ANALYSIS OF FARMERS' ADAPTATION TO CLIMATIC CHANGE IN KILIMANJARO REGION

BY

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ABSTRACT

This study aimed at assessing farmers' adaptation mechanisms to climate change in Kilimanjaro region. Specifically, attention was devoted to examine farmers' awareness and perception towards climate change; adaptation measures used and their influence on crop yield as well as factors which influence adoption of those strategies. The data were collected through household surveys and focused group discussions. A questionnaire was administered to a sample of 175 farming households in twelve villages from Moshi Rural, Hai and Rombo Districts. Data were analyzed using descriptive statistics, Cobb-Douglas production function and linear regressions. Results confirm that farmers are quite aware of climate change and adaptation options. Seasonal drought, temperature change and outbreak of diseases in plant and animals were the most perceived consequences of climate change. The adaptation strategies used included change of farm management practices and adoption off-farm employment. Timing of farm operations, water harvesting, mulching, change of crop varieties, irrigation and agro-forestry were the major farm-copping strategies. These strategies were observed to have positive and significant influence on maize and banana yield. Also the study found out that household assets; household size; education level; extension services; owned land size and access to irrigation are the major factors which influence adoption of adaptation strategies. Moreover, lack of capital and information on climate change as well as reliable weather forecast information were indicated to be the core constraints in adaptation. The relevant policy recommendation from these

results is that enhanced access to credit and information can significantly increase frames' adaptation. Government policies should support research and development on appropriate technologies to help farmers adapt to changes in climatic conditions.

DECLARATION

I, Adeline Ajuaye, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is the result of my original work and has neither been submitted nor being concurrently submitted for a degree award in any other university.

……………………… ………………………….

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……………………… ……………………

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(Supervisor)

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DEDICATION

This work is dedicated to my family, my late father Mr. Stanslaus Ajuaye and my late grandmother Mrs. Yohana Alphonce.

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LIST OF ABBREVIATIONS AND ACRONYMS

BoT	Bank of Tanzania
CCAA	Climate Change Adaption in Africa
CEEPA	Centre for Environmental Economics and Policy in Africa
CVL	Central Veterinary Laboratory
^oC	Degree Celsius
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
Freq.	Frequency
GDP	Gross Domestic Product
GPS	Global Positioning System
ICRAF	International Centre for Research in Agro-forestry
ICRISAT	International Crop Research Institute in Eastern and Southern Africa
IFPRI	International Food Policy Research Institute
IIASA	International Institute for APPLIED System Analysis
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel for Climate Change
Kg	Kilogram
Max.	Maximum
Min.	Minimum
Mm	Millimeters
Vil.	Village
Masl	Meters above sea level
N	Number of observation

NGOs	Non Government Organizations
OECD	Organization for Economic Co-operation and Development
SNAL	Sokoine National Agricultural Library
SUA	Sokoine University of Agriculture
TSH	Tanzania Shillings
UK	United Kingdom
USA	United States of America
USAID	United States Agency for International Development
UN	United Nations
UNFCCC	United Nations Framework convention on Climate Change
URT	United Republic of Tanzania
WB	World Bank

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Climate change is widely agreed to be already a reality, and its adverse impacts on the vulnerability of poor communities are superimposed on existing vulnerabilities (FAO, 2007). Recent evidence and predictions show that climate changes are accelerating and will result in changes to the characteristics of climate risks in terms of frequency, magnitude, timing, duration, and distribution over space, sectors, and households. As climate risks intensify, socioeconomic factors such as economic growth, demographics nutrition and health status are changing human exposure and sensitivity to these risks (Heltberg *et al.,* 2008).

The impacts of climate change are already being experienced in almost every sector of the economy particularly agriculture. The sector has been the major contributor in the economy of many developing countries especially in Africa. The agricultural outputs, as well as the livelihoods of people who depend on it, are particularly vulnerable to climate change (Kurukulasuriya and Rosenthal, 2003). Africa has a wide range of climates that range from the hyper-arid to the very humid. Her vulnerability to climate change and variability is generally well acknowledged and it largely depends on its current and future adaptive capacities. According to Nkomo *et al*. (2006), many African countries including Tanzania are more vulnerable to climate change impacts and their adaptive capacity is low due to their weak economies.

1.2 Definitions of Major Concepts in Climate Change

1.2.1 Climatic change and variability

Climate change can be defined as a systematic change in the key dimensions of climate including average temperature, wind and rainfall patterns over a long period of time (Wikipedia, 2008). It refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer) (IPCC, 2002). Climate change may be due to natural changes or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (Paavola, 2004; IPCC, 2007; Wikipedia, 2008). Climate variability on the other hand refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. Examples of climate variability include extended droughts, floods, and conditions that result from periodic El Niño and La Niña events (USAID, 2007). Climate change therefore, involves changes in the variability or average state of atmosphere over durations ranging from decades to millions of years. These changes are caused by dynamic processes on Earth, external forces including variation in sunlight intensity and more recent by human activities.

1.2.2 Vulnerability to climate change

Vulnerability to climate change is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change (IPCC, 2001). An individual or household is vulnerable to risk(s) associated with climate change if these risk(s) will result in a loss of well-being that pushes the individual or household below a benchmark or threshold level of well-being. Vulnerability is a function of the risks, exposure and sensitivity to risks and adaptive capacity (IPCC, 2001; Heltberg *et al*., 2008).

1.2.3 Adaptive capacity

Adaptive capacity is the ability of the system to adjust to climatic change (including climatic variability (and extremes), to moderate potential changes, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007). Adaptive capacity to climate change refers to both the ability inherent in the coping range and the ability to move or expand the coping range with new or modified adaptations (Smit and Pilifosova, 2001). Adaptation depends greatly on the adaptive capacity or adaptability of an affected system, region, or community to cope with the impacts and risks of climate change. The adaptive capacity of communities is determined by their socioeconomic characteristics. According to IFPRI (2007), access to credit and extension, awareness of climate change as well as access to market information (input and output markets) are some of the important determinants of farm-level adaptation. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Smit and Pilifosova, 2001).

1.2.4 Resilience

Ability by households to resist the potential negative impacts of risky events and the extent to which households can recover from negative impacts of risky events (Heltberg *et al*., 2008). It is the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Resilience may be particularly important in the context of climate change since it emphasizes the ability to build up resilience in order to cope with future events. Climate change may increase the frequency and intensity of natural climatic events that trigger disaster (Glantz, 1992). This means that in order to cope with more extreme events associated with climate change, building resilience is particularly important. This is because the focus of resilience is on more than just coping with current situation. It is about actually building adaptive capacity to help getting through unforeseen future events with no long-term adverse effects (Meena and Sharif, 2008).

1.3 Climate Change in Tanzania

Tanzania just like any other part of the world is impacted by climate change. She regularly suffers from various climate-related hazards, including droughts that have substantial effects on economic performance (OECD, 2003). Increase in the frequency of droughts and floods are projected to affect local production negatively especially in the subsistence sector. This is due to the fact that the country is not resilient to these impacts due to poor economies as pointed out by Adosi (2007). The continuing impact of climatic change is therefore, expected to grow in the coming century as a result of her law capacity to adapt.

1.4 Climate Change in Kilimanjaro

The Kilimanjaro region of Northern Tanzania has experienced significant changes in climate especially in temperature and rainfall variability in recent decades. The most easily recognizable evidence for a steady change in regional climatic conditions on Mount Kilimanjaro, directly influencing landscape characteristics; are the vanishing glaciers (OECD, 2003). Projections show that the majority of the glaciers on Mount Kilimanjaro could vanish in the next 15 years if the recession of the icecap continues (Nkomo *et al*., 2007, Thompson *et al*., 2007). The region is currently suffering from weather problem due to variability in the elements of weather particularly rainfall and temperature (Meena na Shariff, 2008).

1.4.1 Rainfall

The amount of rainfall in Kilimanjaro region shows considerable inter-annual variability, which may have a considerable effect on farming activities by increasing the risk of poor harvests. According to Kilimanjaro Meteorological Office (2007), the rainfall pattern has been varying from year to year with a general declining trend from 1974 to 2004 (Fig. 1). The decrease in the amount of rainfall proves that climate has changed therefore; creating awareness of adaptation measures especially in agriculture which is the most affected sector of the regional economy.

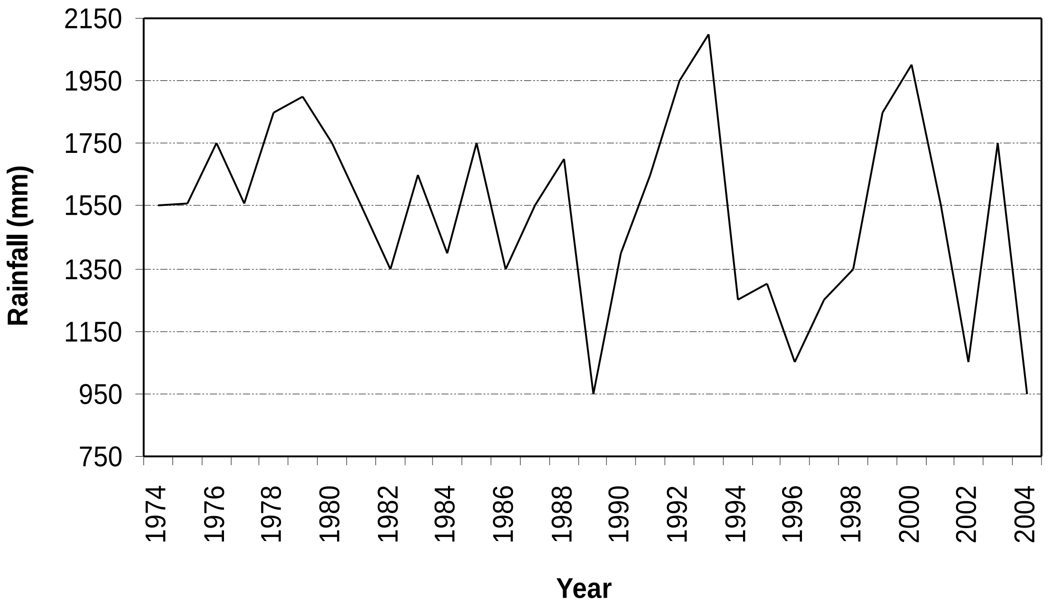

Figure 1: Annual rainfall in Kilimanjaro Region

Source: Kilimanjaro Meteorological Office (2007)

1.4.2 Temperature

Being an important element of weather, temperature in Kilimanjaro has also shown inter-annual variability with significant increase in the past 40 years (Fig. 2). Its variability directly affects amount of rainfall in the region and therefore limit agriculture production as well as livelihoods of subsistence farmers which depends largely on climate particularly rainfall and temperature.

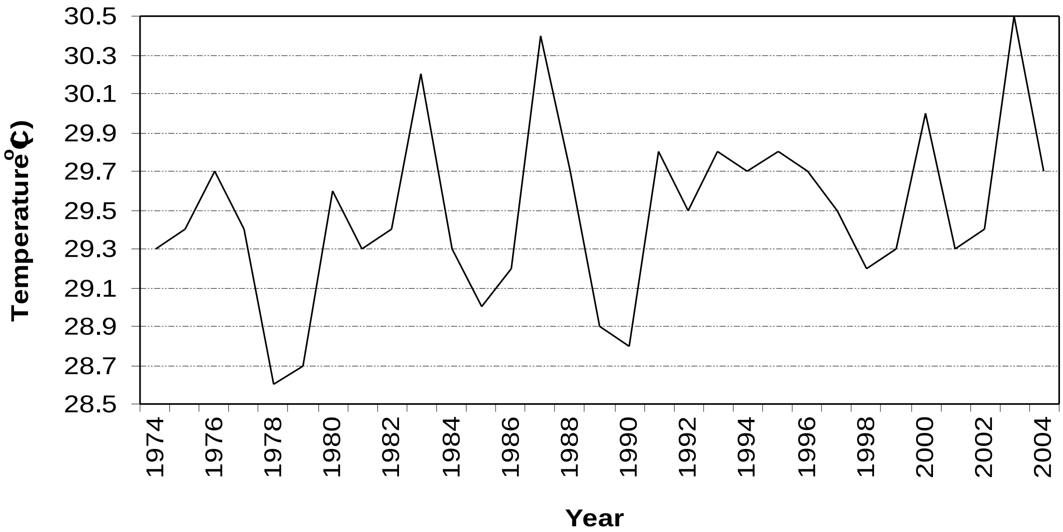

Figure 2: Mean yearly temperature in Kilimanjaro Region.

Source: Kilimanjaro Meteorological Office (2007)

1.5 Climate Change and Agriculture

Agriculture is inherently sensitive to climate conditions, and is among the most vulnerable sectors to the risks and impacts of global climate change (Parry and Carter, 1989; Reilly 1995). Climate change is expected to result in long-term water and other resource shortages, worsening soil conditions, drought and desertification, disease and pest outbreaks on crops and livestock. Vulnerable areas are expected to experience losses in agricultural productivity, primarily due to reductions in crop yields (Rosenzweig *et al.,* 2002). Increasing use of marginal land for agriculture (especially among smallholder farms) is also anticipated as the availability and productivity potential of land begin to decline. The impacts of climate variability and change on the agricultural sector are projected to steadily manifest directly from changes in land and water regimes. Changes in the frequency and intensity of droughts, flooding, and storm damage are expected.

In Tanzania agriculture is the leading sector of the economy accounting for 45 percent of GDP and about 60 percent of export earnings. It is the source of food and raw materials for industries. It also provides livelihoods to 82 percent of the population (URT, 2005). However, the major contribution of agricultural output in Tanzania particularly food crops is derived from small holder farming, where farm production system is mainly traditional and productivity is low (Senkondo, 2000). Being the backbone of the economy, agriculture production continues to depend mainly on rainfall leading to declining output due to variability and unreliability in rainfall.

Adaptation to climate change in agriculture is therefore important for impact and vulnerability assessment and for the development of climate change policy which will help to improve agricultural productivity. Due to continuing change in climatic conditions, small-holder farmers adapt to these changes using several adaptation strategies in order to survive. This study focused on those strategies in order to bring an understanding of their ability to adapt to climate change so as to recommend measures that will improve their adaptive capacity.

1.6 Problem Statement and Justification

Tanzania economy is likely to be more vulnerable to climate change adverse impact due to its dependency on climate change sensitive activity (agriculture). According to BoT (2008), the contribution of agriculture to the GDP has been decreasing due to seasonal droughts in some regions. This is due to the fact that agricultural practices in Tanzania mainly depend on the seasonal rainfall which is significantly varying from season to season. The performance of the Agriculture sector, which has historically been the backbone of Tanzania's economy, is also projected to drop as a result of negative effects of on going global climate change (Levira, 2009).

Adaptation has the potential to significantly contribute to reduction in negative impacts from changes in climatic condition as well as other changing socio-economic conditions. Adaptation options are therefore important to help communities to better face extreme associated with these changes (Adger *et al.*, 2003). Recently, the government has started to pay a special attention to climate change but according to Agrawala *et al.* (2003), the focus is on mitigation, rather than adaptation. Moreover, analysis of National Development Plans and Poverty Reduction Strategy Papers, Scrotal Strategies and Project Documents in climate-sensitive sectors particularly agriculture indicates that such documents generally pay limited attention to climate change adaptation. When climate change is mentioned, specific operational guidance on how to take it into account is generally lacking (OECD, 2006). Therefore, the findings of this study will provide useful information and recommendations to policy markers in setting guidelines for climate change adaptation process in agriculture.

1.7 Research Objectives

1.7.1 General objective

The main objective of this study was to bring understanding of farmers' awareness and perception to climate change and copping mechanisms in adapting to climatic change and variability in Kilimanjaro region.

1.7.2 Specific objectives

The specific objectives were:

(a) To identify the farmers' awareness and perception towards climate change and adaptation measures.

(b) To identify and examine the adaptation strategies used by farmers to cope with climate change and variability.

(c) To analyze the influence of adaptation strategies on crop yield.

(d) To describe the influence of socio-economic characteristics on the adoption of adaptation strategy.

1.7.3 Hypotheses

- The adaptation strategies used by farmers in Kilimanjaro region have no significant effect on agriculture output (crop yield).
- Household socio-economic characteristics have no influence on the adoption of adaptation strategy.

1.8 Limitations of the Study

The major limitation encountered was the duration of the study which was too short to have enough data for making a thorough analysis of climate change adaptation mechanisms in the study area. The duration of one year necessitated adoption of cross-sectional study which depended largely on the ability of respondent to recall. To deal with this problem, an interview schedule was divided into two parts and the questions were asked in two different cropping season. This provided chance of asking few and related questions at a time thus, improve ability of respondents to recall.

Another limitation was the unavailability of secondary data at different levels. The local weather stations and regional statistics department in Kilimanjaro had good data records for the region, but has no enough information to describe the climate and socio-economic condition at various levels particularly ward and village level. This limits the understanding of the actual climatic status in the surveyed villages due to the fact that the regional climatic condition is not uniform to all villages. Despite this limitation, the study managed to capture all relevant information through individuals, the Pangani River Water basin and non governmental organizations such as TIP. However, the study took advantage of Kilimanjaro Climate Livelihood Survey Project (KCLS): an on going joint project in the study area conducted by Ohio State University and Sokoine University of Agriculture to obtain other information particularly rainfall data at village level.

1.9 Organization of the Study

This thesis consists of five chapters. Chapter one provides an introductory part of the research by giving background information of the research, problem statement, significance of the study, and research objectives. Chapter two presents a review of literatures relevant to the study and chapter three describes the methodology employed in this study. The fourth Chapter presents the results and discussion of major findings of the study and chapter five presents general summary of the major findings, conclusion and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Impacts of Climate Change on Agriculture

Ongoing climate changes are predicted to accelerate during this century and one can assume so with the corresponding economic and social impacts. Many studies have been done on climate change impacts and it has been proven that the magnitude if those impacts is increasing decade after decade. The Intergovernmental Panel on Climate Change, IPCC (2007) predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperatures that will cause shifts in crop growing seasons. The Food and Agricultural Organization of the United Nations, FAO (2008) reported that by late this century, the aggregate global effects on agricultural productivity are expected to be negative, and developing countries are expected to suffer sooner and worse. The impact of a single climate, water or weather-related disaster can wipe out years of gains in economic development. Climate change will result in additional food insecurities, particularly for the resource poor in developing countries who cannot meet their food requirements through market access.

In understanding the impacts of climate change effect on environmental integrity and the well-being of local resident, Lange (2000) suggested integrated assessments on a regional to sub-regional scale (integrated regional impact studies). The study involves linking natural resources, climate change and economies. Such studies compare the course of future development of a region under two conditions: (a) by ignoring any change in climate and by projecting present developments of ecosystems and socioeconomic systems in a given region (base line scenario) and (b) by accounting for climate change and its impacts on environmental and socio-economic systems (global change scenario). The differences in the overall development, measured, e.g., by addressing agricultural productivity and the resulting price of food or by accounting for the effect of climate change on fish stock and the consequent shift in the fish markets, constitutes the overall impact of climate change for a given region. In 2006 Lange used this approach to assess the impact of climate change in Europe and reported that climate change has major impacts on snow cover, river discharge see level and terrestrial vegetation. If the affected ecosystem is unable to cope with the pace of the changes in particular plants or tree species; Changes in vegetation cover will have repercussions for ecosystem services, particularly for forestry and reindeer husbandry (Lange, 2007). Using the same approach in Africa, Tanzania in particular, it can be observed that climate change have major impacts on river volume, temperature and precipitation where significant changes have been noticed. These changes resulted into extreme events such as drought which directly affect agricultural productivity, livelihoods and country’s economy.

Most of climate change impacts studies have shown that African countries are more vulnerable to those impacts due to their low adaptive capacity. The review of impact analysis in Africa shows that climate change impacts are common from country to country within the region although they differ in magnitude. In the Analysis of Impacts of Climate Change in Africa, which involved several African countries including Tanzania, Nkomo *et al.* (2006) found out that climate change have resulted to low water supply coverage, increase in human disease incidences, decrease in agricultural productivity, increase food insecurity, lower energy production, environmental conflicts and migration. Heltberg *et al.* (2008) described those impacts in detail with more emphasis on livelihood, displacement and social conflicts. They pointed out that climate change events such as droughts, rising sea levels and more frequent flooding results into sharply declining productivity of agriculture, fisheries, and forestry: if this will continue households will to an increasing extent choose to abandon rural areas in search of alternative livelihoods in less-affected regions (often urban) and sectors (services and manufacturing). It is expected that migration will be the adaptation strategy for many households. Migration can be voluntary or forced, and domestic or international. Conflict could also result, especially if large-scale population movements take place in response to climate change. As vast populations crowd into already congested urban areas, unemployment, crime, and violence would rise. And competition over those resources that are less directly impacted by climate change could greatly increase, resulting in violent conflicts.

2.2 Farmers' Perceptions towards Climate Change

Perception is the process of attaining awareness or understanding of sensory information. What one perceives is a result of interplays between past experiences and one's culture (Wikipedia, 2008). Framers perception has become an important aspect in agricultural researches. The literature on adaptations also makes it clear that perception is a necessary prerequisite for adaptation (CEEPA, 2006). It is believed that farmers perception influence their farming decisions such as cropping system, management strategies and marketing decisions. Therefore, many researchers involve farmers' perception in the studies in agricultural production, risks, impacts, and adaptation to risks and impact. Senkondo (2000) pointed out that risk perception influence farmers objectives and ultimate choice cropping system; in addition to that Mutabazi (2007) reported that the perception and attitude to risks shape the way farmers react to risks., the course of actions taken by an individual decision-maker depends on their perceptions and attitude to risk with regard to expected outcomes of given sources of risks. Neondo (2007) believed that the farmers' misperception affects crop productivity, he pointed out that low crop yields in Africa is not due to climate change but rather farmers failing to exploit opportunities in wetter years: this was supported by Cooper (2007) when he said "Farmers tend to over-estimate the negative impact of variable climates". He argued that although farming practices minimize economic damage during dry years, they fail to exploit opportunities during better years.

In studying adaptation to climate change in agriculture understanding farmers' perception is indeed important. Gbetibouo (2009) revealed that farmers' ability to perceive climate change is a key precondition for their choice to adapt. According to Maddison (2006) and Deressa (2008) adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them. This is to say adaptation involves a two- stage process: first perceiving change and then deciding whether or not to adapt by taking a particular measure.

The analysis of farmers' perception towards climatic change involves several techniques but many scientists use descriptive statistics. This includes exploring farmers awareness and knowledge on climate change variables mainly temperature and rainfall; the changes which commonly noticed by many farmers represents their perception towards climate change. This method was use by Gbetibouo (2009), Deressa *et al*. (2009), Deressa (2008) Nhemachena and Hassan (2007) and Slegers (2008) in climatic change studies in Africa which involved farmers' perception. It was generally observed that farmer's perception depends on their environment and have great influence on their farming decisions. For instance farmers in Tanzania use drought to refer to a year with decreased crop production due drought as a proof to climate change to deficient rainfall or an imbalance between rainfall and sunshine (Slegers, 2008).

2.3 Adaptation to Climatic Change

Having proven that the impacts of climate change are serious and may be more severe in the coming decades; researchers are now involving mitigation and adaptation in climate change studies. Adaptation is considered to be the permanent solution to climate change impacts and trough adaptation studies several adaptation strategies have been developed. Adaptation to climate changes refers to adjustments or interventions which take place in order to manage loses or take advantage of the opportunities presented by the changing climate (IPCC, 2001). It is the process of improving the society's ability to cope with changes in the climatic conditions across time scale from short term (e.g. seasonal to annual) to long term (decade to centuries) (Thiaw, 2007). If appropriate, adaptation can reduce negative impacts and even create benefits from new opportunities provided by changing climate conditions.

Literatures suggest that, for an adaptation to be sustainable it should be planned. According to Lange (2007) various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, as well as autonomous (i.e., intrinsic to the system under consideration) and planned adaptation (i.e., adaptation measures initiated through human activities). Planned adaptation often is interpreted as the result of a deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed and that action is required to minimize losses or benefit from opportunities (Pittock and Jones, 2000; Smit and Pilifosova, 2001). Autonomous adaptations are widely interpreted as initiatives by private actors rather than by governments, usually triggered by market or welfare changes induced by actual or anticipated climate change (Leary, 1999). Smith et al. (1996) describe autonomous adaptations as those that occur “naturally”, without interventions by public agencies, whereas planned adaptations are called “intervention strategies”.

The research results revealed that planned or anticipatory adaptation has the potential to reduce vulnerability and realize opportunities associated with climate change, regardless of autonomous adaptation. This is due to the fact that a planned action involves several sectors and processes thus, more likely to be sustainable and bring desirable results (Smith and Lenhart, 1996; Smit and Skinner, 2002). Implementation of adaptation policies, programs, and measures usually will have immediate benefits, as well as future benefits. Adaptation measures are likely to be implemented only if they are consistent with or integrated with decisions or programs that address climatic stresses. The costs of adaptation often are marginal to other management or development costs. In the study of social and economic copping capacity Yone and Tol (2002) reported that: in managed systems, wealth, availability of technology, appropriate decision-making capabilities, human capital, social capital, risk spreading (e.g., insurance), ability to manage information, and the perceived attribution of the source of risk all contribute significantly to adaptive capacity and the capability of such systems to actively and adequately respond to changing environmental stress.

2.4 Adaptation to Climate Change in Agriculture

Agriculture is among the most vulnerable sectors to the risks and impacts of global climate change (Parry and Carter, 1994; Reilly, 1995). Adaptation is certainly an important component of any policy response to climate change in this sector.

Studies show that without adaptation, climate change is generally problematic for agricultural production and for agricultural economies and communities; but with adaptation, vulnerability can be reduced and there are numerous opportunities to be realized (Smit and Skinner, 2002). While adaptation is often considered as a government policy response in agriculture, it also involves decision-making by agri-business and producers at the farm-level (Adger and Kelly, 1999).

Adaptations in agriculture vary with respect to the climatic stimuli to which adjustments are made (i.e. various attributes of climate change, including variability and extreme events) and according to the differing farm types and locations, and the economic, political and institutional circumstances in which the climatic stimuli are experienced and management decisions are made. Agriculture adaptation involve two types of the production systems: the first is increased diversification that involves engage in production activities that are drought tolerant and or resistant to temperature stresses as well as activities that make efficient use and take full advantage of the prevailing water and temperature conditions among other factors. Crop diversification can serve as insurance against rainfall variability as different crops affected differently by climate event, (Adger *et al.,* 2003). The second strategy focuses on crop management practices geared ensuring that critical crop growth strategies do not coincide with very harsh climatic conditions such as mid-season droughts; crop management practices that can be used include modifying the length of the growing period and changing planting and harvesting dates.

2.5 Adaptation Strategies in Agriculture

Understanding adaptation options adopted by farmers in specific area help in analyzing their adaptive capacity. Smit and Skinner (2002) defined adaptation options are the activities that represent changes in some attribute of the agricultural system (the agriculture sector or farms within it) directly related to reducing vulnerability to climate change. Agricultural adaptation options are grouped according to four main categories that are not mutually exclusive: (a) technological developments, (b) government programs and insurance, (c) farm production practices, and (d) farm financial management. The typology is based on the scale at which adaptations are undertaken and at which the stakeholders are involved. The dissemination of information (on climate change, possible impacts and vulnerabilities, potential adaptation options, etc.) is something governments can do to promote adaptations, and it may be a necessary precursor to adoption of adaptation measures.

The major adaptation options in the agriculture sector include crop diversification, mixed crop-livestock farming systems, using different crop varieties, change planting and harvesting dates and mixing less productive, drought- varieties and high yield water-sensitive crops(Bradshaw *et al*., 2004). In Tanzania, the country is adapting to climatic change in agriculture by: change of crop variety (drought resistance/water logging), irrigation, institute proper land use, Shift to higher ground to avoid floods, abandon most hit areas, Rain water harvesting, water conservation, reservoir construction, planting trees, improve seasonal forecasts, reduce animal numbers, set aside grazing areas, and introduce zero grazing reversed by a forestation on the damaged watershed (Adosi, 2007).

Most of recent climatic change impact studies in agriculture incorporated the role of adaptation options in sustain agricultural productivity. They include Nhemchena and Hassan (2007), Smit and Skinner (2002), Deressa *et al*. (2009), Meena and Shariff (2008), Naylor *et al*. (2006), Gbetibouo (2009) and Apata *et al*. (2009). These studies showed the role of adaptation measures in increasing agricultural production, food security and well being of the people.

Nhemchena and Hassan (2007; 2008) showed that adaptation has a significant role of sustain high productivity levels under changing climatic conditions. Supporting farmers in increasing the adaptation measures trough providing the necessary resources such as credit will help in sustain agricultural productivity. They pointed out that better access to markets, extension and credit services, technology and farm assets (labor, land and capital) are critical for helping African farmers adapt to climate change (Nhemchena and Hassan, 2008).

Smit and Skinner (2002) found out that most adaptation options are modifications to on-going farm practices and public policy decision making processes with respect to a suite of changing climatic (including variability and extremes) and non-climatic conditions (political, economic and social). For progress on implementing adaptations to climate change in agriculture there is a need to better understand the relationship between potential adaptation options and existing farm-level and government decision-making processes and risk management frameworks.

Deressa *et al*. (2009) identified several adaptation measures and their role in agricultural productivity. They focused on factors which determine farmers choice of adaptation measures and founded out that the level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agro ecological settings, and temperature all influence farmers' choices.

Apata *et al*. (2009) also studied adaptation mechanism among food crop farmers and revealed that that capital, land and labor serve as important factors for coping with adaptation. The choice of the suitable adaptation measure depends on factor endowments (i.e. family size, land area and capital resources). The more experienced farmers are, the more likely to adapt.

Gbetibouo (2009) also studied farmers adaptation options in agriculture and found reported out that household size, farming experience, wealth, access to credit, access to water, tenure rights, off-farm activities, and access to extension are the main factors that enhance adaptive capacity. Thus, the government should design policies aimed at improving these factors. Meena and Shariff (2008) studied climate impacts and adaptation in Kilimanjaro Tanzania and reported that gender inequality and poor infrastructure (especially water infrastructures) are the major barriers to adaptation in the region.

According to Gbetibouo (2009) and Deressa *et al*. (2009), the main barriers to adaptation include lack of information on adaptation methods and financial constraints. To enhance adaptation, Government policies and investment strategies should therefore, support education, markets, credit and information about adaptation to climate change, including technological and institutional methods, particularly for poor farmers. However there are few researches on effect of adaptation options on crop yield. Many researches concentrate on perception and determinant of adaptation options but put less attention on influence of those strategies on agricultural output. This study therefore, tried to include that component in understanding farmers' adaptation mechanism in Kilimanjaro region.

2.6 Production Function

Production function explains the technical relationship between input and output. The approach was used in the study in explaining the influence of adaptation strategies on crop yield. According to Hawassi (1997), a choice of production function is based on relevant variables to be included, algebraic form of the function, the logic implied by the function and method of data collected to be employed. In agricultural production, most researchers use Cobb-Douglass production function partly due to its convenience in estimation using the ordinary least square method and its simplicity in interpretation of the coefficients. Another advantage of using Cobb-Douglas production function is that it give immediate measure of response to factor input and also can be used to estimate return to scale. Linear regression is not used because it is not common in agriculture because it assumes the constant return to each input at all levels other input held constant (Mwenda, 1993).

The usual formulation of Cobb-Douglas production function can be specified as follows:

$Y = AL^{\alpha}K^{\beta}$ …………………………………………………………… *(i)*

Where;

A, α and β are constants,

L and K are labour and capital respectively and

Y is output.

Capital can be interchanged with labour without affecting output. Cobb and Douglas also suggested that the share of labour and capital within an economy are relatively constant over time. Analysis of Cobb-Douglas production function is used to examine the influence of factor inputs to production. When we estimated the Cobb-Douglas production function, and find that $\alpha + \beta = 1$, it implies constant returns to scale; and when $\alpha + \beta < 1$, it implies decreasing returns to scale; and when $\alpha + \beta > 1$, it implies increasing returns to scale. In the above equation the relationship between output and inputs is nonlinear. In order to apply OLS regression to estimate parameters the equation will be log-transformed to become linear as shown in equation (ii).

$LogY_i = LogA + \alpha LogL_i + \beta LogK_i + \varepsilon$ …………………………………… *(ii)*

Where:

Y_i is total output of the i^{th} farms,

A is the constant term of the regression,

α and β are elasticities of production with respect to the i^{th} input,

L_i - i^{th} input used in the production process,

K_i - i^{th} input used in the production process and

ε is the error term

2.7 Conceptual Framework for the Study

The conceptual framework (Fig. 3) shows farmers' adaptation process. Adaptation to climate changed will be needed only if there are undesirable impacts experienced or predicted climate change risks. The consequences of changing climatic conditions will be determined to a considerable extent by the nature of the economic, social and technological domain in which those impacts occur. For example, the extent to which the principles of sustainable development are implemented within the policy framework will affect the choice of adaptation options open to the decision-maker. In the case of these socio-economic scenarios, a society with a vibrant economy may be resilient to climate change because resources will be available to respond to the impacts (Kerry and MacLeod, 2001).

Therefore, the adaptation process start with first farmers being aware of climate change impacts (Madison, 2006) such as drought, floods and diseases. The possible causes of these impacts are changes in precipitation and temperature patters thus perception on climate change. Government policies and institutions; private firms and Non Governmental Organizations as well as socio-economic, geographical ant technological factors together shape farmers perception towards climate change. Farmers' perceptions along with these factors lead to choice or formulation of copping strategies that will help them overcome the impacts and build resilience to climate change. Depending on farmers' knowledge and experience which are important elements of perception; selected strategies may be either changing of their current practices or shift to other income generating activities (Kerry and

MacLeod, 2001) rather than agriculture. It is the government policies, institutional, socio-economic, geographical and technological factors which will determine adoption of those strategies. This is to say a farmer will adopt only practices which are within the existing technologies, applicable to their environment and affordable to them; and which are supported by government policies.

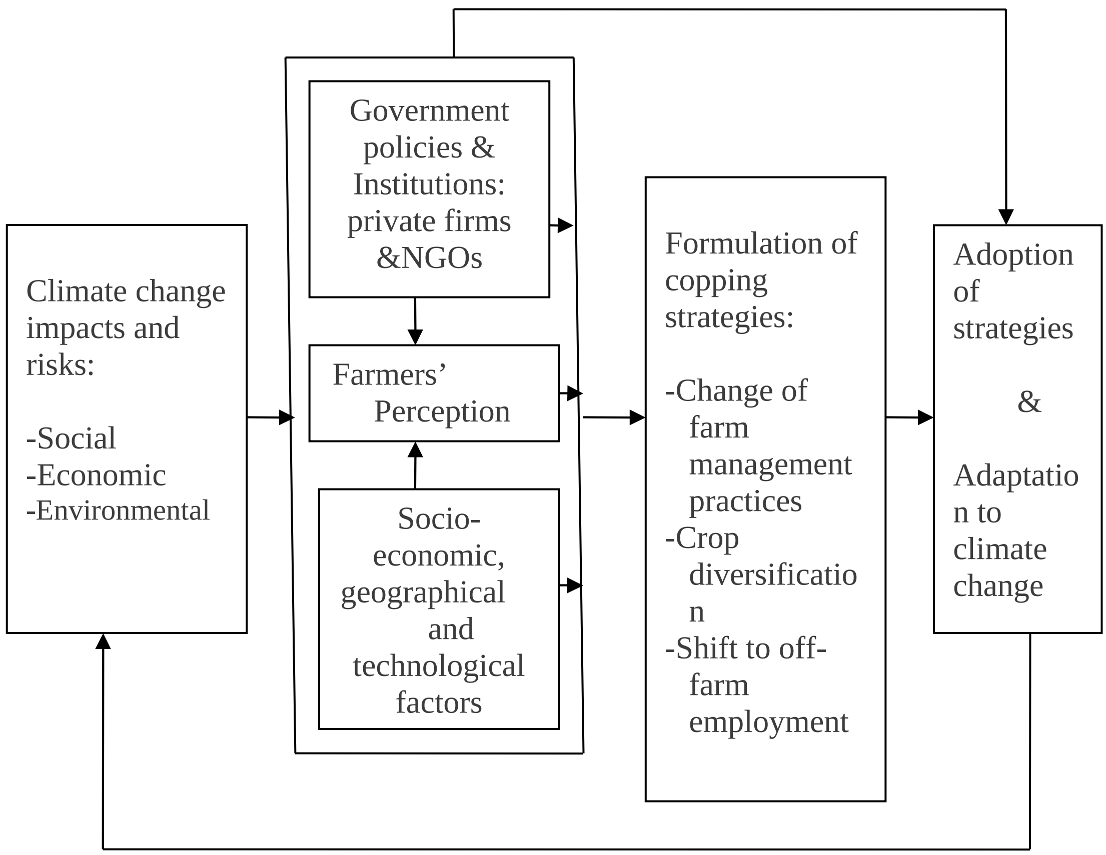

Figure 3: Conceptual framework

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

The study involved two round household surveys where cross-sectional data within the two cropping seasons of the region were collected. The first round was done during the short rain season, “Vuli” (from September to November, 2008) and the second survey was conducted in the main rain season, “Masika” (from February to March, 2009). The two round surveys were adopted in order to observe the climate situation of the major cropping seasons in the region. Direct observations, focused group discussions and household surveys were also done.

3.2 Description of the Study Area

Kilimanjaro is one of the 21 regions of Tanzania Mainland; it is located in the North-Eastern part of Tanzania Mainland. It lies south of the Equator between latitudes $2^{0}\ 25^{1}$ and $4^{0}\ 15^{1}$. Longitudinally the region is between $36^{0}\ 25^{1}\ 30^{11}$ and $38_{0}\ 10^{1}\ 45^{1}$ East of Greenwich. The region has a common border with Kenya in the north, to the southeast it shares border with Tanga region; to the south and west the region borders with Arusha region. The Kilimanjaro Region is administratively divided into seven districts: Rombo, Hai, Siha, Moshi Rural, Moshi Urban, Mwanga, and Same (URT, 1998; 2002).

Rombo district, one of the study areas, is located in the East of Kilimanjaro region. The other two study areas include Moshi Rural and Hai districts. Moshi Rural has a population density that is slightly higher at 294 people per square kilometer (URT, 2002). The demographics of the study area are summarizes Table 1.

Table 1: Kilimanjaro Region (surveyed districts) demographics

District	Area	Administrative units			Population size	Annual growth rate	Average h'hold size	No. of h'holds
		div	ward	Vill.				
Hai	2,112	4	14	82	200,136	1.3	5.4	33,899
Moshi	1,713	4	31	165	504,287	1,9	5.4	62,890
Rombo	1,442	5	20	62	417,602	2.4	5.7	35,078

Source: URT, 2002

3.2.1 Location of the study area

As mentioned above, the survey involved three districts which are located in the Northern side of the region. Fig. 3 shows the location of study area.

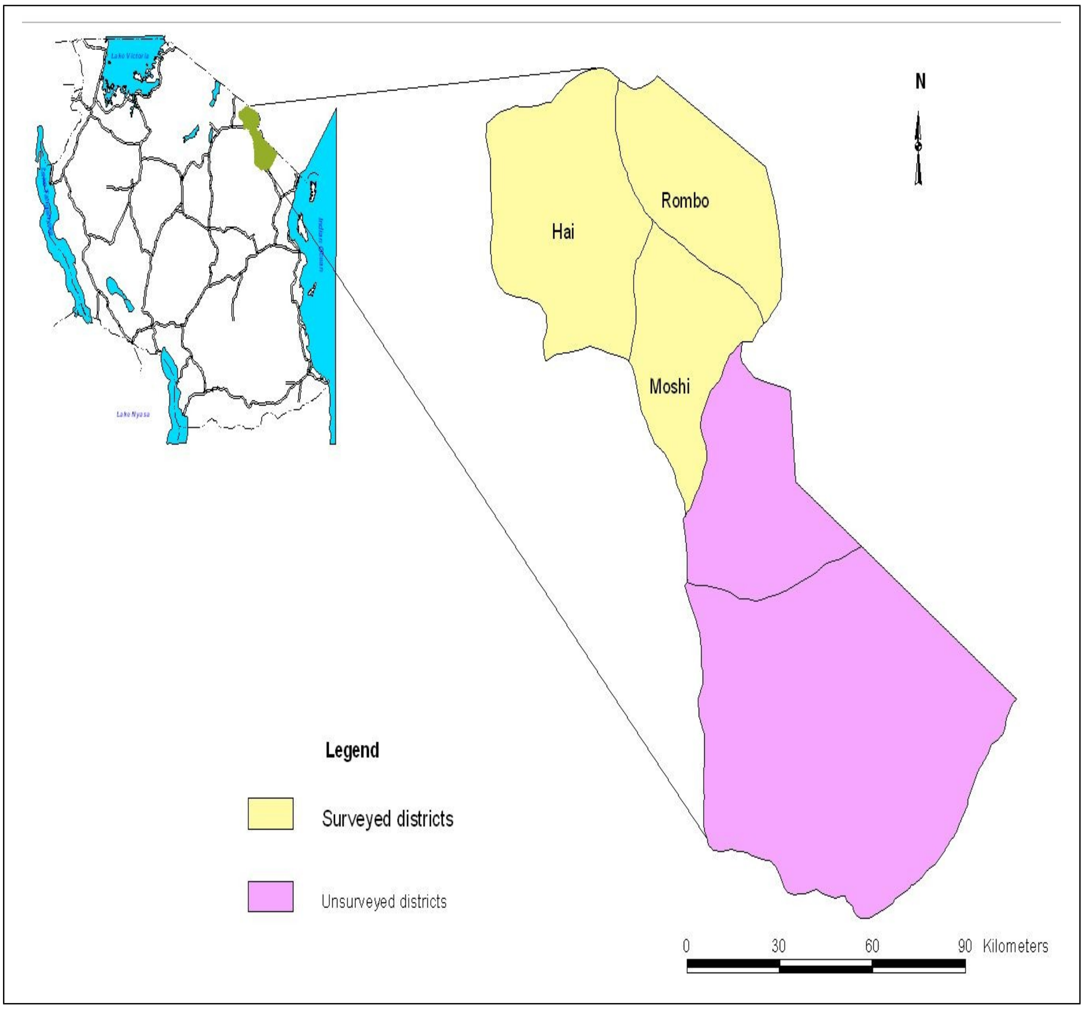

Figure 4: Map of Kilimanjaro region showing the study area

3.2.2 Climate in Kilimanjaro

The climate of the region is not uniform; it varies from humid to semi-arid areas and this makes the region suitable for the study as it can represent the other parts of the country. The seasonal rainfall distribution in particular greatly influences agricultural practices. In the Kilimanjaro region the year can be divided into four periods with respect to the amount of rainfall: There are two rainy seasons - a major one in April - May and a minor one in September - November, and two dry seasons, a major one in December - January and a minor one in July -August. There is marked variation in the amount of rainfall according to altitude and the direction of the slope in the mountainous areas. The mean annual rainfall varies from 500 mm in the lowlands to over 2,000 mm in the mountainous areas (over 1,600 meters above sea level). Temperatures are closely related to altitude; during the rains, extra cloud cover and evaporative cooling tend to reduce maximum temperatures. Cloud cover also tends to raise minimum temperatures. The hot season starts from October - March with high humidity; temperatures going up as far as 40^0C. in the lowlands. In the mountainous areas temperature ranges from about 15^0 - 30^0C. The soils of the region vary; there are alluvial soils which are potential agriculturally through irrigation farming due to unreliability of rainfall in those areas (URT, 1998; 2002).

3.2.3 Regional economy

The greater part of the population (75%) in the region lives in the rural areas heavily dependent on agriculture and livestock keeping for their livelihood (URT, 2002). Main cash crops in the region include coffee which is grown in plantations as well as smallholders. Livestock is ranked as a second vital economic activity in the region. Modern dairy farming is practiced in the highlands and intermediate zones.

Crop production and agricultural expansion in the region is likely to face physical limitations (Arable land is only 48.7% of the total land areas). In the highland areas for instance, a family owns an average of 0.5 of a hectare while in lowland area a family owns 1.5 hectares. The scramble for land and scarcity of land in Kilimanjaro region is thus being experienced day after day. In addition, environmental degradation is increasingly taking place due to poor farm management system such as non-use of soil erosion control methods (URT, 1998; 2002). In this regard, the region needs to intensify land management practices in order to improve land productivity per unit area Generally the experience of land limitation is the factor which mostly contributes to the movement of people out of the region.

3.2.4 Agro-economic/ecological zones

According to URT (1998), the Kilimanjaro region comprised of four ecological zones based on altitude, soils and climate. The upper areas of Mt. Kilimanjaro that lie above the 2,700 meters fall within Kilimanjaro National Park. Towards the lower end of the park there is a forest belt between 1800 and 3100 m.a.sl. Below this is the study area which covers three distinct agro-ecological zones that are the inhabited ecological zones. These are: highland zone (where the “Chagga” home gardens, or “Kihamba”, are located), Intermediate (midlands) and lowlands (“Tambarare”).

3.2.4.1 Highlands zone, E_1

The highlands zone lies between 1,000 and 1,800 meters above sea level. The annual average rainfall falls between 1250 and 2000mm while temperatures range between 15^{0} Centigrade and 20^{0} Centigrade. The Highland zone has good and very fertile soil following the remains of volcanic rocks rich in magnesium and calcium. The crops grown in this zone include coffee, bananas, fruits and Irish potatoes. The main problems in the Highland zone are population pressure exerted on a small land area giving rise to a population density of 650 people per square kilometers. Also there is soil erosion caused by the tendency of the people to cut-down trees, in search of timber and sometimes for acquiring more land for agricultural activities, or simply for settlement (URT, 1998).

3.2.4.2 Intermediate zone, E_2

It lies between 900 and 1100 meters above sea level and receives enough annual rainfall ranging between 800 and 1250 mm. It has a moderate soil fertility which is good for coffee plantations, bananas, maize, and beans and suitable for dairy cattle, goats, pigs, rabbits and poultry farming. Like in the Highlands zone, it has a high population density of 250 persons per sq kilometer leading to land shortage and soil erosion.

3.2.4.3 Lowland plains zone, E_3

This zone lies below 900 meters above sea level and has an average annual rainfall of between 700 and 900 mm, while temperatures are above 30^{0} Centigrade. Common crops grown in this zone include maize, cotton, rice, sorghum, cassava and pigeon peas. Domestic animals that thrive well in the area are beef cattle, goats and sheep. It is from this zone where the best hay for cattle is found, during the dry season livestock keepers from the highland and intermediate zones obtain or purchase hay from this zone. Population density is low with less than 50 people per sq.km. Low density is due to unfavorable climate, explained by devastating effects of frequent floods during long rains and the dry nature of the zone. It is in this zone that irrigation farming is getting popular through efficient utilization of river water from the highlands (URT, 1998; 2002). The major differences between these zones are summarizes in Table 2.

Table 2: The ecological zones of the Study Area

Area	**Altitude (m)**	**Main crop**	**Rainfall (mm)**
Highlands/ Kihamba (E1)	1200-1800	Coffee/bananas	1200-2000
Intermediate/Midlands(E2)	900-1200	Maize/beans	1000-1200
Lowlands/Tambarare(E3)	<900	Maize and livestock	400-900

Sources: URT, 2002

The study villages were selected from eight Wards from the three agro-ecological zones as shown in Fig. 5. They include Machame Mashariki, Marangu Mashariki, Mamsera Juu and Nanjari/Reha for highland zones; the midland zone was represented by Mbokomu, Shimbi Kati and Ikuini while Machame Kusini, Kilema Kusini and Msaranga represented the lowlands. The identification of village agro-ecological zone was done through direct observation on vegetation and physical features and GPS readings.

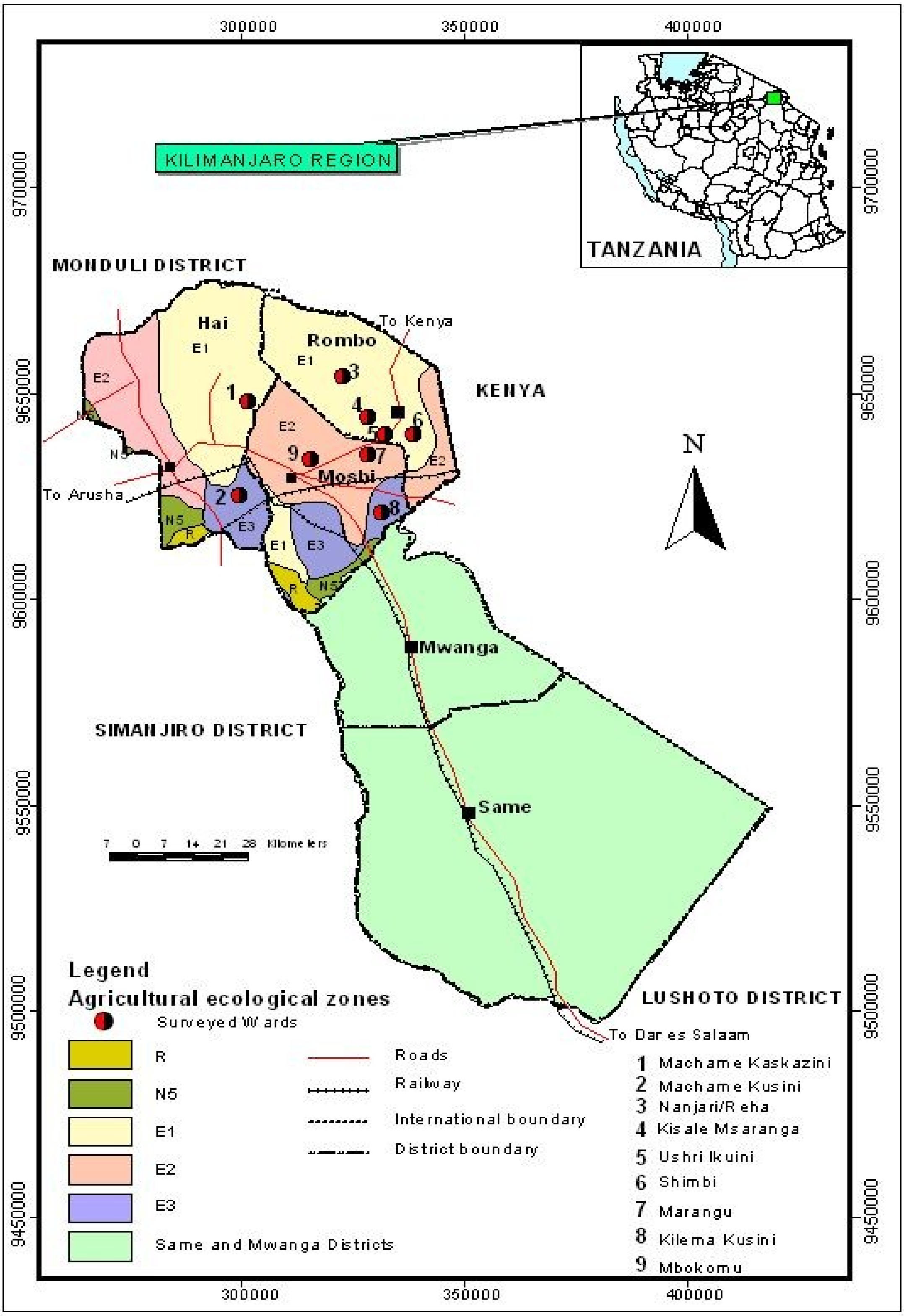

Figure 5: Map of Kilimanjaro region showing Agro ecological zones of the Study area

3.3 Sample Size and Sampling Procedure

Multistage sampling procedure was used; the three named districts in the Northern part of the region which have access to the Mount Kilimanjaro were selected. A total of 12 villages were selected; four from Moshi Rural, three from Hai and five from Rombo district and a sample of 15 households was selected from each village. The selection of villages based on altitude and other physical features such as irrigation channels. The number of villages in each district was determined by the heterogeneity of agro-economic activities following a transit around the mountain.

3.4 Data Collection

3.4.1 Primary data

Primary data were collected through direct observations, focused group discussions with key informants (district and village leaders); and face to face interviews using household survey questionnaires, personal observations, and discussion checklists. The rainfall information was obtained through the rainfall gauge records installed in surveyed villages by the Kilimanjaro Livelihood and Climate Change Project[1].

3.4.2 Secondary data

Secondary data were collected from various documents such as books, online journals, policy documents and official reports available. These were obtained by visiting both published and unpublished relevant documents from Sokoine National Agricultural Library in Morogoro, World Wide Web sites, NGOs, local weather stations, Regional and districts agriculture and statistics departments offices. Also

1 An on going project being carried around Mount Kilimanjaro with Ohio State University in collaboration with Sokoine University of Agriculture

information was obtained from Pangani River Water Basin office and Traditional Irrigation Program (TIP) in Moshi, Kilimanjaro. The secondary data collected during the survey involved information on weather mainly rainfall and temperature; water sources and irrigation systems, agriculture and socio-economic information.

3.5 Methods of Analysis

Different methods of data analysis were employed in this study depending on the specific objectives and hypothesis which tested. The data collected were summarized, coded, and analyzed by using stata and Statistical Packages for Social Science (SPSS) computer programs. The first and second objectives were answered using descriptive statistics. The empirical models (Cobb-Douglas production function and linear regressions) were used to test first and second hypothesis which answered the third and fourth objectives.

3.5.1 Descriptive statistics

Both descriptive and qualitative analyses mainly frequency distribution and percentages were employed in analyzing the demographic, socio-economic characteristics as well as farmers' awareness and perception towards climate change and adaptation measures.

3.5.2 Production function

The Cobb-Douglas production function analysis was used in assessing the influence of adaptation strategies in crop yields for maize and banana. The adaptation strategies included in model the were water harvesting, timing of farm operations, bunds, access to irrigation mulching and change of small scale irrigation. Other variables involved in the analysis were age of respondent, education level, extension services, land size, family labour days; use of hired labour, pesticides and fertilizers. The variables: water harvesting, timing of farm operations, bunds, mulching, change of small scale irrigation use of hired labour, fertilizers and pesticides were included as dummy variables. This means that they were not transformed into logarithmic form during analysis.

The regression coefficients (βs) of each independent variable represent elasticity of production with respect to each factor or strategy used. A positive coefficient indicates that adoption of strategy or increase in factor input increases level of yield while the negative coefficient indicates that the dependent variable lead to decrease in level of output.

Also the coefficient of determination (R^2) was used to measure the variations of dependent variable due to independent variables included in the model while F-values show statistical significance of the model. The main motivation of using logarithmic form for non dummy variables was that: estimates of elasticities can be directly obtained from the linearized equation and also to take care of heteroscedasticity problem.

Equation:

$$\text{Log } Y = \log \alpha + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6\ \beta_5\ \beta_7 D_1 \ldots\ldots + \beta_{13} D_7 + \varepsilon$$

Where;

Y = Quantity of Crop yield

α = Intercept

X_1= Age of respondent in years

X_2= Education level of respondent

X_3= Extension services (number of contacts made with an extension officer)

X_4= Family labor (number of hours spent on farm operation during the cropping season; from land preparation to harvesting

X_5= Land size (land area cultivated in acres)

X_6= Irrigation (number of irrigation done during the cropping season)

D_1 = Dummy variable aimed at capturing the effect of hired labor on crop production (1= if farmer used hired labor; D=0 if otherwise)

D_2= Dummy variable aimed at capturing the effect of fertilizer use on crop production (1= if farmer used fertilizer; D=0 if otherwise)

D_3 = Dummy variable aimed at capturing the effect of pesticides use on crop production (D=1 if farmer used pesticides; D=0 if otherwise)

D_4= Dummy variable aimed at capturing the effect of water harvesting practicing on crop production (D=1 if farmer practiced water harvesting; D=0 if otherwise)

D_5= Dummy variable aimed at capturing the effect of timing of farm operation on crop production (D=1 if farmer used bunds; D=0 if otherwise)

D_6 = Dummy variable aimed at capturing the effect of bund practicing on crop production

(D=1 if farmer used bunds; D=0 if otherwise)

D_7 = Dummy variable aimed at capturing the significance of irrigation channels on crop production with D=1 if farmer has access to irrigation channels and D=0 if otherwise

ε = Error term (Identically and independently distributed)

$\beta_{'s}$= Coefficient of independent variables(Xs and Ds)

3.5.3 Multiple linear regressions

The multiple linear regressions were used to analyze influence of socio-economic characteristics on adoption of risk management strategies which were considered as a means of adapting to climate change and variations. Crop diversification and off-farm activities were analyzed. The variables included in the model were access to irrigation, household assets rainfall variation, altitude and owned land size. The coefficients (βs) of independent variables (socio-economical factors) represent the responsiveness of factors to adoption of strategy. Positive coefficients indicate that a factor increases chance of adoption while negative coefficients indicate that independent variables decreases level of adoption of strategy.

Equations:

In analyzing the influence of socio-economic characteristics on crop diversification; the following equation was used.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_6 X_6 + \ldots + \beta_{10} X_{10} + \varepsilon$$

Where:

Y= Crop diversification

α = Intercept

X_1= Access to irrigation (X=1 if a farmer has access to irrigation; X= 0 if otherwise)

X_2= Household assets (the value of household assets (apart from land in Tsh)

X_3= Amount of rainfall (monthly) in millimeters

X_4= Altitude (meters above sea level)

X_5= Owned land size (in acres)

X_6= Extension services (number of contacts made with an extension officer)

ε =Error term (Identically and independently distributed)

$\beta_{'s}$=Coefficient of independent variables(X_s)

The equation for influence of socio-economic characteristics on choice of off-farm activities was specified as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_6 X_6 + \ldots + \beta_{10} X_{10} + \varepsilon$$

Where:

Y= Off-farm employment

α = Intercept

X_1= Age of household head (in years)

X_2= Household assets (the value of household assets (apart from land in Tsh)

X_3= Household size (number of people in a household)

X_4= Education level

X_5= Amount of rainfall (monthly) in millimeters

X_6= Altitude (meters above sea level)

X_7= Access to irrigation (X=1 if a farmer has access to irrigation; X= 0 if otherwise)

X_8= Household shocks (negative shocks experienced by a household in a period of five years)

X_9= Access to extension services (X=1 if a farmer has access to extension services; X= 0 if otherwise)

ε = Error term (Identically and independently distributed)

$\beta_{'s}$= Coefficient of independent variables ($X_{'s}$)

CHAPTER FOUR

4.0 *RESULTS AND DISCUSSION*

4.1 Social-Economics Characteristics of the Respondents

The socio-economic characteristics examined were sex, age, marital status, education level and occupation. The results are presented in Table 3. Results show that male and female were fairly distributed with male composition dominating (56% of respondents). The literacy level was observed to be high where about 87% of respondents have the formal education. Education is related to ignorance level and development; the more educated a society is the less the level of ignorance and hence the more developed. In agricultural production, education is an important factor in adoption of improved technologies in increasing crop yield. This is to say that large proportion of the sample have the primary knowledge in understanding the climate variables in relation to agricultural production.

The results also indicate that majority of respondents (87%) were aged above 35. This implies that the youth (that is strong labor force) participate less in agricultural production. It may mean that most of the youth in the region move to other places to seek other economic activities.

The income sources were also examined at the household level in order to find the current occupation of the respondents. It was found that 85% of the respondents were engaged in crop and livestock production as their major economic activities.

Table 3: Socio-economic characteristics of the respondents (N=175)

Characteristics	Frequency	Percentage
Sex of respondent		
Male	97	56
Female	78	44
Education level		
None	23	13
Primary	125	72
Secondary	24	13
Post Secondary	3	2
Occupation		
Formal employment	3	2
Farming/Livestock keepers	149	85
Business	6	3
Others	17	10
Marital Status		
Single	16	9
Married	120	77
Widowed	39	22
Age of Respondents		
18-35	22	13
36-50	56	32
51-65	51	29
>65	47	26

4.2 Farmers Perception on Climate Change

4.2.1 Awareness to climatic change

The results show that most of the respondents (95%) are aware of climatic change (Fig. 6). The means of creating awareness on climatic changes are indicated in Fig. 7. There were more than five means (including radio, television, news paper, village meetings, weather stations, extension, friends etc.) but majority (86%) became aware through own observation. It was also observed that among the information media radio was the leading means of disseminating information. However, only 8% of the respondents reported have access to climate change information through extension officers. This imply that extension officers have the vital role of advisory and technical knowledge for the development of the entire community but this role was not well played on climate change issues.

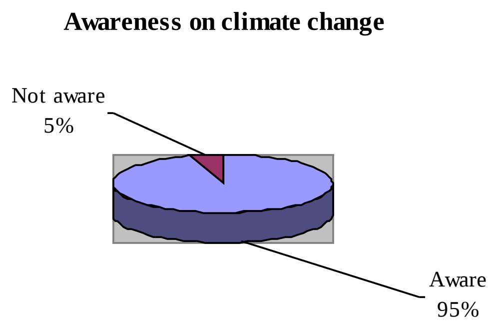

Figure 6: Awareness on climate change

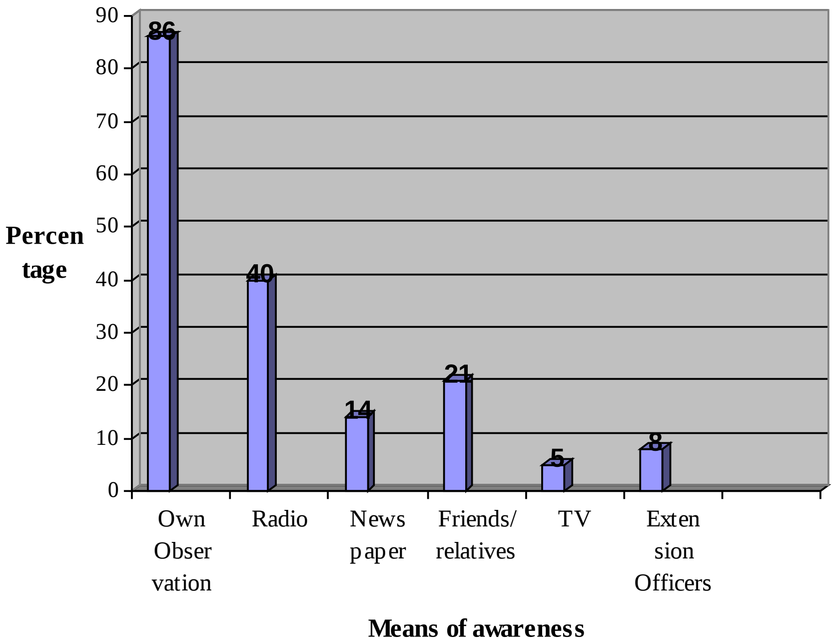

Figure 7: Means of creating awareness on climate change

4.2.2 Perceptions towards climate change/variability

Table 4 presents the results on the aspects that perceived to change as the consequences of climate change. It shows that there are eleven aspects of climate perceived to have changed. The most perceived climate variables that were the result of climate change and considered as risk were seasonal drought (95%), high temperature (81%) and disease epidemics in humans and plants (62%). This implies that seasonal drought is the major perceived climate change impact/problem to farmers. Other aspects such as stormy rainfall, extreme cold and floods were not experienced by the majority in the research area.

Table 4: Perception towards climate change/variability (N=175)

Aspects perceived to change	Frequency	Percentage/%
Seasonal Drought	166	95
High Temperature	141	81
Disease epidemics in human	108	62
Strong wind/hurricane	95	55
Disease epidemics in plants	87	50
Disease epidemics in livestock	87	50
Insect pests in crops	83	47
Insect pests in livestock	75	43
Extreme cold	15	9
Stormy rainfall	11	6
Floods	6	3

4.2.3 Perceived causes of climate change

The main perceived causes of climate change were human activities. The results show that majority (40%) of the respondent perceive human activities as the sole cause of climate changes while (31%) perceived the changes to be caused by both natural and human activities and natural occurrences (Table 5). This means 71% of farmers consider human activities as one of the major causes of climate change.

Table 5: Causes of Climate Change (N=175)

Cause	Frequency	Percentage/%
Human Activities	70	40
Combination	54	31
Indifferent	26	15
Natural Occurrences	24	14
Total	**175**	**100**

4.2.4 Perceived effects of climatic changes

The general effects of climatic changes to surveyed household are presented in Table 6. The major effect was food shortage whereby 53% of respondents claimed to suffer from food insecurity due to insufficient and unreliable rainfall. Income reduction and water scarcity for livestock and household consumption were other effects.

Table 6: Effects of the climatic change (N=175)

Opinions given as effect of climatic change	Frequency	Percentage/%
Food insecurity	93	53
Water scarcity	55	31
Income reduction	20	12
Indifferent	7	4
Total	175	100

4.2.4.1 Perceived impacts of seasonal drought

Since drought was presented as the most perceived consequence of climatic change (Table 4), there was a need to analyze its impacts on crop production and other economic activities. The results show that seasonal drought has more serious impact on crops (Table 7). Majority of the respondents claimed that it was a main cause crop failure. This is to say that despite the attitude and good climatic conditions of the study area whenever there is seasonal drought crop production is the most affected sector resulting to low income and food insecurity.

Table 7: Impacts of Seasonal Drought (N=175)

Effect caused	Frequency	Percentage/%
Crop failure	141	80
Income reduction	104	59
Water scarcity	79	45
Animal disease	46	26
Lack of pastures	32	18
Plant disease	7	4
Insects' outbreak	6	3
Human disease	5	3
Animal deaths	2	1

4.2.4.2 Perceived impacts of high temperature

The survey results show that the affects temperature increase in the region was more experienced in the health sector. Majority of respondents (81%) admitted that high temperature has affected their health (Table 8). This was due to outbreak of malaria which historically was not a problem in Kilimanjaro mountains people. However, the key informants reported that some crops such as temperate fruits which were being cultivated around the mountain have almost failed in production due to temperature increases.

Table 8: Impacts of high temperature (N=175)

Effect caused	Frequency	Percentage
Human health	141	81
Crop failure	61	35
Water scarcity	56	32
Income reduction	43	25
Animal disease	36	21
Plant disease	31	18
Lack of pastures	24	14

4.2.5 Constraints for increased agricultural production and productivity

The study also attempted to identify general challenges to crop production. The results reveal that majority (76%) of respondent perceived seasonal drought as their largest constrain in agricultural productivity (Table 9). Other constrains include unavailability of fertilizers, unavailability of improved seeds and unavailability of pesticides.

Table 9: Crop production constrains (N=175)

Constraints	Frequency	Percentage/%
Prolonged droughts	132	76
Unavailability of fertilizer	123	71
Unavailability of improved seeds	106	61
Weeds	105	60
Unavailability of pesticides	72	41
Inadequate extension services	36	21
Floods	25	14

4.3 Adaptation Strategies to Climate Change

4.3.1 Changing of farming practices

In adapting to climate change and variations in agriculture farmers use several practices to cope with the situation. Table 10 presents results of farm copping strategies used by farmers in the research area. It was observed that farming practices changed with respect to climate change and variations were timing of farm operation, water harvesting/ “makinga maji” and water conservation (mulching). Other practices were planting of early maturing plants, planting drought tolerant varieties, planting high yielding varieties and small scale irrigation.

The results show that the most copping strategy used is timing of farming operations. About 73% of respondent use this strategy (Table 11). Crop rotation was not adopted by many households because of small plot sizes as well as the perennial crops (coffee and banana) which could not easily permit crop rotation. It was observed that the farm practices especially planting dates were highly changing from season to season due to unreliability of rainfall. Most farmers did planting after the second rain in order to minimize risk of wasting their inputs in cases where the first rain ceases.

However, to some extent timing of farming practices were not much reliable. Sometimes farmers do wrong timing: they admitted there were cases where they did early planting (before or just after the first rain) the rains delayed resulting to loss of inputs. In other scenarios farmers hesitate to sow their seeds after the first rain expecting that rains will stop but it happened otherwise. This indicates that farmers are flexible to change their practices in increasing productivity but there is no reliable weather forecast information to support them (Fig. 12). Nevertheless, farmers are doing their best in coping with climate variability without being influenced by weather forecasts (Fig. 11). Therefore, provision of more accurate weather forecast information is important in assisting farmers' decisions.

Rainwater harvesting through "makinga maji" and mulching were practiced as a means of moisture conservation in overcoming the drought problem. Also planting of hybrid seed with (short maturity time, drought tolerant and high yield) was practiced and claimed to be useful but less than fifty percent of the respondents adopted this practice. This is due to the fact that these varieties were not affordable to every household. Many respondents (61%) (Table 10) admitted that the improved varieties were one of their major constraints in crop production. The survey also revealed that farmers would like to do irrigation as an alternative to rainfall in the drought periods but most of them had no access to irrigation water. Results indicate that irrigation practices only have changed by majority of households (Table 10). This signifies that for those with access to irrigation channels are still doing irrigation provided that irrigation water is available. However having access to irrigation is not enough solution in overcoming drought because they also face a problem of water scarcity. Through focused group discussion it was observed that all surveyed villages have been experiencing this problem with Rombo district being most affected due to absence of permanent rivers. The district and village executives revealed that rivers which were historically permanent have now become seasonal.

Table 10: Changing farming practices (N=175)

Practice	Changed (freq/%)	Not changed (freq/%)
Timing of farm operations	127(73)	48 (27)
Water Harvesting (makinga maji)	104(54)	71(46)
Mulching	87(50)	88 (50)
Early maturing varieties	82(47)	93(53)
Drought tolerant varieties	77(44)	98(56)
High yielding varieties	69(39)	106(61)
Small scale irrigation	31(18)	144(82)
Agroforestry	22(13)	153(87)
Crop rotation	15(8)	160(92)
Terracing	12 (7)	163(93)

4.3.2 Changing livestock production practices

Majority of farmers in Kilimanjaro practice mixed farming (crop-livestock farming).The survey results revealed that the main livestock keeping practices which have been changed were zero grazing (52%) and destocking (36%) as shown in Table 11. It was observed that zero grazing has been the main livestock keeping in the study area. Due to unavailability of enough pastures in the area zero grazing involves purchase of grass and feeds leading to increase in production costs. To cope with costs farmers practice destocking to maintain a number that is manageable to them. In other cases animals were sold in order to generate income for the family during economic hardships for instance buying food in the period of low crop yield. However, the change of these practices was not exclusively due to climate variations but also due to small owned land areas.

Table 11: Changing livestock production (N=126)

Practice	Frequency	Percentage
Zero grazing	90	52
Destocking	61	36
Move animal to other places permanently	6	4
Move animals to other places temporarily	2	1
Silage making	2	1

4.4 Weather Forecast Information Sharing

The results shows that majority (71%) of the respondents have access to information of weather forecasts (Fig. 8). Information is an important aspect in any decision making process. Effectiveness of practices used by farmers depends largely on how well they were informed during adoption of those practices.

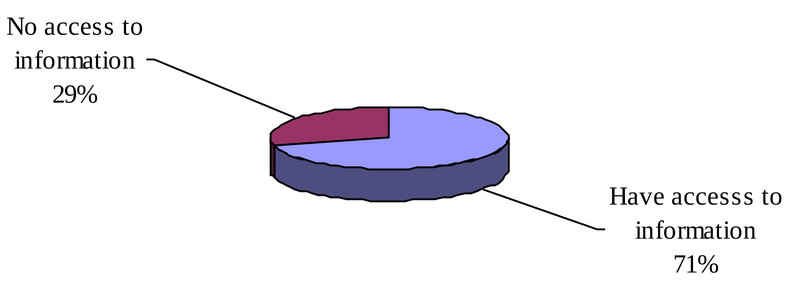

Figure 8: Access to weather forecast information

4.4.1 Types of weather forecast information received

The respondents reported to have access to information mainly on start of rain (61%) (Fig. 9). This implies that start of rain is the only forecast information which is well accessed by the people in the research area. This type of forecast is not enough in making farming decisions. Other types of weather forecasts such as duration/end of rainfall, temperature change, occurrence of floods and strong wind are mutually important but were not usually reported.

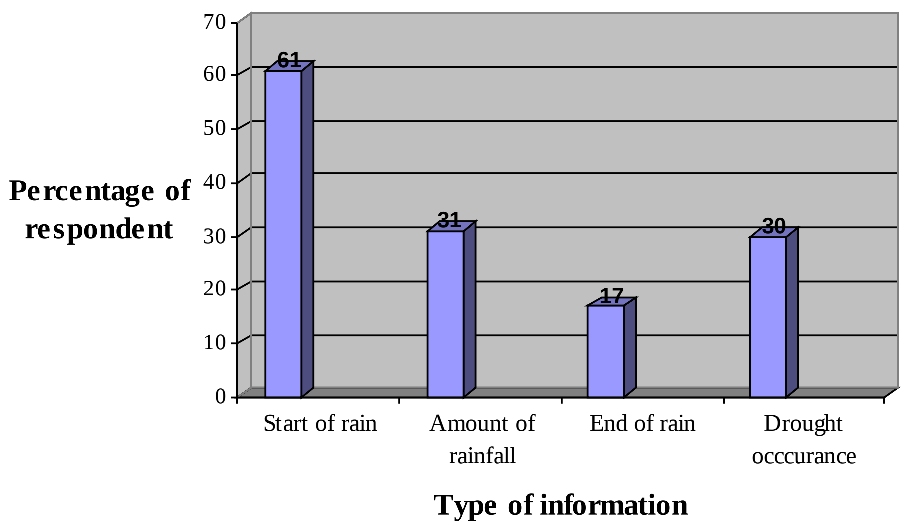

Figure 9: Type of weather information received

4.4.2 Means of getting weather forecast information

The study shows that radio (81%) was the main source of weather forecasting information (Fig.10). It was also reported that majority of respondents (74%) proposed radio to continue being the major media in the future while the remaining prefer other methods such as extension officers, religious servants, village meeting and television.

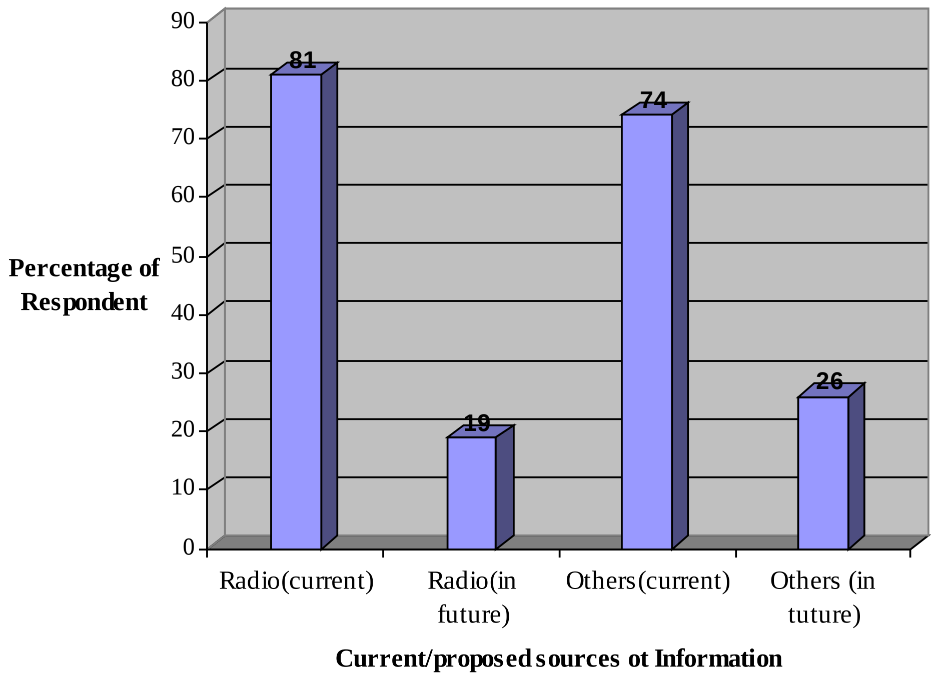

Figure 10: Means of getting weather forecast information

4.4.3 I Influence and usefulness of weather forecast information on farming decisions

In Fig.8 it was shown that 71% of respondents have access to weather forecast information. Unexpectedly, results also reveal that large proportion of respondents (77%) has not been influenced by weather forecast information in making their farming and livestock related decisions (Fig.11). This is because the weather forecast information was reported to be unreliable as shown Fig. 12.

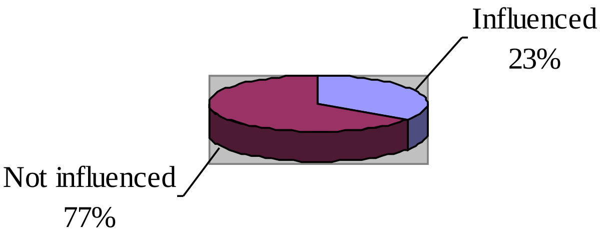

Figure 11: Influence of weather forecast information on farming practices

4.4.4 Reliability of weather forecast information

Basing on farmers' experience, it was observed that the weather forecast information received were not reliable to majority (89%) of respondent (Fig. 12). Having access to information is important but accuracy, reliability and usefulness of that information may be more important. Unreliable information may lead to loss due to wrong choice of practice thus became less useful in farmers' decisions.

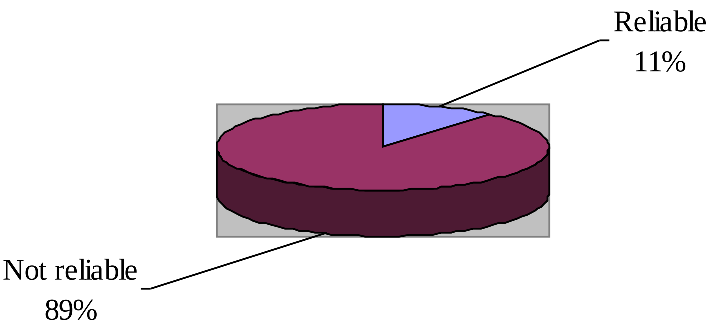

Figure 12: Reliability of weather forecast information

4.5 Farmers Perceived Constraints in Responding to Climate Changes

The results reveal that lack of capital was the major constraints facing farmers in changing their farming practices that will enhance their capacity in responding to climate change. Majority (70%) of respondent (Fig. 13) reported that lack of credit or savings was a main barrier to adaptation. Lack of access to appropriate seed, lack of security of property rights and lack of market access were expected constraints to adaptation. These were reported by several researchers including Deressa (2009) and Nhemachena and Hassan (2007) but hardly mentioned as barriers to climate change in study area. This is because most of these problems have direct influence on capital shortage. Respondents believed that availability of capital will solve many of their climate related problems including construction and improvement of irrigation channels and other infrastructures.

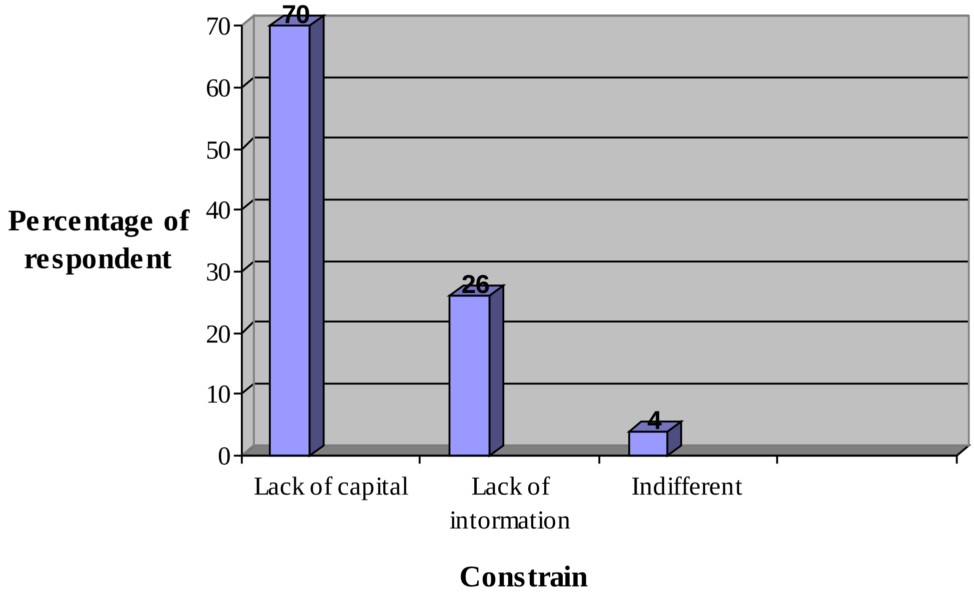

Figure 13: Farmers constrain in adapting to climate change

4.6 Influence of Adaptation Strategies on Crop Yield

4.6.1 Influence of adaptation strategies on maize yield

The Cobb-Douglas results representing the effect of adaptation strategies on maize yield are shown in Table 12. The F-value was significant at 99% ($P<0.001$) and 95% ($P<0.05$) significance levels. This is to say that the model was statistically very significant in explaining influence if independent variables on maize yield. R-square (R^2) was 0.879 indicating that variables included in the model accounted for about 87.9% of total variation on maize yield achieved by household.

Results show that irrigation, age, family labor, hired labor, bunds, and water harvesting were statistically significant in explaining the variation on maize yield. Examination of coefficients of estimated equation reveals that family labor; irrigation, water harvesting and bunds have positive influence on maize yield. Increases number of working days and irrigation increases maize yield. Similarly, the use of water harvesting and bunds lead to increase in the level of maize yield achieved by farmers. Age of respondent was observed to be negatively related to maize output. Increase in number of years lead to decrease in the level maize. This is because as the respondent become older he/she loses working energy thus contributing less in production. Other variables such as use of hired labor, fertilizer, pesticides, and timing of farming operation were expected to influence maize production. Results indicated that these variables have positive influence on maize yield but they were statistically not significant in explaining the variation in maize yield at predicted level. This may be de to the fact that the study involved production analysis on the household plots where farm yard manure is normally used. Also there was no significant use of pesticides as there was no significant outbreak of disease in maize during the survey period.

Table 12: Influence of adaptation strategy on maize yield

Factors influencing maize production	Coefficients	Std. Err.	t-test	Sig.
Age of household head	-0.403	0.417	-4.303	0.001*
Education level of household head	0.151	0.421	1.494	0.156
Extension services	-0.232	0.217	-1.703	0.109
Family labor	0.309	0.439	2.822	0.013**
If hired labor used	0.191	0.226	2.087	0.054
If fertilizer used	0.112	0.275	1.325	0.205
If pesticides used	0.109	0.210	1.279	0.220
Land size	0.120	0.296	1.495	0.156
Water harvesting	0.414	0.474	3.117	0.007**
Timing of farm operations	0.065	0.310	0.750	0.465
Bunds	0.452	0.241	4.643	0.000*
Number of irrigation	0.474	0.006	4.548	0.000*
Access to small scale irrigation	-0.016	0.247	-0.203	0.842
Constant	5.993	1.950	3.073	0.008**

N= 65

Adjusted R-square = 0.879

F-value = 16.715

*significant at 0.001

**significant at 0.05

4.6.2 Influence of adaptation strategy on banana yield

Results are presented in (Table 13). The F-value was also significant at 99% ($P<0.001$) and 95% ($P<0.05$) indicating that the model was statistically significant. The coefficient of determination, R^2 was 0.696 meaning that the variables included in the model explain about 69.9% of the variation in banana yield achieved by farmers. Results show that only extension services.

Results show that only education level and irrigation were significant in explaining variations on banana yield. It is indicated that increases education level, farmers' contact with extension officer and irrigation lead to increase in level of banana yield achieved by respondents. This is due to the fact that knowledge and skills in management practices are required in improving banana production under climate changing conditions. Education level helps to improve of farmers' personal knowledge and skills while extension supports farmers by creating awareness, capacity building and disseminating new technologies. Similarly, the increase in number of irrigations was observed to increase banana yield. It was indicated that seasonal drought is the major climate change problem (Table 4) which contain crop production. Therefore, when used as an alternative to rainfall; irrigation contributes positively and significantly in the level of crop yield.

Table 13: Influence of adaptation strategy on banana yield

Factors influencing banana production	**Coefficients**	**Std. Err.**	**t-test**	**Sig.**
Age of household head	0.162	0.034	1.707	0.097
Education level of household head	0.213	0.061	2.094	0.044**
Extension services	0.551	0.069	4.642	0.000*
Family labor	-0.041	0.036	-0.429	0.670
Irrigation	0.545	0.066	5.716	0.000*
Land size	0.090	0.193	0.993	0.328
Water harvesting	0.101	0.260	0.893	0.378
Mulching	0.104	0.163	1.132	0.265
constant	1.390	0.754	1.843	0.074

N= 57

Adjusted R-square =0.696

F-value = 13.300

*significant at 0.001

**significant at 0.05

4.7 Influence of socio-economic characteristics on adoption of adaptation strategy

4.7.1 Influence of socio economic characteristics on adoption crop diversification

The results are presented in Table 14. The F-value was significant at 99% (P<0.001) and 95% (P<0.05) significance levels. This shows that the model used was statistically very significant in analyzing the socio-economic factors influencing crop diversification.

Results indicate that all factors were significant at predicted levels except altitude. This point out that crop diversification can be practices any where being in low or high altitude provided that the necessary production conditions exist. For instance if farmers can afford and have access to means of production such as knowledge/skills, water and other inputs; growing of diverse crops will be possible.

Access to irrigation and increase in amount of rainfall increases chance of adopting crop diversification. This is due to the fact that farmers who have irrigation channels or who obtain relatively larger amount of rainfall in their area a better position of growing several crops. Availability of water maintains farming activities by growing different types of crops. In cases where rainfall fails farmers have irrigation as alternative to rainfall, thus encourage them to grow more crops. Also irrigation permits cultivation of high-moisture sensitive crops such as vegetables leading cultivation of more crops in areas with access to irrigation water.

Similarly, household assets increase chances of adopting crop diversification. This implies that wealthier farmers are more likely to grow different crops as they can afford more inputs including renting or buying plots. Extension services were also observed to have positive impact on diversification. The more a farmer makes contacts with an extension officer the more aware of practices he/she become hence, increase their chances of adoption.

On the other hand, owned land size was observed to decrease chances of crop diversification. This can be explained by the fact that people in the study tend to have small land sizes (home plots/"Kihamba") where they grow many crops on the same land. The larger plots (normally found in the lowlands) were mainly used during the main rain season and for specific crops only particularly maize.

Table 14: Influence of socio-economic characteristics on adoption crop diversification

Factors influencing adoption of crop diversification	Coefficients	Std. Err.	t-test	Sig.
Access to irrigation	0.7743394	0.2933647	2.640	0.009**
Household assets	0.0002634	0.0000564	4.670	0.000*
Rainfall amount	0.0083908	0.0036871	2.280	0.023**
Altitude	0.0002195	0.0006599	0.330	0.740
Owned land size	-3.2300630	0.1641475	-19.68	0.000*
extension	0.9170211	0.2878271	3.190	0.002**
Constant	5.5644530	0.7100779	7.840	0.000*

R-square = 0.486

F-value = 63.60

*significant at 0.001

**significant at 0.05

4.7.2 Influence of socio-economic characteristics in adopting off-farm activities

From the results (Table 15), The R-square was 0.5663 meaning that the dependent variables explained about 56.63% variation in the independent variable. Results indicates that household size, age, education level, rain variation, altitude, access to irrigation and extension services were significant in adoption of off-farm activities at 99%(P<0.001) and 95% (P<0.05) significance level.

Results show that increases in number of household assets and household decreases the chance of adopting off-farm activities. This is due to the fact that the more capital and labour (family) a household has; the more likely it is to stick on on-farm production. This was also discovered by Mishra and Godwin (1997) when studying off-farm income. They reported that reducing of farm income support off-farm income. Therefore, farmers with few asserts are more subjected to low farm income thus, tend to seek for off-farm employment (sources of off-farm income) to supplement their farm income.

It was also observed that, increase in education level increase chances of adopting off-farm activities. In the studies of off-farm income; Phimister and Roberts (2006); Mishra et al. (2002) and Olfert (1992) also found out that education level is a potential factor influencing off-farm labor. This means that the more educated a farmer is the more he become aware of other income generating activities and eligible to be employed therefore increase their chances of adopting non-farming activities.

Unexpectedly, rainfall, altitude and access to irrigation were observed to have positive relationship with of off-farm activities. Increase in rainfall amount, altitude and extension services increase chances of adopting off-farm activities. This is due to the fact that, both demand and supply of off-farm labor depend on whether there is work available within a realistic commuting zone from the farm residence (Huffman, 1991; Lass et al., 1991). In Kilimanjaro, people are more populated at higher altitude; where there is normally more rainfall suitable for crop production. This results to small plot areas for agriculture leading to necessity of seeking alternative sources of income. Also there is tourism activities in these areas thus provide more opportunity for non-farm activities such as business and porter or guard for tourists.

Table 15: Influence of socio-economic characteristics adoption off-farm activities

Factors influencing adoption of off-farm activities	Coefficients	Std. Err.	t-test	Sig.
Age of household head	0.0003474	0.0001871	-1.86	0.063
Household assets	0.0002787	0.0000336	-8.29	0.000*
Household size	0.0676702	0.0257450	-2.63	0.009**
Education level of household head	0.1004271	0.0188021	5.34	0.000*
Rainfall amount	0.0048089	0.0012562	3.83	0.000*
Altitude	5.2445600	0.1812155	28.94	0.000*
Access to irrigation	-2.0507740	0.167159	-12.27	0.000*

		0		
Household shocks	0.0817623	0.1050600	0.78	0.436
Extension services	0.4193614	0.1146087	3.66	0.000*
Constant	0.3667623	0.6473810	0.57	0.571

R-square = 0.5663

*significant at 0.001

**significant at 0.05

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aim of this study was to examine farmer adaptation strategies to climate change in Kilimanjaro region. The specific objectives were to: 1) identify the farmers' awareness and perception towards climate change and adaptation measures, 2) identify and examine the adaptation strategies used by farmers to cope with climate change and variability, 3) analyze the influence of adaptation strategies on crop yield and 4) describe the influence of socio-economic characteristics on the adoption of adaptation strategy. Analysis of quantitative and qualitative data collected from the survey was done by using Cobb-Douglas production function, regression analysis and descriptive statistics (frequency, multiple responses analysis, and percentages).

The study attempts to describe effects of climate change, copping strategies used to cope with those impacts; influence of those strategies on crop yield; factors influencing adoption of those strategies as well as the challenges farmers face in adapting to climate change. Based on the results which addressed the research objectives, the following conclusions were made.

5.1.1 Farmers' awareness and perception towards climate change

Farmers in Kilimanjaro region are quite aware of climate change. They perceived climate change as variations in rainfall and temperature patterns which result into seasonal drought and diseases to both plant and human. Drought was believed to be the major cause of crop failure resulting to low income and food insecurity while increase in temperature observed to have more effect on human health especially on increase of malaria cases in the study area.

5.1.2 Adaptation strategies to climate change and variability

The study found out that adaptation to climate change involved two major aspects: firstly, it involves changing in agricultural practices. Several agricultural practices have being changed in order to cope with varying climate. Those management strategies include timing of farming operation, water harvesting; planting of early maturity, drought tolerant and high yield varieties; mulching, irrigation and agro-forestry. Secondly, it involve shift to off-farm activities: farmers in the study area have adopted non agricultural activities (such as small business, local brewing and wage employment in tourism, construction, transportation, security and cleaning companies) in order to supplement their farm income which have been falling as a result of climate change.

5.1.3 Influence of adaptation strategies on crop yield

The coping strategies used by farmers in the study area have positive and significant influence on crop production. Those strategies include timing of farm operations, water harvesting, mulching, change of crop varieties, irrigation and agro-forestry. This concludes that farmers are doing well in adapting to climate change. However, it was observed that farmers lack enough support from government and other developmental stakeholders in their adaptation process. This was due to lack of regional adaptation guidelines and policies which promote availability of capital (credit) to farmers. Also there was no sufficient and reliable weather forecast information to support farmers' decisions.

5.1.4 Influence of socio-economic factors on the adoption of adaptation strategy

The examination of socio-economic characteristics indicated that; access to irrigation, household assets, land size, education level, rainfall amount and extension services were the positive and significant factors influencing adoption of adaptation strategies. Moreover, the major constraints/barriers to farmers' adaptation to climate change were lack of capital and lack of information. Also the study found out that farmers in the study area have access to forecast information on the information on start of rain, amount of rainfall and drought occurrence were accessible to farmers through several means particularly radio. However, these weather forecasts were not useful in farming activities because they were claimed to be less reliable.

5.2 Recommendations

Basing on the above conclusions, the following recommendations were made.

5.2.1 Policy recommendations

Given the production and adaptation constraints, the following recommendations are put forward in order to improve crop production under varying climate:

- Improve farmers' adaptation mechanism through provision of relevant climatic and agronomic information. The weather forecasts should be improved to make sure that they are adequate and more reliable in making farm-related decisions. Also clear arrangement should be done to make sure that the forecasts information reaches farmers at appropriate time and through appropriate media. This can be achieved through provision of both human and physical resources necessary for adaptation. Such resources include weather specialists, extension officers, construction of irrigation channels and input distribution.

- Introduce and encourage the creation of a sustainable rural credit system (credit for input distributors and farmers). Availability of capital facilitates technical innovations and timely availability of necessary inputs. Therefore, the Government should set policies support loan provision for small holder farmers.

5.2.2 Production recommendations

Based on the findings of this study the following recommendations are made to ensure sustainable and profitable production under varying climates:

- Provision of land and land-use rights for agriculture. This will help to avoid environmental degradation thus, support adaptation.

- Improved environmental and soil water conservation methods in overcoming the problem of water scarcity. Therefore, promotion and improvement of water conservation practices such as mulching, deep ploughing and agro-forestry can significantly support adaptation. The government can intervene by providing conservation skills and ensure availability of materials such as mulching materials and relevant tree varieties.

5.2.3 Areas for further research

There should be more studies on adaptation in different parts of the country in order to identify relevant adaptation options for specific agro-ecological zones. This will help policy makers in developing adaptation framework and guidelines for the nation hence, improve and sustain agricultural productivity.

REFERENCES

Adger, W. N., Hug, S., Brown, K., Conway, D. and Hulme, M. (2003). Adaptation to Climate Change in Developing World. *Journal of Development studies 3 (3)*: 179-195.

Adger, W. N. and Kelly, P. M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. *Mitigation & Adaptation. Strategy for Global Change* 4(3): 253–266.

Adosi, J. (2007). Climate Change Related Vulnerability, Resilience and Adaptation in Tanzania. [http://www.wmo.ch/pages/prog/wcrp/pdf/3.7_Adosi_Resilience_JSC-28_Afr_28.03.2007.pdf] site visited on 6/4/2008.

Agrawala, S., Moehner, A., Hemp, A., Aalst., Hitz, S., Smith, J., Meena, H., Mwakifwamba, S. M., Hyera, T. and Mwaipopo, O. U. (2003). *Development and Climate change in Tanzania: Focus on Mount Kilimanjaro.* OECD, Paris, France. 72pp.

Ajayi, O. C., Akinnifesi, F. K., Sileshi, G., Chakeredza, S., Mn'gomba, S., Nyoka, I. and Chineke, T. (2008). Local solutions to global problems: The Potential of Agroforestry for Climate Change adaptation and mitigation in Southern Africa. *Regional meeting "Knowledge and Action on Forests for Climate Change Adaptation in Africa"*. 18-20 November 2008, Accra, Ghana. 17pp.

Apata, T. G., Samuel, K. D. and Adeola, A. O. (2009). Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria. *International Association of Agricultural Economists Conferenc.* 16-22 August 2009, Beijing, China,. 15pp.

Bradshaw, B., Dolan, H. and Smit, B. (2004). Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies. *Climatic Change Journal* 67: 119–141.

BoT (2008). *Economic Bulleting for quarter ending June, 2008* 15(2). Government Printers, Dar es Salaam, Tanzania. 102pp.

Carter, T. R., Parry, M. L., Harasawa, H. and Nishioka, S. (1994). *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations.* Department of Geography, London University College, London, United Kingdom. 59pp.

CEEPA (2006). Climate Change and African Agriculture: Policy Note No. 10, Agricultural Annex, 0002. University of Pretoria, South Africa. 7pp.

Cooper, E. (2007). Farmers Misperception to Climate Change: A Report presented on Climate Change in Africa, Eastern and Southern International Crop Research Institute

(*ICRISAT)*. *Workshop on climate change in Africa*. 17, September 2007. Nairobi, Kenya. 19pp.

Deressa, T. (2008). Analysis of Perception and Adaptation to Climate Change in the Nile Basin of Ethiopia. [http://www.africametrics.org/documents/ conference08/day1/session1/deressa.pdf] site visited on 29/4/2009.

Deressa, T., Hassan, R. M., Ringler, C., Alemu,T. and Yusuf, M. (2009). Determinants of farmers' choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia. *Journal of Global Environmental Change* 19(2): 248-255.

FAO (2008). Climate Change Adaptation and Mitigation in the Food and Agriculture Sector: Technical Background Document from the Expert Consultation: *High level Conference of Food Security*. 5- 7 March 2008, Rome, Italy. 17pp.

FAO (2007). Adaptation to Climate Change in Agriculture, Forestry and Fisheries:Perspective, framework and priorities. [http://www. Fao.org/docrep/fao/009/j9271e/j9271e.pdf] site visited on 5/8/2009.

Gbetibouo, G. A. (2009). Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: IFPRI discussion paper 00849. [http://www.economicsclimatechange.com/2009/03/understanding-farmers-perceptions-and.html] site visited on 23/8/2009.

Glantz, M. (1992), Global Warming and environmental change in Sub-Saharan Africa. *Journal of Global Environmental Change* 2(3): 183-204.

Hawassi, G. H. (1997). The Effect of Fertilizer subsidy removal on Fertilizer use and production of Maize in Mbinga District: A Thesis submitted in fulfilment of the requirement for the Degree of Masters of Science in Agricultural Economics of Sokoine University of Agriculture, Morogoro, Tanzania. 151pp.

Heltberg, R., Jorgensen, S. L. and Siegel, P. B, (2008). Climate change, Human Vulnerability and Social Risk management. Social dimensions of climate change. A paper presented in the *Workshop on Social Aspects of Climate Change*, March 5-6 2008. World Bank headquarters, Washington D.C. 56pp.

Huffman, W. E. (1991). Agricultural Household Models: Survey and Critique. In: *Multiple Job Holding among Farm Families.* (*Edited by Lass, A. O., Findeis, L. J. and Halberg, M. C.*). Ames IA: Iowa State University Press. pp. 239– 262.

IFPRI (2007). Micro level Analysis of Farmers adaptation to Climate change in Southern Africa. [http://www.ifpri.org/publication/micro-level-analysis-farmers-adaptation-climate-change-southern-africa] site visited on 5/4/2008.

ILRI (2006). *Mapping Climatic Change Vulnerability and Poverty in Africa*, ILRI. Nairobi, Kenya. 292pp.

IPCC (2001). *Climate Change: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom. 1033pp.

IPCC (2007) .*Climate Change: The physical science basis; Summary for Policymakers*. Cambridge University Press, Cambridge, United Kingdom. 98pp.

Kerrry, A. and Macleod, A. (2001). *Potential Adaptation Strategies for Climate Change in Scotland*. University of Edinburgh, Scottish Executive Central Research Unit, Scotland. 82pp.

Kurukulasuriya, P. and Rosenthal, S. (2003). Climate Change and Agriculture: A Review of Impacts and Adaptation. *World Bank Economic Review* 20(39): 367-388.

Lange, M.A. (2007). Assessing climate change impacts in the European north. *Climate change Journal* 87(1-2): 7-34.

Lass, D. A., Findeis, J. L. and Hallberg, M. C. (1991). Factors Affecting the Supply of Off- Farm Labor: A Review of Empirical Evidence. In: *Multiple Job Holding among Farm Families.* (*Edited by Lass, A. O., Findeis, L. J.*

and Halberg, M. C.). Ames IA: Iowa State University Press. pp. 239–262.

Leary, N. A. (1999). A framework for Benefit-cost analysis of Adaptation to climate change and climate variability: Mitigation and Adaptation Strategies: *Journal of Global Environmental Change* 4(3): 307–318.

Levira, P. W. (2009). Climate Change Impacts in Agriculture sector in Tanzania and its mitigation measure. *Journal of Earth and Environmental Science* 6: 37- 42.

Maddison, D. (2006). The perception of and adaptation to climate change in Africa. CEEPA Discussion Paper No.10. [http://ideas.repec.org/p/wbk/ wbrwps/ 4308.html] site visited on 23/8/2009.

Meena, E. H. and Sharif, S. Z. (2008). Gender, Poverty and Food Security in relation to Climate Change impact and adaptation, a case of Kilimanjaro Region. [http://www.nlcap.net/fileadmin/NCAP/Countries/Tanzania/032135.070 212.TAN.CON-02.Output12.Gender_poverty.pdf] site visited on 25/6/2009.

Mishra, A. K. and Goodwin, B. K. (1997). Farm Income Variability and the Supply of Off-Farm Labour. *American Journal of Agricultural Economics* 79(3): 880-887.

Mishra, A., El-Osta, H., Morehart, M., Johnson, J., and Hopkins, J. (2002), Income Wealth and the Economic Well being of Farm Households. *Agricultural Finance Review* 62(2): 135-148.

Mishra, A., Morehart, M., El-Osta, H., Johnson, J. and Hopkins, J. (2002). Wealth and Income Contribute Jointly to the Economic Well-Being of Farm Operator Households. *Rural America* 17(2): 12-13.

Mitchell, T., Tannerand, T. and Wilkinson, E. (2006). Overcoming the barriers: Mainstreaming climate change adaptation in developing countries. *Tearfund Foundation Monitoring and Assessment*, 61(1), 9–35.

Mutabazi, K. D. (2007). Farmers' perceptions, attitudes and adaptation to Rainfall Variability Risks in dry land areas of Tanzania. A Thesis submitted in fulfilment of the requirement for the Degree of Doctor of Philosophy of Sokoine University of Agriculture. Morogoro, Tanzania. 194pp.

Mwenda, M. S. J. (1993). The Economics of Resource Use under Traditional farming system in Kondoa District: The Case of Bereko Division. A Thesis submitted in fulfillment of the requirement for the Degree of Masters of Science of Sokoine University of Agriculture. Morogoro, Tanzania. 150pp.

Nhemachena, C. and Hassan, R. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agriculture & Resource Economics* 2(1) 83-104.

Nhemachena, C. and Hassan, R. (2007). Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper No. 00714. [http://www.ifpri.org/pubs/ib/rb15/rb15_07.pdf] site visited on 18/5/2008.

Naylor, R. L., Battisti, D. S., Vimont, D. J., Falcon, W. P. and Burke, M. B. (2006). Assessing risks of climate variability and climate change for Indonesian rice agriculture. *Science Journal* 312(5782): 1918 – 1921.

Neondo, P. (2007). Low Yield due to Wary Farmers, not Climate Change. [www.scidev.net/low_yield_wary_farmers_not_climatechange.hotmail] site visited on 2/6/ 2009.

Nkomo, J. C., Nyong, A. O. and Kulindwa, K. (2006).The impact of climate change in Africa: The Impacts of Climate Change in Africa. Paper submitted to The Stern Review on the Economics of Climate Change. [www.hm-reasury.gov.uk/.../Chapter_5_The_Impacts_of_Climate_ Change_in_frica-5.pdf] site visited on 10/6/2008.

OECD (2003). *Development and Climate Change in Tanzania: Focus on Mount Kilimanjaro: Working Party on Global and Structural Policies*. OECD, Paris, France. 71pp.

OECD (2006). Putting Climate Change Aadaptation in the Development mainstream: Policy brief. [http://www.oecd.org/dataoecd/57 / 55/36324726. pdf] site visited on 19/9/2009.

Osbahr, H. and Robert, T. (2007). Adapting to climate change and variability in southern Africa: Farmer responses to intra-seasonal precipitation trends. *Climatic Change Journal* 83: 301-322.

Paavola, J. (2004). Livelihoods, Vulnerability and Adaptation to Climate Change in the Morogoro Region, Tanzania. *Journal of Environmental Science & Policy* 11(7): 642-654.

Parry, M. L. and Carter, T. R. (1989). An assessment of the effects of Climatic Change on Agriculture. *Climate Change Journal* 15: 95–116.

Phimister, E. and Roberts, D. (2006). The Effect of Off-farm Work on the Intensity of Agricultural Production; *Journal of Environmental & Resource Economics* 34: 493–515.

Pittock, B. and Jones, R. N. (2000). Adaptation to What and Why. *Environmental Monitoring and Assessment*. 61(1): 9–35.

Rasmus, J., Siegel, B. and Lau, S. (2008). Climate Change: Human Vulnerability, and Social Risk Management: working paper: Social Development Department, The World Bank. Washington D.C. 53pp.

Reilly, J. (1995). Climate change and global Agriculture: Recent findings and issues. *American Journal of Agricultural Economics* 77: 727–733.

Senkondo, E.M. (2000). Risk attitude and Risk perception in Agroforestry Decisions:The case of Babati. Tanzania. Dissertation for the Award of PhD Degree at Wageningen University, Mansholt, The Netherlands. 208pp.

Senkondo, E.M.M., Msangi, A.S.K., Xavery, P., Lazaro, E.A. and Hatibu, N. (2004) Profitability of Rainwater Harvest for Agriculture Production in selected Low-land Areas of Tanzania. *Journal of Applied Irrigation Science* 39(1):65-81.

Slegers, M. F. W. (2008). Exploring Farmers' Perception of Drought in Tanzania and Ethiopia. *Tropical Research Management Papers*. Wageningen University and Research Centre of Land, Ireland. 195pp.

Smit, B., Burton, R. J., Klein, T. and Street, R. (1999). The science of Adaptation: A framework for assessment: Mitigation and Adaptation Strategies. *Journal of Global Environment Change* 4: 199–213.

Smit , B., Burton, R. J., Klein, T. and Wandel, J. (2000). An anatomy of adaptation to climate change and variability. *Climatic Change Journal* 45: 223-251.

Smit, B. and Ellen, W. (2005). Climate Change Adaptation in Light of Sustainable Agriculture: *Journal of Sustainable Agriculture* 27(1): 113-123.

Smit, B. and Pilifosova, O. (2001). Adaptation to Climate Change. In*: Context of Sustainable Development and Equity. Contribution of the Working Group to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, United Kingdom. pp. 879–912.

Smit, B. and Skinner, M. W. (2002). Adaptation options in Agriculture to Climate Change: A Typology. *Mitigation and Adaptation Strategies for Global Change* 7: 85–114.

Smit, B., Ludlow, L. and Brklacich, M. (1996). Implications of a global climatic warming for agriculture: A review and appraisal. *Journal of Environmental Quality* 17 (4): 519-27.

Smith, J. B. and Lenhart, S. S. (1996). Climate change adaptation policy options: *Journal of Climate Research* 6: 193-201.

Thiaw, I. (2007). Managing risks of climate change for human well being; The case for adaptation. [http://www.climateactionprogramme.org.] Site visited on 15/6/2008.

Thompson, L.G., Mosely-Tompson, E., Davis, M. E., Henderson, K. A., Brecher, H. H., Zagorodnov, V. S., Mashiota, T A., Mikhalenko,V. N., Hardy, D.R. and Beer, J. (2002). Kilimanjaro ice core records: Evidence of

Holocene Climate Change in Tropical Africa. *Science Journal* 298: 589-593.

URT (2003). Agricultural sector Development Programme Framework and Process. Government Printers, Dar es Salaam, Tanzania. 73pp.

URT (2005). National Strategy for Growth and Reduction of Poverty (NSGRP). Vice President's Office, Dar es Salaam, Tanzania. 109pp.

URT (1998). *Kilimanjaro Region Socio-Economic Profile*. The planning commission in Dar es Salaam and Kilimanjaro Regional commissioner's office, Government Printers, Dar es Salaam, Tanzania. 238pp.

URT (2002). *Kilimanjaro Region Socio-Economic Profile*. The planning commission in Dar es Salaam and Kilimanjaro Regional commissioner's office, Government Printers, Dar es Salaam, Tanzania. 237pp.

USAID (2007). Adapting to Climate Variability and change: A Guidance manual for Development Planning. [http://www.usaid.gov/our_work/ environment/climate/docs/reports/cc_vamanual.pdf] site visited on 4/5/2009.

Valdivia, C., Jetté , C., Quiroz, R., Gilles, J. L. and Materer. S. (2000). Peasant Households Strategies in the Andes and Potential Users of Climate

Forecasts: El Niño of 1997-1998. *American Agricultural Economics Association; Annual Meeting.* 30, July – 2, August, 2000. Tampa, Florida. USA. 19pp.

World Bank (2007). *Poverty and Environment: Understanding Linkages at the Household Level. The Environment Department Report 40218.* World Bank, Washington DC. 81pp.

Wikipedia (2008). Climate Change. [http://en.wikipedia.org/wiki/Climate_change] site visited on 3/4/2008.

Yone, G. and Tol, R. S. J. (2001). Indicators for Social and Economic Coping Capacity -Moving Toward a Working Definition of Adaptive Capacity, *Journal of Global Environmental Change* 12: 25-40.

Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zamonglio, F., Shale, M. and Smith B. (2008). Climate Change and Adaptation in African Agriculture. [http://www.wikiadapt.org/filestore/FinalRockefellerReport4April08 .pdf] site visited 18/6/2009.

APPENDICES

Appendix 1: Household survey questionnaire

SOKOINE UNIVERSITY OF AGRICULTURE

DEPARTMENT OF AGRICULTURE ECONOMICS AND AGRIBUSINESS

Analysis of Farmers' Adaptation to Climate Change in Kilimanjaro Region

HOUSEHOLD SURVEY QUESTIONNAIRE

Greetings. *My name is*………………; *a student from Sokoine University of Agriculture. I am carrying out a survey on climate change and variability in your area as a part of my maters degree in Agricultural economics. I would like to learn from you today the present status of climate change, efforts used to reduce vulnerability and adaptation strategies in enhancing agricultural productivity* *under climate change and variability. The findings of this study can provide basic information future interventions for your socio-economic wellbeing. May I assure you that the information you give here will be treated as confidential and the analyzed report will be shared with you and everyone else who is interested in the community*

Questionnaire No……………

Village name: ……… Ward: ……… District ………… Date ………....

Section 1: General information

1. Name of the respondent: ……………………………………..
2. Sex: Male ❒ Female ❒
3. Are you a Household Head? (Respondent):Yes ❒ No ❒ What is your age? ……… years
4. If not what is your relationship with the head of the household? Wife ❒ Child ❒ Parent❒ Other ❒
5. Marital status: Married ❒ Single ❒ Divorced ❒
6. If yes are you living together? Yes ❒ No ❒; Divorced? Yes ❒ No ❒ Widow? Yes ❒ No ❒
7. What is your education level? Did not attend school ❒ Primary education ❒Secondary Education ❒ Vocational training/VETA❒ College ❒
8. Total number of people in the household…………..

Household members:

Category	Male	Female
Elders above 60 years		
Adults between 35 – 60 yrs		
Adults btn 18 – 35 yrs		
Children below 18 yrs of age		
Members capable to work		

9. What is your main economic activity? Farmer❒ formal employment ❒ business ❒ other ❒
10. Have any member of your family work for salary or wage in the past 12 months? Yes ❒ No ❒
11. What kind of work? ....

12. Have you or any family member operated in non agriculture enterprise in the past 12monthsw? Yes ❒ No ❒

13. Has any member of your household made contact with extension officer in the past twelve month? Yes ❒ No ❒

14. How many times did you contact extension officer in past 12 months?

Knowledge on Climate variability and change

15. Are you aware that climate has changed or is changing? Yes❒ No❒ Don't know ❒

16. From where have you heard about climate change? (tick as appropriate):

a. Own observation ❒ f. Told by NGO working in our area ❒

b. Newspapers ❒ g. Researchers ❒

c. Village meetings❒ h. Listening to radio ❒

d. Told by neighbors/friends/family❒ i. Department of meteorology❒

e. Input supplier❒ f. Television ❒ j. Others, (specify)❒

17. When did you hear about this?

a) Recently ❒ b) Long ago ❒ c) None of the above ❒

18. How well have you been informed about climate change and variability?

a. Very well ❒
b. Fairly well ❒
c. Fairly badly ❒
d. Very badly ❒

19. Do you think that climate change is a bad or good thing? Bad thing ❒ Good ❒

Give brief explanations of your above opinion…………………………

Perceptions towards climate change/variability

20. Describe aspects of climate perceived to have changed?

Aspect	**Changed? 1=Yes 2=No**	**Frequency of occurrence** 1= More frequent 2=Frequent 3=Less frequent 4=Not frequent	**Severity** 1= More severe 2=Severe 3=Less severe 4=Not severe	**Is it perceived as risk? 1=Yes 2=No**	**How concerned are you?** 1=Unconcerned 2=Concerned 3=Extremely concerned
Seasonal drought					
Floods					
Stormy rainfall					
Strong wind/hurricane					
High temperature					
Extreme cold					
Insect pests • Crops					
• Livestock					
Disease epidemics • Plants					
• Livestock					
• Human					
Others (specify)					

21. What do you consider to be the cause(s) of these changes? Human activity ❐ Natural occurrence ❐ A combination of the above ❐ Don’t know ❐

The impact of climate change

22. Have the changes in climate affected you in anyway? Yes ❐ No ❐

23. If yes, for each of the following described how they have affected you\

Risks/events	Description 1=Crop failure; 2=Reduced income; 3=Water scarcity; 4=Destruction of infrastructures; 5=Lack of pastures; 6=Soil erosion; 7=Land slides; 8=Animal diseases9=Human diseases; 10=Plant diseases; 11=Outbreak of insects/pest; 12=Death of animals
Seasonal drought:	
Floods/Stormy rainfall:	
Strong wind (hurricane):	
Change in temperature:	

24. In your opinion which sector has been most affected?

Sector	Most affected	Affected	Not affected
a. Crops			
b. Livestock			
c. Health			
d. Infrastructure			
e. Other (specify) …………………..			

25. Now I would like to ask about your main constraints for increased agricultural production and productivity. Please indicate in the order of importance.

(a) Crop production

Constraint	**Constraint priority (e.g put 1, 2, 3, etc)**
Unavailability of improved seeds	
Unavailability of fertilizer	
Weeds	
Inadequate extension services	
Unavailability of insecticides	
Prolonged drought	
Floods	
Others; (specify)……………..	

(b) Livestock production

Constraint	Constraint priority (e.g put 1, 2, 3, etc)
Unavailability of improved breeds	
Unavailability of pastures	

Unavailability of water	
Livestock diseases	
Inadequate extension services	
Unavailability of veterinary drugs	
Others; (specify)…..	

Adaptation strategies to build resilience into the agricultural production systems

26. Have you changed any of your farming practices in order to adjust to the changes in climate?

Crop production	Yes ❒ No ❒
Livestock production	Yes ❒ No ❒
Others (specify)	Yes ❒ No ❒

27. If yes for any of the above, please describe changes you have made (Crops)

Sector	**Practice**	**1=changed 2=Not changed(move to next practice)**	**Have the changes been effective? 1=Yes 2=No**	**To what extent been effective?** 1. Most effective 2. Effective 3. Less effective 4. Not effective at all
Crop production	(a) Crop rotation			
	(b) Water harvesting			
	(c) Small scale irrigation			
	(d) Timing of farm operations			
	(e) Planting drought tolerant varieties			
	(f) Planting early maturing varieties			
	(g) Planting high yielding varieties			
	(h) Agroforestry			
	(i) Mulching			
	(j) Terracing			
	(k) Sunken beds (makinga maji)			
	(l) …………………			

	…..			

If yes for any of the above, please describe changes you have made (Livestock)

Sector	**Practices**	**1=changed 2=Not changed(move to next practice)**	**Have the changes been effective? 1=Yes 2=No**	**To what extent been effective?** 1. Most effective 2. Effective 3. Less effective 4. Not effective at all
Livestock production	(a) Hay			
	(b) Silage making			
	(c) Destocking			
	(d) Zero grazing			
	(e) Moving animals to other places permanently			
	(f) Moving animals to other places temporarily			
	(g) ………………………			

28. . What facilitated you to change your farming practices?

(i) ....

(ii) ………………………………………………………………………………

(iii) ………………………………………………………………………………

(iv) ………………………………………………………………………………

What facilitated you to change your livestock practices?

i) ……………………………………………………………………………

ii) ……………………………………………………………………………

iii) ……………………………………………………………………………

iv) ……………………………………………………………………………

Climate Information sharing

29. Do you have any access to weather forecast information? Yes ❒ No ❒

30. What type of weather information do you have access to?

a) Start of rain ❒
b) End of rain ❒
c) Amount of rainfall ❒
d) drought occurrence ❒
e) Wind ❒
f) Floods❒
g) other (specify………..)❒

31. Are these forecasts (i) seasonal ❒; (ii) monthly❒ (iii) Ten day ❒ (iv) Daily❒

32. From where are you getting weather information?

a) District Meteorological station ❒
b) Radio ❒
c) Local (indigenous) weather forecasting ❒
d) Extension officer ❒
e) Village meeting ❒
f) Local Newspapers ❒
g) Researchers ❒
h) NGOs working in our area ❒
i) Television ❒
j) Friends, family, neighbors ❒
k) Others; (specify) ❒

33. How would you like to receive weather forecast information in future? ....

34. From the weather information source mentioned above, which one do you consider most reliable and adequate? …………………………………..

35. Does weather forecasts and information influence your crop related decisions? Yes❒, No❒

36. Judging from experience, letting weather forecasts and information influence your crop related decisions has been: Extremely useful❒, Useful❒ Not useful❒

37. A lot of people may advise you that weather forecasts and weather information should influence your crop related decisions, how would you rank that?

Category of advisers	Extremely useful	useful	Not useful
Spouse			
Neighbours & relatives			
Children			
Village Extension Officer			
Researchers			
Input supplier			
Media			
NGOs			
Financial institutions			

38. Please rate the extent to which indigenous weather forecasts influenced each decision in the last season (2008/20079)

(i) Crop production

Practices changed	Influence	Not influenced
(a) Crop rotation		
(b) Water harvesting		
(c) Small scale irrigation		
(d) Timing of farm operations		
(e) Planting drought tolerant varieties		
(f) Planting early maturing varieties		
(g) Planting high yielding varieties		
(h) Agroforestry		
(i) Mulching		
(j) Terracing		
(k) Tie ridges		
(l) Sunken beds (majaruba)		

Livestock production

Practices changed	Influence	Not influenced
(a) Hay		
(b) Silage making		
(c) Destocking		
(d) Zero grazing		
(e) Moving animals to other places permanently		
(f) Moving animals to other places temporarily		

39. With whom have you been sharing climate information for decision-making in farm activities?

a) Fellow farmers ❒

b) Extension workers ❒

c) NGOs working in our village ❒

d) Village leaders ❒

e) Input suppliers in the District/village ❒

f) Others; (specify) ❒

Agricultural productivity

Now I would like to you about plot areas and agricultural productivity during the last season

Information on cropping land

40. What was the size of parcel that you cultivated last season?
41. What was the value of the parcel? Estimates in TSH……………..
42. Parcel status: Own❒ Rented ❒
43. If rented how much are you paying per season? Estimates in TSH……………..
44. What is the distance of parcel from home in km? ....km
45. In which year did you first acquire this land?
46. What is the cropping system did you use on the parcel? Monocropping ❒ intercropping ❒
47. Have you planted any trees in the parcel during the last five years? Yes❒ No❒
48. Did the parcel have access to irrigation? Yes ❒ No❒

Information on labour

49. how many person days did your household members contributed to the following farm activities

Activity	Person days
prepare and sow	
Apply input	
Weed and prune	
Irrigate	
Harvest and transport from the farm to home	
Drying and processing	
Transport from home to the market	

50. Did your household hire any labour in the last cropping season? Yes ❒ No❒. If yes, how many person days did the hired labour contributed to the following farm activities

Activity	**Number of people employed**	**Person days**	**Payments in TSH**
prepare and sow			
Apply input			
Weed and prune			
Irrigate			
Harvest and transport from the farm to home			
Drying and processing			
Transport from home to the market			

Information on non-labor inputs

51. Did u use any purchased seeds in the last season? Yes ❒ No❒. If yes. how much did you spend on buying seeds?…………….TSH
52. Did you apply fertilizer in the last cropping season? Yes ❒ No❒. if yes, how much did you spend on fertilizer?…………………..TSH
53. Did you apply manure in the last season? Yes ❒ No❒. if yes, how much did you spend on burying/transport manure?..................TSH
54. Did you apply pesticides or herbicides during the last cropping season? Yes ❒ No❒. If yes. how much did you spend on pesticides/herbicides?...................TSH

Information on crop cultivated

55. What type of crop did you cultivated during the last season? Please indicate the yield(quantity) and producer price during the last season

Crop type	**% of crop per acreage**	**Units**	**Quantity**	**Producer price**
Maize				
Coffee				
Banana				
Beans				
Vegetables				
Others (specify)				

56. What were the main causes of crop damage? Indicate with order of importance ie.1, 2 etc.

    i. Rain shortage
    ii. Floods
    iii. Crop diseases
    iv. Insect damage
    v. Animal damage
    vi. Bird damage
    vii. Stealing
    viii. Others (specify)

Farmers' General Opinion

57. What constrains you from changing farming practices that would enhance your capacity to respond to climate change?

(i) ....

(ii) ……………………………………………………………………………

(iii) ……………………………………………………………………………

(iv) ……………………………………………………………………………

(v) ……………………………………………………………………………

58. In your own opinion(s) what do you think should be done to cope with climate change and variability?

(i) ……………………………………………………………………………….

(ii) ……………………………………………………………………………….

(iii) ………………………………………………………………………………..

(iv) ……………………………………………………………………………….

(v) ……………………………………………………………………………….

59. Is there anything else you want to tell us about climate change in this area?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

END

Thank you very much for your cooperation

Appendix 2: Household shocks

Type of shock	**Has your household experienced any of the following shocks in the past five years?** 1 = Yes 2 = No
Illness of a household member	
Death of a household member	
Drought	
Excessive rains	
Loss of crops in the field	
Livestock loss	
Loss of crops in storage	
Major change in price of a cash crop (e.g., coffee)	
Major change in the price of a food crop	
Loss of employment	
Theft	
House damaged or destroyed by fire	
Loss of land	

Coping Strategies

What does your household do when faced with a negative shock?

1 = Draw down on savings or assets
2 = Borrow money
3 = Obtain assistance from family members
4 = Obtain assistance from sources outside your family
5 = Seek new ways to earn income

(Read strategies 1- 5 to respondent and ask if the household uses any of these strategies. If so, list the strategies in columns 1 -5 by order of importance).

1	**2**	**3**	**4**	**5**

Appendix 3: Checklist for key informants

1. Are there any indications of climate change in your area?
2. What are the causes of those changes?
3. What do you consider to be the major impacts of climate change?
4. To what extent are you affected with these changes?
5. Is climate change the major constraint in agriculture production?
6. What have you being doing to cope with these changes?
7. Are there any polices to support your copping strategies?
8. Have these strategies being effective in your area?
9. What challenges do you face in copping with climate change?
10. What do you suggest to be done in assisting you adapting to climate changes?