate and create awareness to farmers in the low zone about recommended agronomic practices from land preparation, planting, weeding and harvesting as well as making the necessary soil improvements through inputs such as manure, commercial fertilizers and good quality seed. For instance, one of the essential requirements for a farmer seeking to embrace CA is thorough initial land preparation to loosen up the soils in order to improve aeration, water infiltration and prevent hardpan formation.

As part of IPM awareness creation, there is need to first document the wide array of traditional and botanical methods of pest control possessed by farmers. This will then be followed by education of farmers about the same methods through extension activities, seminars and workshops so that the knowledge is shared with those who do not have it. Farmers should also be educated on the importance of using chemicals as a last resort in IPM.

Finally, while CA presents a viable option for climate change adaptation, there is need for more long term studies to confirm the results obtained in this research across the different agro-ecological zones and cropping systems.

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ANNEX 1

SEMI STRUCTURED QUESTIONNAIRE FOR FOCUS GROUP DISCUSSION

1. Have you observed any changes in your village over the last 20 years? If yes, please name changes and the possible causes of these changes.

2. What challenges and opportunities have been brought by these changes?

3. Has the village been affected by climatic events in the last 10 years? If yes,

   a. Type of event

   b. Outcomes of the event

   c. Losses accrued from the event

4. Has the community put in place any measures to adapt to these changes in climatic events? If yes, what actions have been taken?

5. If not, what are the reasons for not putting in place any measures?

6. Have you observed any variations in rainfall over the last 20 years?

7. If yes, what are these variations?

8. Have u noticed any variations in temperature over the last 20 years? If yes, what are the variations?

9. Have your households been affected by these rainfall variations in terms of land use and agricultural production? If so, please explain.

10. What is the main economic activity in the village?

11. Has the community diversified to other economic activities due to these changes?

12. How would you consider the crop yields you get currently and those you used to obtain from the same area of land 20 years ago?

13. Does the village have any programs or institutions put in place to help people in case of disasters or extreme climate conditions?

14. Has the government been involved in activities aimed at helping households whenever disasters occur in the village?

15. Have there been any efforts by the agricultural offices to introduce new farming techniques to the village to help cope with the impacts of climate change?

16. Do you have possible ideas for adaptation that you could not implement due to limitations? If so

   a. What are the ideas?

   b. What are the limitations?

ANNEX 2

HOUSEHOLD QUESTIONNAIRE FOR ASSESSMENT OF HOUSEHOLD VULNERABILITY AND RISK

I am a student from the University of Nairobi studying 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) ____

A. DEMOGRAPHIC PROFILE

	CODE	RESPONSE
A1. Name of the Respondent (Optional)	*(Mark N/D if the information is not available)*	
A2. Address		
A3. Mobile Phone Number		
A4. Age		
A5. Gender	1. Male 2. Female	
A6. 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	
A7. Ethnicity (Optional)	(*Mark N/R if there is no response)*	
A8. Religion (Optional)		
A9. Occupation		
A10. Respondent's Relationship with household head	1. Household head 2. Mother 3. Father 4. Husband 5. Wife 6. Child 7. Grandchild 8. Other Relative (Specify)	

A11. 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)	
A12. 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	
A13. 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	
A14. 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. Dairy farming 3. Ranching (Beef farming) 4. Goat/sheep rearing 5. Cash Crop Farming 6. Short Term Agricultural Wage Labour (<3 Months) 7. Short Term Non-Agricultural Wage Labour (<3 Months) 8. Permanent/ Salaried Agricultural Related Employment 9. Permanent/Salaried Non-Agricultural Related Employment 10. Business (Specify) 11. Remittances (Indicate Source) 12. Pension 13. Government Welfare 14. Other(Specify)	
A15. Other Sources of Household Income (Specify)		
A16. Household size (members currently living in the household)		
A17. 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 4. None	

B. DEPENDANTS IN THE HOUSEHOLD

B1. Member	B2. Age	B3. Marital Status	B4. Level of Education

Inform the respondent that the succeeding questions address only the other household members who contribute to the household income

C. MEMBERS CONTRIBUTING TO HOUSEHOLD INCOME

C1. Member 1. Head of Household 2. Spouse(s) 3. Son 4. Daughter 5. Granddaughter 6. Grandson 7. Grandmother 8. Grandfather 9. Other (Specify) (*if more than one member is contributing, indicate them ALL)*	C2. Age	C3. Occupation 1. Smallholder Farmer 2. Casual Farm Labourer 3. Self employed 4. Business and Retail/Trader 5. Artisan/Mechanic/Factory Worker/Mason 6. Health Worker (Private/Public) 7. Teacher(Private/Public) 8. Government Employee 9. Parastatal Employee 10. Transport Sector 11. Other (Specify)	C4. Contribution to the household (In terms of Days per Week) C4.1 On Farm Contribution	C4.2 Off Farm Contribution

D. SOCIAL SAFETY NETS

D1. Group 1. Farmers' Association 2. Youth union 3. Women's union 4. Political group 5. Religious group 6. Credit /Saving group 7. Community Based Organization 8. Water Resource Users Association 9. Staff Association 10. Other (Specify)	D2. Member (Use codes in C1 of preceding table)	D3. Duration of Membership (*In case of multiple membership indicate the earliest year joined*)	D4. Type of help received from group 1. Loan 2. Credit 3. Livestock/Poultry 4. Transportation Support 5. Marketing of Produce 6. Technical/Equipment Support 7. Seeds 8. Tree Saplings (Agro-forestry) 9. Food aid 10. Land preparation 11. Harvesting 12. Weeding 13. Buying inputs 14. Building and maintenance of terraces 15. Other (Specify)

E. HOUSEHOLD ASSETS

E1. Type of Asset (Owned by the Household)	E2. 1:Yes; 2: No	E3. How many?	E4. Who owns these assets? From C1 (member id)
1. Primary residence a. Permanent b. Semi-permanent c. Temporary			
2. Business building			
3. Solar panel			
4. Toilet (pit)			
5. Toilet (modern flush)			
6. Car			
7. Motorcycle			
8. Refrigerator			
9. Television			
10. Radio			
11. Cell phone			
12. Bicycle			
13. Computer			
14. Hand Cart			
15. Tractor			
16. Other (Specify)			

F. HOUSEHOLD CHARACTERISTICS

F1. Do you own the main dwelling See Codes	F2. Roof material for the main dwelling unit See Codes	F3. Main source of cooking fuel See codes	F4. Main source of lighting See Codes

F1
1. Owned
2. Rented
3. Other (Specify)

F2
1. Thatch
2. Sticks
3. Tin
4. Iron roof sheets
5. Asbestos
6. Tiles
7. Other (Specify)

F3
1. Firewood from own woodlot
2. Firewood from neighbours' woodlot
3. Firewood bought from the market
4. Firewood from the gazetted forest
5. Gas (LPG)
6. Electricity
7. Animal Dung
8. Biogas
9. Farm residue
10. Other (Specify)

F4
1. Electricity
2. Candle
3. Lanterns
4. Firewood
5. Solar Panel
6. Generator
7. Biogas
8. Other (Specify)

G. DOMESTIC WATER USE

G1. Sources of domestic water **key**	G2. Distance to source ***km***	G3. Time to Source	G4. Seasonal Use ***key***	G5. How do you consider quality ***key***	G6. Used for ***key***	G7. Payment for use? ***1=Yes, 2=No***	G8. If yes, how much? (*in local currency)*	
							Amt/month	***Amt/liter***

G1. Source of Rain Water

1. Rooftop rainwater
2. Borehole
3. Spring
4. River
5. Dam
6. Water Pan
7. Lake
8. Stream
9. Piped water at source
10. Piped water into dwelling
11. Irrigation canal
12. Water vendor
13. Other (Specify)

G3. Key for Time to source

1. <30 min
2. 30-60 min
3. > 2 hrs

G4- Key for seasonal use:

1. Rainy season
2. Dry season
3. All year

G5 – Key for water quality:

1. very good
2. good
3. fair
4. poor
5. very poor

Key for G6- used for:

1. Drinking
2. Livestock watering
3. Washing
4. Cleaning
5. All household needs
6. Other (specify ________)

H. ACCESS TO BASIC FACILITIES

H1. Type of Facility	H2. Do you currently have access? (1: Yes; 2: No)	H3. If no, why? ***(key)***	H4. If yes, distance from the household (km)	H5. Did you have access 10 years ago? (1: Yes; 2: No)
Electricity (*ask if electricity is available in the h/hold)*				
Telephone (land line)				
Mobile Phone				
Primary School				
Secondary School				
Medical center				

Market				
Grocery/Hardware Store/Agrovet				
Transport (Bus, Motorcycle, Taxi, Tuk Tuk (Bajaj, Animal Powered Transport)				
Water Point				
Extension Services				

Key for H3 If no access, why?

1. Government did not provide
2. Financial constraints
3. Not available
4. Political instability
5. Insecurity
6. Cultural belief
7. Religious belief
8. No need
9. Time Distance
10. Terrain
11. Physical Constraint
12. Other, specify___________________

I. AVAILABILITY OF AND ACCESS TO WEATHER FORECAST

I1. Are weather forecasts available for your local area (1. Yes 2.No)			
I2. Does your household have access to weather forecasts (1. Yes 2. No 3. Other (Specify)			
I3. If no, give reasons			
I4. If yes, what type of weather forecast do you have access to 1. Conventional Weather Forecast (Provided by National Meteorological Agent) 2. Traditional Weather Forecast (Provided through local observations) 3. Both			
I5. What is the temporal scale of the weather forecast provided? 1. Daily Forecast 2. Weekly Forecast 3. Monthly Forecast 4. Seasonal Forecast 5. Annual Forecast	I6. Source	I7. Level of Reliability	I8. How information is utilized

<table>
<tr>
<td rowspan="2">Source of Forecast(I6)
1. Radio
2. Newspaper
3. TV
4. Chiefs’ barazas
5. Government extension agents
6. Traditional forecasters
7. Local elders/religious leaders
8. Friends or neighbours
9. Other (Specify)</td>
<td>For level of reliability of the forecast (I7): 1. Very Reliable, 2. Reliable, 3. Unreliable, 4. Very Unreliable 5. No Answer</td>
</tr>
<tr>
<td>For utilization of information (I8):
1. For land preparation
2. For seed selection and preparation
3. For fodder collection and storage
4. For planting
5. For pesticide/herbicide application
6. For harvesting
7. For post harvest activities
8. Other (Specify)</td>
</tr>
</table>

J. CLIMATE IMPACTS TO THE HOUSEHOLD MODULE

J1. Has your household been impacted/affected by climatic events in the last 10 years? (1. Yes 2. No)						
J2. If yes, which climatic events (climate events that significantly affected household income) have affected your household during the last 10 years?						
J3. Type of event (key)	**J4. When was the event (year in last 10 years)**	**J5. What was the outcome of the event?** (key)	**J6. What did you do? - Action?** (key)	**J7. Who took the action?** *(member id C1)*	**J8. How widespread was the event?** (key)	**J9. Estimate of the amount of loss/gain to the household** ***(local currency)***

Key-Type of climate event (J3):
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. Heat waves
16. Others (specify)

Action (J6)
1. Did nothing
2. Assistance from friends/relatives
3. Relied on savings
4. Government food aid
5. Sold land
6. Sold house
7. Sold crops
8. Sold livestock
9. Changed farming practice
10. Bought food
11. Reduction in household food consumption
12. Sought off-farm employment
13. Ate different types of food
14. Ate wild plants/fruit/animals
15. Exchange animals for cereals

How widespread was the impact (J8)?
1. My household only
2. A few households in the village
3. Most households in the village
4. All households in the village
5. A few households in the region
6. Most households in the region
7. All households in the region

Outcome of climate event (J5)

1. Decline in crop yield
2. Increase in crop yield
3. Loss of income
4. Gain of new income sources (Specify)
5. Loss of assets
6. Acquisition of new assets
7. Loss of entire crop
8. Death of livestock
9. Decline in livestock production
10. Increase in livestock production
11. Increase in food prices
12. Decrease in food prices
13. Food Shortage
14. Food Surplus
15. Damage to infrastructure (e.g. roads, canals, sewerage)
16. Increase in area under production
17. Increase in the length of growing season
18. Increase in the number of growing seasons
19. Occurrence of conditions suitable for growth of new crops and fruit
20. Change in the onset and cessation of the growing season
21. Others (specify)

16. Borrowed from bank
17. Borrowed from private money lenders
18. Borrowed from relatives and friends
19. Household member migrated to other rural area
20. Household member migrated to urban area
21. Participated in Food for Work initiative
22. Kept children out of school
23. Others (specify)

K. EARLY WARNING SYSTEM FOR CLIMATE EXTREMES

K1. Have the incidents of 1. drought/ 2. floods changed in your area? 1. Yes 2. No _________

K1.1 If yes, have they 1. Increased 2. Decreased

K1.2 Give reasons for change ____

K1.3. Did you have access to early warning before the last drought/flood? 1. Yes 2. No ____________________

K1.4. If no to the above question, why? 1. Not available, 2. Non access to media devices 3. Delay in the reception of information 4. Other (Specify)

K1.5. If yes, how did you utilize the information in coping with the drought/flood? ____________________

1. Stocking up on food items

2. Digging trenches
3. Planting drought resistant crops
4. Selection of drought resistant seed/crop varieties
5. Purchase of irrigation equipment
6. Purchase of rooftop rainwater harvesting equipment
7. Moving livestock/poultry to higher ground
8. Stocking up on fodder
9. Preparing the furrows
10. Other (Specify)

K2. When was the last drought the household experienced? ______________ (year)	**K3. When was the last year the household experienced too much rain/flooding? ____________ (year)**
K4. Do you have food reserves for use during the dry season/periods of drought? 1. Yes 2. No	**K4.1. Do you have food reserves for use during periods of drought/floods?** 1. Yes **2.** No
K5. If yes to the above question, how long do the reserves last you in times of need? 1. 0-2 month 2. 2.1 -4 months 3. 4.1-6 months 4. > 6 months	**K5.1 If yes to the above question, how long do the reserves last you in times of need?** 1. 0-2 month 2. 2.1 -4 months 3. 4.1-6 months **4. > 6 months**
K6. During the last large drought, did you change your farming practice (crop and livestock)? _______ (1. Yes 2. No)	K7. During the last year with too much rain, did you change your farming practice (crop and livestock)? ________ (1. Yes 2. No)
K8. 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)	

K9. If you changed the farming practices please answer the following questions							
Drought				**Flooding/Too much rain**			
K10. If yes, what did you do? (key)	K11. If yes, how?	K12. If yes, who? (C1-member id)	K13. Indicate from whom you got information on how to implement the change Key**:** 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)	K14. If yes, what did you do? (key)	K15. If yes, how?	K16. If yes, who? (member id-C1)	K17 Indicate from whom you got information on how to implement the change Key: 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)
1. Change in planting dates 2. Change in crop variety 3. Change in crop type 4. Other (Specify)				1. Change in planting dates 2. Change in crop variety 3. Change in crop type 4. Other (Specify)			

Drought				**Flooding/Too much rain**			
If yes, what did you do? (key)	**If yes, how?**	**If yes, who? (C1-member id)**	**Indicate from whom you got information on how to implement the 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?**	**If yes, who? (C1-member id)**	**Indicate from whom you got information on how to implement the change** **Key: 1. Relative 2. Neighbor 3. Project/NGO 4. Government extension 5. Other (specify)**
K21. Diversification of crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticulture 3. Cash crops 4. Drought resistant crops 5. Trees for timber 6. Trees for firewood 7. Other (Specify)				K21.1 Diversification of crops from staple to: (Yes/No) If yes: 1. Fodder 2. Horticulture 3. Cash crops 4. Drought resistant crops 5. Trees for timber 6. Trees for firewood 7. Other (Specify)			
K22. Increase in land size under cultivation (specify unit of measurement)				K22.1 Increase in land size under cultivation (specify unit of measurement)			
K23. Decrease in land size under cultivation (Specify unit of measurement)				K23.1 Decrease in land size under cultivation (Specify unit of measurement			
K24. Change in fertilizer application (Yes/No) If yes: 1. Manure 2. Compost 3. Crop residue 4. Commercial				K24.1 Change in fertilizer application (Yes/No) If yes: 6. Manure 7. Compost 8. Crop residue 9. Commercial			

fertilizer 5. Other (Specify)				fertilizer 10. Other (Specify)			
K25. Use of pesticides (Yes/No) If yes: 1. Organicl to Synthetic 2. Synthetic to Organicl 3. Mix of synthetic and Organic 4. Other (Specify)				K25.1 Use of pesticides (Yes/No) If yes: 5. Organicl to Synthetic 6. Synthetic to Organicl 7. Mix of synthetic and Organic 8. Other (Specify)			
K26. Implement soil conservation and water harvesting techniques (Yes/No) (See codes) 1. Terraces 2. Minimum tillage 3. Grass strips 4. Cover crops 5. Diversion ditches 6. Agro forestry 7. Irrigation 8. Zai Pits 9. Other (Specify)				K26.1 Implement soil conservation and water harvesting techniques (Yes/No) (See codes) 1. Terraces 2. Minimum tillage 3. Grass strips 4. Cover crops 5. Diversion ditches 6. Agro forestry 7. Irrigation 8. Zai Pits 9. Other (Specify)			
K27. Indicate change in agriculture and livestock production	**Fill in code from K27 as appropriate**			K27.1 Indicate change in agriculture and livestock production	**Fill in code from K27 as appropriate**		

3. Mixed crop and livestock production 4. Shift from crop to livestock production 5. Shift from livestock to crop production 6. Grow trees with crops (Agro-forestry) 5. Grow trees with pasture 6. Increase in shade trees on the farm 7. Change pattern of animal consumption 8. Increase the number of livestock 9. Shift from crop to fish farming 10. Crop production to fodder production 11. From staple crops to cash crops 12. Decrease the number of livestock (de-stocking) 13. Diversify livestock feeds 14. Change livestock feeds 15. Supplement livestock feeds 16. Change veterinary interventions				1. Mixed crop and livestock production 2. Shift from crop to livestock production 3. Shift from livestock to crop production 4. Grow trees with crops (Agro-forestry) 5. Grow trees with pasture 6. Increase in shade trees on the farm 7. Change pattern of animal consumption 8. Increase the number of livestock 9. Shift from crop to fish farming 10. Crop production to fodder production 11. From staple crops to cash crops 12. Decrease the number of livestock (de-stocking) 13. Diversify livestock feeds 14. Change livestock feeds 15. Supplement livestock feeds 16. Change veterinary interventions			

17. Change portfolio of animal species 18. Change animal breeds 19. Move animals to another site 20. Seek off farm employment 21. Migrate to another piece of land 22. Set up communal seed banks/food storage facilities 23. Other (Specify)				17. Change portfolio of animal species 18. Change animal breeds 19. Move animals to another site 20. Seek off farm employment 21. Migrate to another piece of land 22. Set up communal seed banks/food storage facilities 23. Other (specify)			

L. Have any other events/shocks affected your household during the last 10 years? ___________________ (1=Yes, 2=No)
(*Has this household been affected by a serious shock—an event that led to a serious reduction in your asset holdings, caused your household income to fall substantially or resulted in a significant reduction in consumption?)*

L1. Type of shock (See Codes)	**L2. When was the shock (year in last 10 years)**	**L3. What did the shock result in?** (See Codes)	**L4. Who in the household was most affected by the shock?** (C1- member id)	**L5. What did you do? - Action?** (See Codes)	**L6. Who took the action?** (C1-member id)	**L7. How widespread was the shock?** (See Codes)	**L8. Estimate of the amount of loss to the household**

Key for preceding question Other types of shocks (L1)

Production shocks
1. Insect pests attack on crops before harvest,
2. Other pest attacks on crops before harvest
3. Crop loss during storage,
4. Plant disease
5. Animal disease,
6. Wildlife damage to crops

Market shocks
7. Large increase in input prices,
8. Large decline in output prices,
9. Inability to sell agricultural products,
10. Inability to sell non agricultural products,
11. Inaccessibility to markets

Political and social shocks
12. Expropriation of land by government,
13. Ethnic violence
14. Forced migration/relocation
15. Discrimination for political reasons,
16. Forced contributions
17. Arbitrary taxation,
18. Discrimination for social reasons,
19. Corruption

Criminal shocks
20. Theft of crops,
21. Theft of livestock;
22. Destruction or theft of tools or inputs for production,

Idiosyncratic (personal) shocks
23. Loss of job by family member;
24. Death of family member (specify)
25. Illness of family member (specify)
26. Separation of family member[s],
27. Dispute with extended family,
28. Dispute with others in village;
29. Imprisonment
30. Other [specify]

Key for L3 - Outcome of shock:
1. Loss of assets,
2. Loss of income,
3. Decline in crop yield;
4. Loss of entire crop
5. Death of livestock;
6. Decline in livestock productivity
7. Food shortage/insecurity
8. Other, [specify_______________]

Key for L 5Action
1. **Did nothing,**
2. **Sold livestock,**
3. Sold crops
4. Sold land/home
5. Sold assets
6. **Borrowed from relatives or friends**
7. **Borrowed from bank,**
8. Borrowed from private money lenders
9. **Received food aid,**
10. **Participated in food for work,**
11. **HH head migrated to other rural area,**
12. **HH plus others migrated to rural area,**
13. **Migrated to urban area,**
14. **Sought off-farm employment,**
15. **Bought food**
16. **Ate less;**
17. Ate different foods
18. Kept children home from school
19. **Other [please specify_ _________]**

Key for L7 – How widespread

1: Only my household
2: Some households in the village
3: Most households in the village
4: All households in the village
5: Many households in the region
6: Some households in the region
7: All households in the region

M. LAND TENURE, LAND CHARACTERISTICS, OWNERSHIP AND MANAGEMENT MODULE.

(For this section please ask the respondent to indicate the main parcel of land plus other additional land parcels)

Land characteristics

M1. Area/Size of Parcel (Specify unit of measurement)	M2. Major land use type **(key)**	M3. Major crops (food/cash crop)*(list—one per plot or intercropping)*	M4. Distance from household (km)	M5. Soil type **(See Codes)**	M6. Soil fertility **(See Codes)**	M7. Change in soil quality in the last ten years 1. Improved 2. Same 3. Declined	M8. Reason for change in soil quality (key)	M9. Slope **(See Codes)**	M10. Erosion **(See Codes)**	M11. Who manages plot *(member id)* **(See Codes C1)**

Key for Major land use type (M2):
1. Crop production;
2. Agro-forestry
3. Livestock
4. Grazing land/pasture land
5. Kitchen garden;
6. Farm forestry
7. Fish farming
8. Fodder farming (e.g. solely napier grass on plot)
9. Tree farming
10. Horticulture
11. Other (pls. specify) ________

Key for - Soil type (M5):
1. Black,
2. Brown
3. Grey
4. Red
5. Yellow
6. Murram
7. Sandy
8. Clay
9. Other [pls. specify]________

Key for Soil fertility (M6):
1. Very fertile
2. Moderate
3. Poor

Key for Change in soil quality (M8)
1. Irrigation
2. Improved land use practices
3. Use on inputs
4. Floods
5. Drought
6. Other (specify)

Key for Slope (M9):
1. Flat,
2. Slight incline (up to 20 degrees),
3. Steep

Key for Erosion (M10):
1. No erosion
2. Mild erosion
3. Severe erosion

N. LAND OWNERSHIP AND ITS HOLDING IN THE LAST 12 MONTHS

N1. Land ownership **(key)**	N2. Land title at the parcel level **(key)**	N3. How was the land acquired? **(key)**	N4. If rented, what is the annual rent			N5. Who in this household acquired this parcel? (C1- Member id)	N6. Who has the right to give away this plot? (C1-Member id)
			Cash (*In local currency)*	In kind (units)	In kind (*estimate amount in local currency)*		

N6.1. Have your land holdings increased or decreased in the past 10 years? (1.Increase 2. Decrease 3. No change) ________________________________

N6.1.1 If there has been change, give reason ____

N6.2. What were your total land holdings in 2004? __________________ (*state unit of measurement)*

Key for N1 – Land ownership:
1. Own land and own use,
2. Renting out (cash rent),
3. Renting in
4. "Pure" Sharecropping in,
5. "Pure" Sharecropping out,
6. "Cost-sharing" Sharecropping in
7. "Cost-sharing" Sharecropping out
8. Communal land (traditional ownership),
9. Borrowed land in (Do not pay money or in kind for usage),
10. Borrowed land out (does not receive money or in kind payments for usage)
11. Other (pls. specify___________)

Key for N2- Land title:
1. Government title,
2. Communal tenure [clan, not written],
3. No title
4. Leased in from government
5. Private lease
6. Own title deed

Key for N3- How acquired:
1. Inherited
2. Purchased,
3. Received from the government,
4. Allocated by the community
5. Leased
6. Other [please specify]____________

N7. LAND MANAGEMENT (CROP AND GRAZING LAND)

N7.1 What type of soil and water management practices are you using on crop land? (key)	N7.2 Since when did you start using this practice? (year)	N7.3 What previous practices did you use? (key)	N7.4 Why did your practices change? (key)	N7.5 What management techniques are you using for grazing land? (key)	N7.6 Since when did you start using this practice? (year)	N7.7 What previous practices did you use? (key)	N7.8 Why did your practices change? (key)	N7.9 If using water harvesting, what type? (key)	N7.10 If using irrigation, what type? (key)	N7.11 What source of water do you use for irrigation? (Key)

Keys next page

N7.12. Are you leaving land fallow? ____________________________ (1=Yes 2=No)

N7.13. Do you consider your grazing land to be over grazed? ______________ (1=Yes 2=No 3= Don't know)

N7.14. What do you do with crop residues after harvesting? ____________________________________ (Key)

Key for N7.14

1. Slash and burn
2. Slash and leave it on the surface for livestock to graze on
3. Slash and store as forage for livestock
4. Do nothing and leave the residue as they are until the next season
5. Slash and sell the residue
6. Slash and use as thatch material
7. Slash and leave them lying on the surface until the next season
8. Use as firewood
9. Used for trash line making
10. Slash and use for mulching
11. Other (specify)

Key for N7.1 and N7.3 – Type of soil and water conservation:

1. Nothing
2. Fanya Juu terraces (soil bunds up slope)
3. Fanya Chini (soil bunds down slope) (creates a cut off drain or a retention ditch)
4. Bench terraces
5. Trenches
6. Irrigation
7. Stone bunds
8. Mulching/surface cover
9. Trash line
10. Log line
11. Slash and burn
12. Grass strips
13. Hedge rows (shrubs)
14. Conventional tillage
15. Minimum tillage
16. Infiltration ditches
17. Ridge and furrow
18. Fallowing
19. Improved fallowing
20. Composting
21. Farm yard manure
22. Green manure
23. Fertilizer (inorganic straight)
24. Fertilizer (inorganic compound)
25. Agroforestry
26. Shade trees
27. Cover crops
28. Crop rotation
29. Crop rotation with legumes (nitrogen fixing)
30. Intercropping
31. Small dams
32. Water pans
33. Others, specify______________

Key for N7.5 and N7.7- Grazing land management

1. Enclosure of the land
2. Restriction on livestock numbers (destocking)
3. Maintain large stocks
4. Removal of unwanted bush
5. Periodic resting
6. Open grazing area
7. Zero grazing
8. Cattle routing
9. Common watering points
10. Supplementary fodder production
11. Others, specify__________________

Key for N7.4 and N7.8- Why has your crop land/grazing land practices changed?

1. To increase productivity/yield
2. To increase water holding capacity
3. To increase biological control of pests and diseases
4. To reduce conflict with neighbors
5. To increase soil fertility
6. To reduce erosion
7. Other, specify_____________________

Key for N7.9- Type of water harvesting

1. Roof water harvesting
2. Earth dams
3. Tree crop ditches
4. Ridge and furrow
5. Retention ditches
6. Road water harvesting
7. Catchment tanks
8. Underground tanks
9. Rock catchments
10. Extraction from springs
11. Extraction from rivers
12. Extraction from lakes and reservoirs
13. Sand dams
14. Other, specify_______________________

Key for N7.10 -type of irrigation

1. Flood irrigation
2. Ridge and Furrow irrigation
3. Drip Irrigation
4. Overhead irrigation
5. Watering Can
6. Other (Specify)

Key for N 7.11-Sources of Water for Irrigation

1. Public borehole
2. Private borehole
3. Springs
4. Lakes and reservoirs
5. Dams
6. Water Pans
7. River
8. Rainwater
9. Other (Specify)

O. AGRICULTURE PRODUCTION AND FOOD SECURITY MODULE

O1. Does your household normally undertake crop farming? 1. Yes-Rain-fed 2. Yes-irrigated 3. Yes R&I 4. No	O2. Did your household grow any crops during the last 12 months? 1. Yes 2. No		O3. If no in the previous question, what was the reason (See Codes)	O4. Name all crops that the h/hold farmed in the last 12 months by season and acreage				O5. Expected harvest in the last 12 months		O6. How much did h/hold actually harvest in the last 12 months from parcel planted (See codes)		O7. How much of the harvest was consumed by the household in the last 12 months		O8. How much of the harvest was sold in the last 12 months		O9. What was the total earning from the sales (*in local currency)*	O10. In the last 12 months has the household had to acquire land elsewhere for crop production (If yes, give reason) 1. Yes 2. No
	Long rains (LR)	Short rains (SR)		LR		SR		LR	SR	LR	SR	LR	SR	LR	SR	Amt	
				Crop	Acreage	Crop	Acreage	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty		

Key for not growing crops (O3)

1. No seeds
2. Delay in seed reception
3. Poor seed quality
4. Inaccessibility to land
5. Insufficient land acreage
6. High/Low temperatures (*indicate the exact one)*
7. Inadequate/excessive rainfall (*indicate the exact one*)

Key for types of crop in h/hold (O4)

1. Maize
2. Sorghum
3. Millet
4. Cowpeas
5. Pigeon peas
6. Beans
7. Green grams
8. Fodder crops

O6-O8 (Indicate the quantity e.g. 500/1 (Quantity/unit of measure)

1. Kilogram
2. 50 kg bag
3. 90 Kg bag
4. Bunch
5. Piece
6. Heap
7. Debe
8. Gorogoro/kasuku (2 kg)
9. Basket

8. Late onset 9. Early cessation of rainfall 10. Late onset and early cessation of rainfall 11. Drought 12. Floods 13. Inadequate extension services 14. Cultural belief and practices 15. Insect pest attacks 16. Plant diseases 17. Wildlife conflict 18. Land not arable 19. Soil erosion 20. Others(specify)	9. Cassava 10. Yams 11. Avocado 12. Sweet potatoes 13. Arrow roots 14. Bananas 15. Vegetables (Specify) 16. Coffee 17. Others (specify)	10. Crate 11. Others(specify)

P. FARMING PRACTICES

P1. What is the major cropping system on your farm? 1. Mono cropping 2. Intercropping 3. Mixed cropping 4. Agro forestry 5. Crop rotation 6. Other (specify)	P2. Methods of land preparation 1. Ox plough 2. Tractor 3. Manual (jembe) 4. Other (specify)	P3. Do you have any cover crops on your farm? 1. Yes 2. No If yes, specify	P4. Do you mulch your crops? 1. Yes 2. No	P5. Are you aware about conservation agriculture (CA)? 1. Yes 2. No	P6. How did you get to know about CA 1. Relative 2. Neighbor 3.Project/NGO 4.Government extension 5. Other (specify)	P7. Do you practice it on your farm? 1. Yes 2. No	P8. If no, what are the reasons? 1. Lack of knowledge 2. Small farm size 3. Expensive 4. No specific reason 5. Not profitable (explain) 6. Risk prone e.g. pests and diseases 7. Other(specify)

Q. HOW DOES THE HOUSEHOLD OBTAIN SEEDS FOR THE MAIN STAPLE CROP FOR PLANTING?

Q1. Staple Crop	Q2. Means of obtaining seeds 1. Buy seeds 2. Save seeds 3. Receives seeds for free 4. Borrow seeds	Q3. Mention Source 1. Own seed 2. Government 3. Agro-vet 4. Neighbours 5. Relatives	Q4. How often? 1. Always 2. Sometimes 3. Never

	5. Other (specify)	6. Farmers' Associations 7. NGOs 8. Other (Specify)	

R. AGRICULTURAL INPUTS FOR CROP PRODUCTION

R1. Inputs for coffee *(For use in Ethiopia and Tanzania only)* 1.Commercial fertilizer 2. Compost 3. Crop Residue 4.Fungicides 5. Manure 6. Pesticides 7. Irrigation facilities 8. Hired manpower 9. Improved coffee variety 10. Other (Specify)	R1.1 Type of coffee farm 1. Shaded 2. Non shaded	R1.2 No. of Coffee Plots (*indicate size and specify unit of measurement)*	R1.3 No. of coffee trees (Total)	R1.4 Current Season (See codes in R 1) Did you have access Yes/No		R1.5 Previous Season (See codes in R1) Did you have access Yes/No		R1.6 In use for more than 10 years (See codes in R1)	R2. Name of Crop	R2.1 Inputs 1.Commercial fertilizer 2. Compost 3. Crop Residue 4.Fungicides 5. Manure 6. Pesticides 7. Irrigation facilities 8. Manpower a)Hired manpower b)Household manpower 9. Improved coffee/seed variety 10. Other (Specify)	R2.2 Value inputs *(In local currency)*
				Expected	Actual	Expected	Actual				

S. CAUSES OF CROP DAMAGE AND LOSS

S1. Major causes of crop losses (in the past 12 months)	
S1. List crop(s) (use key)	**S2. Causes (use key) – if possible name the species e.g. coffee berry borer**
Crops 1. Maize 2. Sorghum 3. Millet 4. Cowpeas 5. Pigeon peas 6. Beans 7. Green grams 8. Fodder crops 9. Cassava 10. Yams 11. Avocado 12. Sweet potatoes 13. Arrowroots 14. Bananas 15. Vegetables (specify) 16. Coffee **17.** Others (specify)	**Causes** 1. Insects 2. Diseases (*name species where possible*) 3. Weeds *(name species where possible)* 4. Poor seed quality 5. Drought 6. Floods 7. Inadequate rainfall 8. Soil Erosion 9. Land not arable (soil fertility/moisture) 10. Frost 11. Excessive rainfall 12. Late onset of rainfall 13. Early cessation of rainfall 14. Strong winds 15. High/Low temperatures 16. Wildlife damage (*Indicate species where possible*) *17.* Domestic animal damage *(Indicate species where possible)* **18.** Others (specify)

T. IF DAMAGE WAS CAUSED BY INSECTS WHICH INSECT PESTS CAUSED THE MOST LOSSES?

T1. List Crop(s)		T2. Name pest(s) –(*if English name is not known use local name*)				T3. Estimate amount of damage (%)			
		Pre- harvest pest(s)		Post-harvest pest(s)		Pre-harvest loss		Post-harvest loss	
Crop	Acreage	LR	SR	LR	SR	LR	SR	LR	SR

U. CROP PEST CONTROL PRACTICES

U1. Traditional methods 1.Crop rotation 2.Trap cropping 3.Early planting 4.Mixed cropping 5. Using ash 6.Sanitation 7. Other (Specify)	U2. Biological methods 1.Predators 2.Parasitoids 3.Microbial agents/Bio-pesticides 4.Botanicals 5. Other (Specify)	U3. Mechanical methods 1.Handpicking 2.Shaking 3.Spraying with water 4. Other (Specify)	U4. Chemical methods 1.Insecticides 2.Fungicides 3.Bactericides 4.Herbicides 5. Other (Specify)	U5. Do you practice integrated pest management? 1.Yes 2.No *(If no, answer the succeeding table)*	U6. If Yes, indicate the sources of information about the practice 1. Relative 2. Neighbor 3. NGO 4. CBOs 5. Barazas/chief's meetings 6. Media (TV, radio, newspaper) 7. Research institutions/universities 8. Government extension 9. Farmers' associations 10. Other (specify)

. BARRIERS TO PEST MANAGEMENT

U7 Barriers to pest management	
Option	**Barrier (specify)**
Traditional	
Biological	
Mechanical	
Chemical	
IPM	
	Key 1. Lack of technical information 2. Affordability 3. Lack of technical know-how 4. Lack of/inadequate extension services 5. Inaccessible methods 6. Cultural/religious barriers 7. Other (specify)

V. PESTICIDE USE

(*Ask the farmer what pesticides are used to control insect pests, plant diseases and weeds)*

V1. List Crop	V2. Name pesticide used	V3. Others (specify)	V4. At what stage do you apply the pesticides? **(Key)** 1. Before pests attack 2. Once pests appear on some plants 3. When majority of plants have been attacked 4. When all plants are pest-infested	V5. Effectiveness of the pesticides (**Key**) 1. Very effective 2. Moderate **3.** Ineffective

W. PEST MONITORING

	Response (use key)
W1. Do you practice monitoring of pests on your farm? 1.Yes 2.No	
W1.1 If yes, how often do you monitor? 1.Once a week 2.Twice a week 3. Twice a month 4..Once a month 5.Twice a season 6. Once a season 7.Other (specify)	
W2. What monitoring method(s) do you use? 1.Visual 2.Traps 3.Other (specify)	

W2.1 If no, give reasons	

X. Have there been any changes in pest management practices in the last 10 years? 1. Yes 2. No ____________________________

X1. If yes, please give reasons for the change

____

X2. If damage was caused by diseases, indicate the disease and the amount of damage/loss caused

X2.1. List Crop(s)		X2.2. Name disease(s) –(*if English name is not known use local name*)		X2.3. Estimate amount of damage (%)	
		Pre- harvest diseases		Pre-harvest loss	
Crop	Acreage	Long Rains	Short Rains	Long Rains	Short Rains

Y. POLLINATION

Y1. Does your household own any beehives 1. Yes 2. No

Y1.2 If yes, how many beehives does your household own? ___________________________

Y2. Apart from honey production, what other benefits do you derive from honey production? ____

Y3. How many kilos of honey do you produce per year? ______________________________

Y4. Has the honey production in your household increased/decreased/remained the same in the past 10 years?

Y5. If yes, indicate the reason for change ____

Y6. What is the main reason for producing honey in your household?

1. Domestic use
2. Domestic use and sales
3. For sale only
4. Other (Specify)

Y7. Do you have access to wild honey? 1. Yes 2. No _____

Y7.1 If yes, how do you access it?

1. Collected by household member
2. Bought
3. Received from neighbor/relative
4. Other (Specify)____

Z. WILDLIFE DAMAGE

Z1. Have you experienced any wildlife damage in your farm? 1. Yes 2. No _______________

Z1.2 If yes, what kind of damage?

Z1.2 Type of damage **(Key)**	Z1.3 Change in frequency **(Key)**	Z1.4 Estimated loss (*In cash or in volume)*	Z1.5 Species responsible for damage	Z1.6 Crop Species damaged	Z1.7 Actions taken 1. Yes 2. No.	Z1.8 Measures taken to prevent damage

Key for Z1.2 Type of damage
1. Damage to staple crops
2. Damage to cash crops
3. Damage to fruits/horticulture
4. Damage to assets/property
5. Damage to humans
6. Other (Specify)

Key for Z1.3 Change
1. Increased
2. Decreased
3. Remain the sam

THANK YOU VERY MUCH FOR YOUR ANSWERS!